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Optimization of glomalin-related soil protein extraction in soil of citrus (*Citrus species*) orchard

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ABSTRACT

The study was undertaken to analyze the effects of high temperature autoclaved time, centrifugal time and weight of soil samples on glomalin-related soil protein (GRSP) concentration in Xanthi-Udic ferralsol of a citrus (*Citrus species*) orchard. The results showed that extraction of easily-extractable GRSP should adopt the following protocol: 0.75 g soil sample was incubated in 6 ml 20 mM citrate buffer (pH 7.0), which was autoclaved at 0.11 Mpa and 121°C for 1 h, and centrifugated at 10,000×g for 20 min. For the determination of difficultly-extractable GRSP, the residual of EE-GRSP extraction was mixed with 8 ml 50 mM citrate buffer (pH 7.0), autoclaved at 121°C and 0.11 Mpa for 1 h, and centrifugated at 10,000×g for 10 min. Extraction of GRSPs in different soil types still needs to be checked.

KEY WORDS: Arbuscular mycorrhizal fungi, Glomalin, Soil protein, Citrus, Orchard, GRSP

Glomalin is a special glycoprotein released by extraradical mycelium and spores of arbuscular mycorrhizal fungi (AMF) in the system of plant and the AMF has shown important functioning in terrestrial ecosystems (Wright and Upadhyaya 1998; Wright *et al.* 1996). In general, glomalin is quantified by Bradford and MAb32B11-ELISA assay following extraction (Wright and Upadhyaya 1998). Meanwhile, Bradford assay is widely used to determine glomalin concentration. In general, easily extractable glomalin and total glomalin are extracted with 20 mM citrate buffer (pH 7.0) for 0.5 h and 50 mM citrate buffer (pH 8.0) for 1 h, at 121°C and autoclaving, respectively (Wright and Upadhyaya 1998; Rillig 2004). Wright and Upadhyaya (1998) initially considered that autoclaving at 121°C and 0.11 Mpa in citrate buffer can strongly destroy all proteins except glomalin. However, Purin and Rillig (2007) found that high temperature extraction did not exclude all heated-stable proteins. The current extraction method of glomalin can lead to the co-extraction of proteins of AMF and non-AMF origin. As

a result, Rillig (2004) proposed the term of glomalin-related soil protein (GRSP) to replace glomalin in soils.

When glomalin was released by AMF into soils, the GRSP showed an important contribution to aggregate formation and stabilization by cementing water-stable aggregates, sandy soil, clay, and soil organic matters together. Moreover, contribution of GRSP on aggregate stability was stronger than root mycorrhizal colonization (Peng *et al.* 2011; Wu *et al.* 2014). The GRSPs also put off the degradation of soil organic carbon (Rillig *et al.* 1999), glue heavy metal in contaminated soils (Cornejo *et al.* 2008), and modulate plant/soil water status (Zou *et al.* 2014).

Recently, Wu *et al.* (2014) divided GRSP into two fractions, easily-extractable glomalin-related soil protein (EE-GRSP) and difficultly-extractable glomalin-related soil protein (DE-GRSP). But, extraction techniques of both the substances are still held to debate, and some extracted processes to some extent affect the extraction quantity of EE-GRSP and DE-GRSP. Studies have confirmed that GRSP could provide the positive effects on aggregate stabilization and soil fertility in citrus orchard (Wu *et al.* 2014; Zou *et al.* 2014). Therefore, present study was undertaken to optimize the methods of EE-GRSP and DE-GRSP extraction in soil of a Citrus orchard.

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MATERIALS AND METHODS

Soil samples were collected in the Citrus Orchard of Yangtze University, Jingzhou, China (30°36'N, and 112°14'E), on 21 April 2013, where 26-year-old Citrus unshiu grafted on Poncirus trifoliata was planted. The citrus orchard carried out the no-tillage soil management with natural grass cover. The soil is classified as Xanthi-Udic Ferralsols (FAO system). About 1 kg soil was collected in 5-10 cm depth within a 2-m radius of the tree canopy. Soil samples from 2-tree/block were mixed as one composite sample, air-dried, ground, and then sieved (4 mm) for the analysis of GRSP.

Extraction of EE-GRSP was followed as per Wright and Upadhyaya (1998) based on three considerations of soil weight, high-temperature autoclaved time, and centrifugal time. In the process, optimal result was further considered as a condition of the next extraction. A 0.25, 0.5, 0.75, 1, and 1.25 g soil sample were mixed respectively with 2, 4, 6, 8, and 10 ml citrate buffer (20 mM, pH 7.0), autoclaved for 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5 and 5 h at 121°C and 0.11 Mpa, and centrifuged at 10,000×g for 5, 10, 15, 20 and 25 min. The supernatants were collected and assayed as per Bradford (1976) method using a bovine serum albumin solution as the standard. There were 20 treatments with four replicates.

The DE-GRSP was extracted using the protocol of Wu *et al.* (2014) with minor modification. The sediment of EE-GRSP centrifugation was incubated with 8 ml 50 mM citrate buffer (pH 7.0), autoclaved at 121°C for 1 h, and centrifuged at 10,000×g for 5, 10, 15, 20, and 25 min. The supernatants were assayed using the Bradford (1976) method with a bovine serum albumin standard. There were five treatments with four replicates.

The data (means ± SE, n = 4) were analyzed by one-way variance (ANOVA). Duncan's multiple range test ($P < 0.05$) was used to compare the significant differences among the means.

RESULTS AND DISCUSSION

According to the protocol of Wright and Upadhyaya (1998), soil sample was mixed with citrate buffer in a 1 : 8 ratio (m/v). They thought that the GRSP extracted concentration was no different in terms of 1 : 8 ratio. On the basis of the ratio of soil weight vs citrate buffer (1:8, m/v), we found that within the range of 0.25-0.75 g soil sample, EE-GRSP concentration significantly increased with increase in soil sample weight, and EE-GRSP concentration was highest value (1.41 mg/g DW soil) at 0.75 g soil (Fig. 1). With the continual increase of soil samples, EE-GRSP concentration significantly decreased in the range of 0.75 to 1 g soil sample and gradually increased in 1-1.25 g soil sample. Therefore, when the

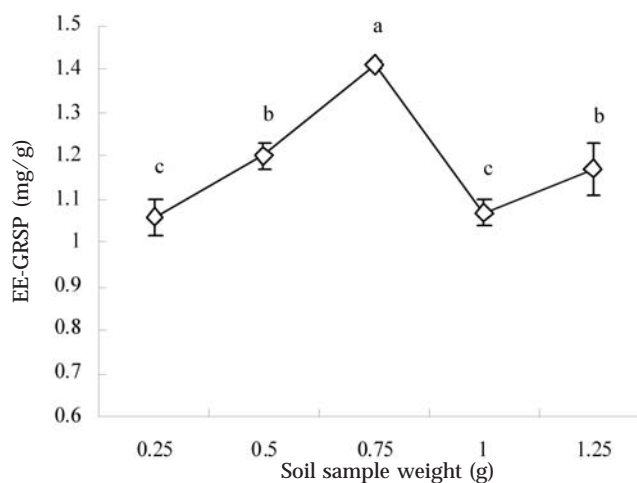


Fig. 1. Effect of soil sample weight on EE-GRSP concentration in soil of a citrus orchard

0.75 g soil sample was incubated with 6 ml citrate buffer, EE-GRSP concentration was the highest, which can be considered as an optimized condition for subsequent test.

When 0.75 g soil sample was incubated with 6 ml citrate buffer, high-temperature autoclaved time strongly affected EE-GRSP concentration (Fig. 2). In a range of 0.5-5 h, the highest and the lowest EE-GRSP concentration was observed in 1 h and 1.5 h of high-temperature autoclaved time, respectively (Fig. 2). It suggests that in a range of shorter autoclaved time, extension of autoclaved time would make the combination of soil organic matter and GRSP more weakly. However, EE-GRSP concentration was obviously decreased after the high-temperature autoclaved time was more than 1 h, implying that EE-GRSP might not be able to endure the long time autoclaved process, resulting in a large number of EE-GRSP degradation.

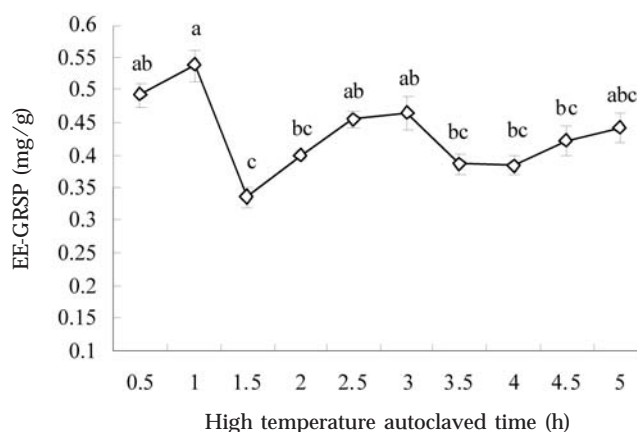


Fig. 2. Effect of soil sample weight on EE-GRSP concentration in soil of a citrus orchard.

In the present study, 0.75 g soil sample was mixed with 6 ml citrate buffer, which was autoclaved (0.11 Mpa, 121°C) for 1 h. and then, centrifugal time strongly affected EE-GRSP concentration. EE-GRSP concentration significantly increased with the increase of centrifugal time in a range of 5-20 min and significantly decreased in a range of 20-25 min (Fig. 3). It concludes that 20 min of centrifugal time would benefit the extraction and isolation of EE-GRSP.

In addition, we also found that DE-GRSP concentration significantly increased with the increase of centrifugal time in a range of 5-10 min and significantly decreased in a range of 10-25 min (Fig. 4). Xie *et al.* (2011) reported that time and force of

centrifugation are able to isolation of both soil aggregates and GRSP. Therefore, the present study suggests that increasing centrifugal force and centrifugal time may isolate more GRSP fractions from soils.

Thus, 0.75 g soil sample was incubated in 6 ml 20 mM citrate buffer (pH 7.0), which was autoclaved at 0.11 Mpa and 121°C for 1 h, and centrifugated at 10,000×g for 20 min. The residual of EE-GRSP extraction was mixed with 8 ml 50 mM citrate buffer (pH 7.0), autoclaved at 121°C and 0.11 Mpa for 1 h, and centrifugated at 10 000g for 10 min. The two supernatants were determined using the Bradford (1976) assay with bovine serum albumin as a standard. Certainly, extraction of GRSP fractions still needs to be checked and adjusted in different soil types.

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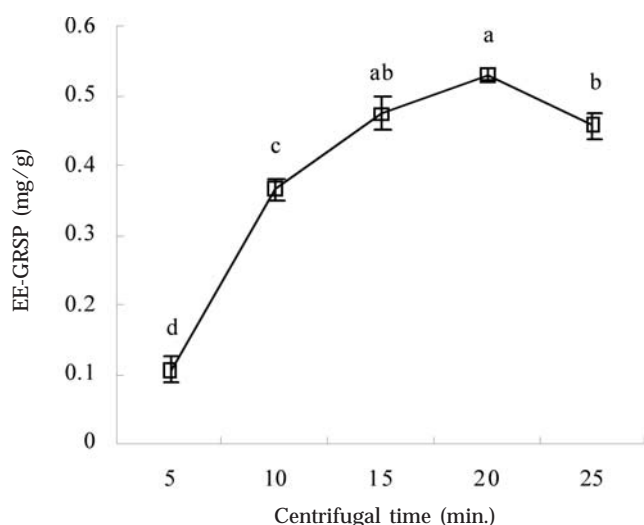


Fig. 3. Effect of centrifugal time on EE-GRSP concentration in soil of a citrus orchard

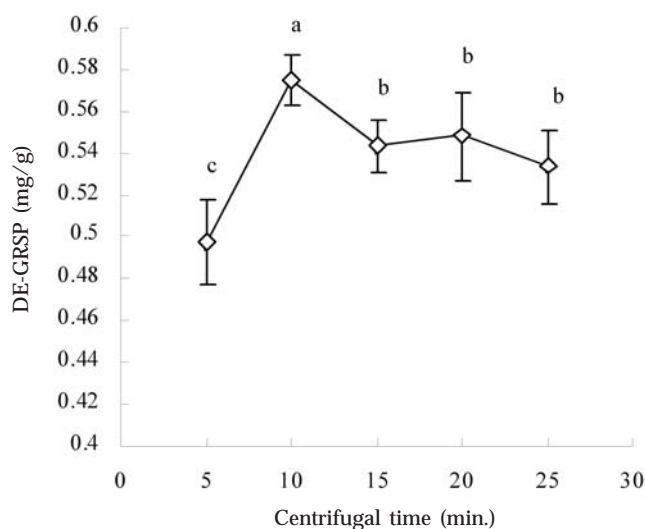


Fig. 4. Effect of centrifugal time on DE-GRSP concentration in soil of a citrus orchard

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Spatial and temporal variability in canopy properties and root yield in cassava (*Manihot esculenta*) field under various fertilization regimes

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ABSTRACT

A field experiment was conducted to study the spatial and temporal variability of canopy properties and tuberous root yield in a cassava (*Manihot esculenta* Crantz) field under two fertilization regimes. Spatial and temporal variability of canopy properties and root yield may be affected by various intrinsic and extrinsic factors. Spatio-temporal variations were studied using classical and geostatistical techniques. The data related to different plant growth factors clearly showed that application of plant nutrients at the recommended rates resulted in increased plant growth. Leaf area index had higher variability among different canopy properties. Spherical model fitted best for most of the parameters. The nugget to sill ratios of root yield were lesser than 25% (24.84), exhibiting strong spatial dependency, while that of unfertilized field was greater than 75% (81.82), indicating weak dependency. Moderate spatial dependency was noted for most of the canopy properties studied at different growth stages, with a nugget accounting for 7.53-100 of the total variability. The spatial correlation distances of all the canopy properties and root yield varied from 1.41 to 40.73 m. Kriged interpolation maps of canopy properties and root yield developed indicated entirely different distributions exhibiting completely patchy appearance in leaf area index, stem dry matter (%) and root yield which may be due to various intrinsic factors.

KEY WORDS: Spatial variability, Temporal variability, Semivariograms, Geostatistics, Kriging

Cassava (*Manihot esculenta* Crantz), commonly known as tapioca, is a native of South America. This crop is affected by factors that vary both in space (spatial variability) and time (temporal variability). Uniform management of crops grown under spatially variable conditions can result in less than optimum yield due to nutrient deficiencies as well as excessive fertilizer application that may potentially reduce environmental quality (Redulla *et al.*, 1996). Classical statistical procedures have been commonly used to assess the spatial and temporal variability in canopy properties. Geostatistics uses semivariogram technique to measure spatial variability of regionalized variable and provides input parameters for spatial interpolation of kriging (Webster and Oliver, 2011). Nugget-sill ratio is used to qualitatively define spatial dependence values (Camberdella, 1994). Canopy properties of cassava such as plant height, leaf number and leaf, stem and root weights may vary within field depending on temporal and spatial variability of different soil characteristics. Mohawesh *et al.* (2005) reported that leaf area index

(LAI) exhibited strong spatial correlation while plant height exhibited weakest spatial correlation in a study conducted at a cassava plantation area in north-eastern part of Thailand. Sinha and Nair (1971) found a positive correlation between leaf area index and yield of storage roots of cassava, indicating that leaf area is crucial in determining crop growth rate and storage bulking rate of cassava. The optimal LAI for storage root bulking rate is 3.35. In order to obtain high storage root yield, crop should reach an LAI of 3.0-3.5 as quickly as possible and maintain that LAI for as long as possible (Cock *et al.* 1979).

The effect of long-term no tillage on spatial variability of yield of soybean and maize was studied by Vieira *et al.* (2010). Silva (2006) studied the spatial and temporal variability of irrigated maize yield. Spatio temporal analysis of rice yield variability in two Californian fields was done by Roel and Plant (2004). Management of spatial variability in sweet potato production was studied by Shankle and Main (2002). Wirth *et al.* (2001) studied spatial and temporal

variability in canopy structure in a tropical moist forest. Spatial and temporal variability of yield of corn and soybean were studied by earlier researcher (Jaynes and Colvin 1997; Roel and Plant 2004). Porter *et al.* (1998) reported that yield variability may be due to interactions among climatic growing conditions, soil properties and crop. Therefore, study was undertaken to assess the spatial and temporal variation in canopy properties and root yield in a cassava field under two levels of NPK fertilization in an Ultisols and to prepare kriged interpolation maps.

MATERIALS AND METHODS

Study site : A field experiment on spatial and temporal variability in canopy properties with special reference to phosphorus nutrition was conducted at the farm of Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram, Kerala, India (Latitude: 8° 32' N, Longitude: 76° 55' E, Altitude : 50 m above mean sea-level) during two consecutive years (2008-2009 and 2009-2010). The soil was a clayey, skeletal, isohyper-thermic, typic plinthustults. The soil was highly acidic with a pH of 4.50 (1:2.5 soil:H₂O) and had an organic carbon content of 0.72%.

Experimental details : Cassava was cultivated in two adjacent fields, each having an area of 1000 m² (25m × 40 m). One field was fertilized and that received NPK as fertilizers as per the recommendations (Mohan-kumar 2000), whereas other field was unfertilized. The cassava cultivar, Sree Vijaya, was used. All other soil and crop management practices were done as per the standard recommendations in both fields (Mohan-kumar 2000). The entire dose of P fertilizer and 50% of N and K fertilizers were applied as basal dose 10 day after planting when new shoots emerged and the remaining dose of N and K fertilizers were applied 60 days later. The crop was planted in July 2008 and harvested in January 2009 during first year. During second year, crop was planted in June 2009 and harvested in December 2009. In each field, spatial and temporal variability of canopy properties were studied from 6 m × 6 m square grid at 10 m apart. The leaf area index (LAI) was recorded from 24 plants each from fertilized and unfertilized fields. At the time of harvesting yield was recorded from 55 plants each from fertilized and unfertilized fields.

Plant characteristics and tuberous root yield : Destructive sampling technique was used for measurement of plant height and fresh weight of estimation of leaf, stem and tuberous root. Four plants were removed from each sampling point at each time interval. Plant characteristics like plant height, leaf number and LAI were recorded at four different growth phases. Four plants at the centre of each sampling point

were labelled for calculation of LAI. The LAI was calculated by linear measurement method (Ramanujam and Indira 1981). For calculation of LAI, length of middle lobe, breadth of middle lobe, number of lobes and number of leaves were recorded. The LAI was estimated using the formula.

$$\text{LAI} = \frac{\text{Length of middle lobe} \times \text{breadth of middle lobe} \times \text{number of lobes} \times \text{number of leaves}}{\times 0.44}$$

Leaf, stem and root weights at four different growth stages, viz. 40, 80, 120 and 160 days after planting was done by uprooting 24 plants each time. Leaf, stem and root samples (50 g each) were collected and dried in a hot air oven at 65° C until constant weight is attained, dry matter (%) was calculated and dry weight of samples were also estimated. The crop was harvested manually at physiological maturity (6 months). The root yields were recorded from 55 spatially distributed sampling points each from fertilized and unfertilized fields.

Statistical analysis : Statistical analyses were done in three stages. First, the frequency distributions were analysed and normality was tested using the Kolmogorov-Smirnov test (k-s test). Secondly, distribution of data was described using conventional statistics such as mean, minimum, maximum, skewness, kurtosis, standard deviation (SD) and coefficient of variation (CV). Thirdly, geostatistical analysis was performed using the VESPER software version 1.6 (Minasny *et al.* 2002) to determine the spatial and temporal dependency of canopy properties to find out any spatially dependent variance within the field.

The semivariance is calculated using the following equation :

$$\hat{\gamma}(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [z(S_i) - z(S_i + h)]^2$$

where, $\gamma(h)$ is semi-variance; h is lag; $n(h)$ is number of pairs h unit apart and $z(S_i)$ is observation at site S_i . Isarithmic maps of different variables were produced by kriging technique (Warrick *et al.* 1986). Descriptive statistical techniques were used to measure variables to obtain the mean, minimum, maximum, skewness, kurtosis, standard deviation and co-efficient of variation. If skewness is positive, data distribution indicates that there is a long tail of high values (to the right), making the median less than the mean and converse applies in which case the median is greater than the mean. Kurtosis describes the shape of a random variables probability density function. If kurtosis value is greater than 3 for a random variable, it is said to be leptokurtic but if it is lesser than 3, then it will be platykurtic (Li *et al.* 2012).

Parameters defining semivariogram models are nugget (variability at a smaller scale than sampling interval and/or sampling and analytical error), sill and range. The sill expresses the distance (range) beyond which samples is not correlated. The range of the semi-variogram is defined as the distance at which variogram stabilizes around a limiting value, the sill, which can be approximated by the total variance of $Z(s)$. According to Camberdella *et al.* (1994) nugget to sill ratio is used to qualitatively define the spatial dependence values with values lesser than 25% reflect strong spatial dependence, values between 25% and 75% are considered to reflect moderate spatial dependence and values greater than 75% reflect weak spatial dependence. The property is considered non-spatially correlated (pure nugget), if the ratio is 100% or the semivariogram slope is close to zero.

Surface maps of canopy properties were prepared using semivariogram parameters through ordinary kriging. Kriging of geostatistics is an optimum interpolation technique for making unbiased estimates of regionalized variables at unsampled locations in which structural properties of semi-variogram and initial set of samples are used. The spatial prediction of values of a variable 'Z' at an unsampled point 'So' is estimated by the formula (Chiles and Delfiner 1999).

$$\sum_{i=1}^n \lambda_i Z(S_i)$$

where, S denotes set of spatial coordinates, n is the number of neighbouring samples and λ_i are weights associated with the sampling points S_i . The predicted

value $Z(S_o)$ at the point 'So' is a weighted average of values Z at n surrounding points.

RESULTS AND DISCUSSION

Plant characteristics and tuberous root yield: There is descriptive statistics of plant height at different growth stages of cassava (Table 1). Plant height indicated a general trend of increasing value with respect to the growth of the plant from 40 DAP till harvesting in both the fields. Positively skewed nature was observed at 40 DAP growth stage of fertilized field and at 160 DAP and harvesting stage of fertilized field. All other growth stages of both fields exhibited negative skewness values. Kurtosis values which represents the shape of a random variables probability density function, were found to be lesser than 3, making it to platykurtic.

The standard deviation values of plant height ranged from 4.04 to 29.68, while that of unfertilized field were from 2.47 to 25.96. The CV per cent of both fields at different growth stages falls within the intermediate range ($10\% < CV < 100\%$) (Hillel 1980). Plant height indicated higher in fertilized field compared with that of unfertilized field which may be due to the application of inorganic fertilizers at the recommended rate at the proper growth stage. On the other hand, unfertilized field does not received accurate nutrients in recommended rate and hence resulted in reduction in plant height.

The descriptive statistics of total leaf production by cassava at four different growth stages in fertilized and unfertilized fields are shown in Table 2. Total leaf production of cassava increased from 40 DAP till harvesting in both fields. Negative skewness values

Table 1. Descriptive statistics of variability of plant height (cm) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	16.45	9.50	26.50	0.23	0.37	4.04	24.54	0.129
80	63.22	30.50	98.00	-0.01	-0.96	19.97	31.59	0.273
120	94.40	60.50	129.50	-0.19	-0.53	17.47	18.51	0.175
160	157.74	120.50	228.00	1.18	0.50	29.68	18.81	0.191
Unfertilized field								
40	15.23	11.00	19.50	-0.01	-0.86	2.47	16.23	0.236
80	56.80	21.50	87.50	-0.21	-0.16	15.85	27.91	0.362
120	77.92	52.00	110.00	0.10	-0.98	16.79	21.55	0.405
160	120.13	68.00	167.00	0.15	-0.55	25.96	21.61	0.293

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

Table 2. Descriptive statistics of variability of total leaf production (number) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	17.17	9.00	26.00	-0.10	-1.10	4.67	27.20	0.287
80	75.46	40.00	129.00	0.31	-0.15	22.93	30.38	0.165
120	126.71	67.00	216.00	0.48	1.34	32.87	25.95	0.294
160	223.17	93.00	376.00	0.35	-0.03	74.04	33.17	0.319
Unfertilized field								
40	14.79	7.00	22.00	-0.14	-0.88	4.22	28.54	0.334
80	70.33	31.00	107.00	-0.29	-0.34	19.82	28.18	0.276
120	112.83	55.00	223.00	1.22	2.39	36.43	32.29	0.249
160	202.75	63.00	418.00	1.06	1.42	79.52	39.22	0.185

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

were recorded at 40 DAP of fertilized field and 40 and 80 DAP of unfertilized field. All other growth stages of both the fields showed positively skewed values, indicating asymmetry in sampling distribution with higher values tailing to the right (Li *et al.*, 2012). The kurtosis values of both fields at all growth stages studied indicated values lesser than 3, making it platykurtic. The CV values of both fields at all growth stages studied indicated 'low' and 'intermediate' variations according to Hillel (1980). Low variations (CV < 10%) were recorded at 40 DAP in both fields and all other growth stages of both fields depicted intermediate variations

since $10\% < CV < 100\%$. The observed values clearly indicate that fertilized field received accurate amounts of nutrients in the form of inorganic fertilizers which might have resulted in luxuriant growth of leaves at the active growth stages of cassava; whereas reverse happened in the case of unfertilized field.

The classical statistical analysis of spatial and temporal variability of dry matter (%) in cassava leaves in fertilized field and unfertilized field is given in Table 3. Leaf dry matter (%) in cassava showed an increase in value at 80 and 120 DAP (active growth stages), of both fields. The data sets of dry matter (%) in leaves in

Table 3. Descriptive statistics of variability of leaf dry matter (%) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	20.67	15.49	23.99	-0.71	-0.01	2.24	10.86	0.284
80	22.77	19.86	26.12	0.06	-0.03	1.52	6.66	0.172
120	23.25	16.68	27.72	-1.17	4.83	3.00	8.62	0.349
160	20.58	12.82	24.60	-0.90	0.64	3.08	14.99	0.263
Unfertilized field								
40	22.72	18.49	27.84	0.50	-0.03	2.34	10.31	0.194
80	23.22	19.50	26.22	-0.28	-0.82	1.82	7.82	0.214
120	26.24	24.20	29.32	0.62	-0.28	1.36	5.18	0.308
160	23.10	16.42	32.44	-0.04	-0.74	4.33	18.76	0.283

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

fertilized field at 40 DAP and 120 DAP of unfertilized field were positively skewed making asymmetry in sampling distribution. All other growth stages of both fields showed platykurtic nature except 120 DAP of fertilized field which indicated leptokurtic nature since the value was greater than 3. The standard deviation values of all growth stages of fertilized field ranged from 1.52 to 3.08 while that of unfertilized field were 1.36–4.33. The CV values of 40 and 160 DAP datasets of both the fields show 'intermediate' variation (Hillel 1980), since $10\% < CV < 100\%$. Other two growth stages (80 DAP and 120 DAP) of both fields indicated 'low' variation because the CV values were less than 10%.

Leaf dry matter (%) exhibited increase at 80 and 120 DAP because these are the active growth stages of cassava whereby leaf production indicated sharp increase and thereby the leaf dry matter.

The spatial and temporal variability of stem dry matter at different growth stages of cassava indicated a general trend of increase in value at all growth stages studied in both fields (Table 4). All growth stages of both fields showed positively skewed nature. Leptokurtic nature of kurtosis values were noted at all growth stages of both fields, since values were greater than 3. The standard deviation values of fertilized field were in the range of 1.50 to 4.52 and that of unfertilized

Table 4. Statistics of variability of stem dry matter (%) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	9.49	7.03	13.65	0.64	1.22	1.50	15.80	0.247
80	16.38	9.68	25.03	0.45	-0.90	4.52	27.63	0.166
120	15.02	9.06	26.82	1.42	4.51	3.53	23.47	0.229
160	20.64	15.52	27.02	0.38	-0.79	3.33	16.15	0.275
Unfertilized field								
40	10.98	6.89	14.77	0.04	-0.70	2.07	18.87	0.134
80	13.24	10.20	19.92	1.09	0.99	2.42	18.29	0.193
120	20.27	14.80	30.28	0.76	-0.32	4.43	21.85	0.283
160	27.22	21.42	38.10	1.03	0.74	4.37	16.06	0.362

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

Table 5. Statistics of variability of tuberous root dry matter (%) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	0	0	0	0	0	0	0	-
80	17.83	14.02	23.52	0.45	-0.43	2.43	13.60	0.269
120	24.00	18.36	29.58	-0.09	-0.49	3.05	12.70	0.192
160	31.77	22.86	39.86	0.27	0.40	4.07	12.81	0.198
Unfertilized field								
40	0	0	0	0	0	0	0	-
80	22.39	11.02	51.60	1.84	3.18	10.61	47.40	0.308
120	28.21	23.18	34.66	0.24	-0.81	3.41	12.08	0.247
160	37.66	29.64	57.04	1.60	2.58	6.70	17.79	0.261

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

field was 2.07 to 4.43. The CV (%) of all growth phases of both fields were in the 'intermediate' range.

The dry-matter content of tuberous roots (Table 5) was more in unfertilized field compared to those of fertilized field at all the growth stages studied. On 40 DAP, there was no root production and hence values are reported as zero. The root dry matter indicated a general trend of increase in value from 40 DAP till harvesting. Skewness indicated negative value only at 120 DAP of fertilized field, whereas all other growth stages of both fields showed positively skewed nature making asymmetry in sample distribution. The kurtosis values of data sets of both fields except that at 80 DAP of unfertilized field indicated a value greater than 3(3.18) exhibiting leptokurtic nature. The standard deviation values of fertilized field ranged from 2.43 to 4.07 while that of unfertilized field was from 3.41 to 10.61. All the CV values indicated an intermediate variation with the values being $10\% < CV < 100\%$.

The leaf area index (LAI) in cassava (Table 6) showed an increasing trend from 40 DAP till 160 DAP at all the four growth stages studied in both fields.

Negatively skewed values were observed at 120 DAP growth stage of fertilized field. The kurtosis value at 40 DAP of unfertilized field was found to be greater than 3 (3.34) making it leptokurtic. Fertilized field had standard deviation values between 0.08 and 1.61 was found to be negative on 120 and while that of unfertilized field it was between 0.07 and 0.91. The CV indicated an intermediate variation of all data sets both in fertilized field and unfertilized field. In cassava, a positive correlation between LAI and yield of storage roots have been reported indicating that leaf area is crucial in determining crop growth rate and storage bulking of cassava as reported by Sinha and Nair (1971).

The descriptive statistics of tuberous root yield of cassava at the four different growth stages studied (Table 7). Fertilized field indicated a higher tuberous root yield when compared with that of unfertilized field, which may be due to application of recommended nutrients inorganic fertilizers at the appropriate growth period of cassava. The mean tuberous root yield of both fertilized and unfertilized fields were 2.64 and 1.94 kg/plant respectively. The root yield ranged from

Table 6. Descriptive statistics of variability of leaf area index (LAI) at different growth stages of cassava as affected by fertilizer application

Growth stage (DAP*)	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
40	0.14	0.05	0.36	1.49	2.40	0.08	59.44	0.241
80	1.13	0.39	2.40	1.01	0.73	1.61	60.96	0.128
120	1.78	0.45	3.58	0.33	-0.41	0.90	50.85	0.169
160	2.56	0.97	4.91	0.25	-0.35	1.17	45.94	0.361
Unfertilized field								
40	0.10	0.01	0.34	1.30	3.34	0.07	71.05	0.247
80	0.96	0.27	2.15	0.52	-0.45	0.91	51.33	0.205
120	1.43	0.33	2.62	-0.03	-1.07	0.73	50.99	0.193
160	1.90	0.77	3.87	0.53	-0.59	0.91	47.85	0.316

*DAP, days after planting; SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

Table 7. Descriptive statistics of variability of root yield (kg/plant) of cassava as affected by fertilizer application at harvest

Treatment	Mean	Minimum	Maximum	Skewness	Kurtosis	SD*	CV* (%)	p -value ks*- test
Fertilized field								
	2.64	0.78	7.0	0.83	1.57	1.22	46.13	0.254
Unfertilized field								
	1.94	0.42	5.22	1.02	1.47	1.01	52.29	0.307

SD, standard deviation; CV, coefficient of variation; ks, Kolmogorov Smirnov test

0.78 to 7 kg/plant in fertilized field whereas in unfertilized field the yield ranged from 0.4 to 5.22 kg plant. Both fertilized and unfertilized fields recorded positive skewness values giving asymmetry in sample distribution. The kurtosis values exhibited platykurtic nature, with the values being less than 3. The CV values of both fields indicated intermediate variation in the case of tuberous root yield. Similar studies on the yield of corn and soybean were reported by Jaynes and Colvin (1997) and Roel and Plant (2004). The mean and standard error graphs of canopy properties and root yield are given in Fig. 1.

Geostatistics of plant characteristics and root yield:

Spatial and temporal variability of plant characteristics and root yield were studied using semi-variograms. The semi-variance of a property is defined as half the expected difference between values at places x and $x+h$ (Mc Bratney and Webster 1983). The resulting omnidirectional semi-variograms for canopy properties and root yield at four different growth stages were

constructed. The spatial attributes of these fitted semivariograms are based on smallest root mean square error (RMSE) value. Plant height at different growth stages studied displayed differences in their spatial dependency.

Plant height at different growth stages studied displayed differences in their spatial dependency. Spatial structure analysis of plant height at four different growth stages revealed that plant height at all stages is well fitted to spherical semivariogram model except 40 days which was found to be exponential (Table 8). Nugget effect contributed very low values at 40 DAP, indicating it to be highly spatially structured, whereas all others depicted high values. The spatial correlation distance (range) varied from 2.23 to 9.95. The nugget to sill ratios of all growth stages except that at 160 DAP indicated a value of 7.53, which is lesser than 25% making strong spatial dependency, whereas that at 80 DAP indicated weak spatial dependency since the value being greater than 75% (79.46).

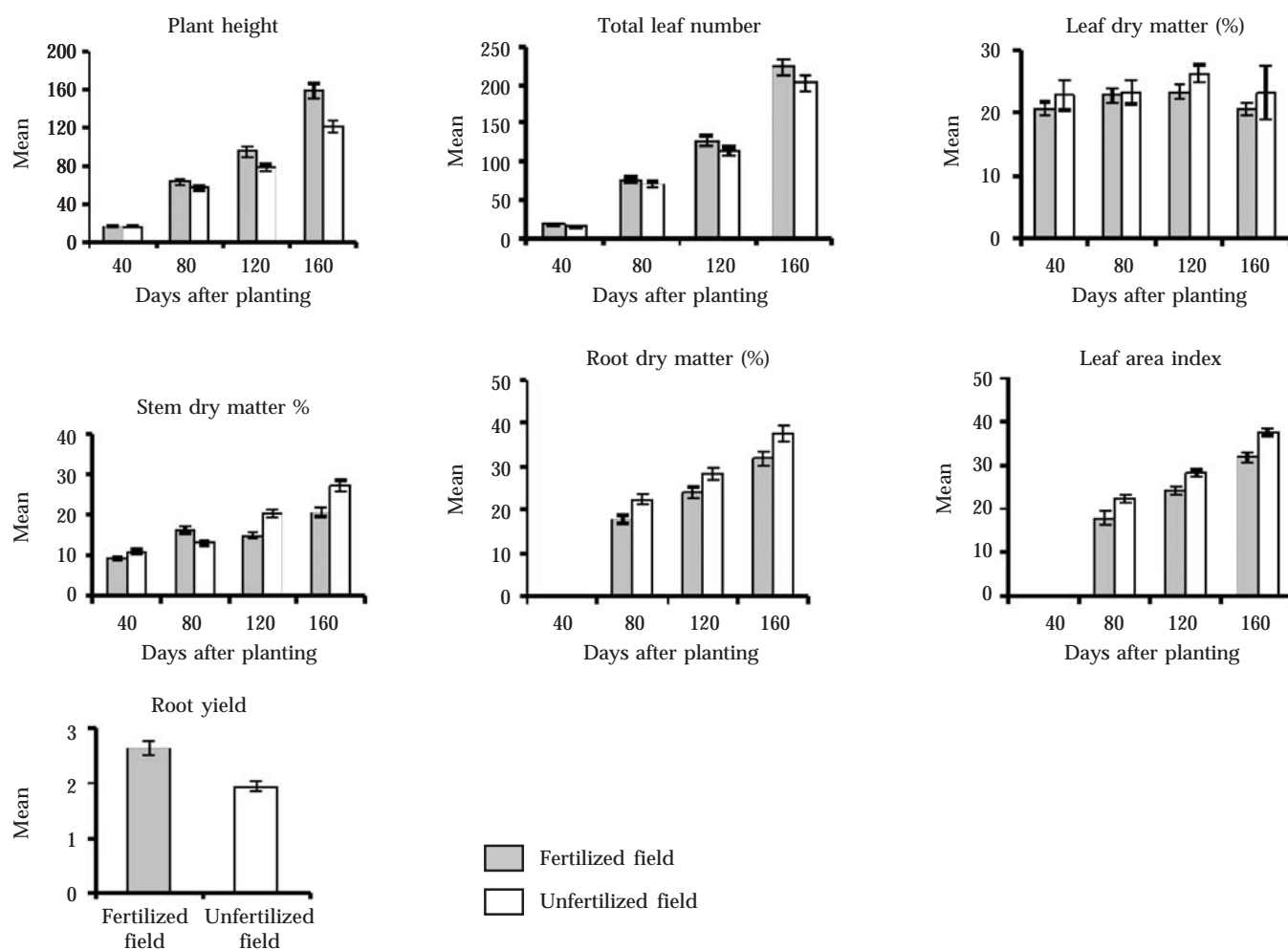


Fig. 1. Mean and standard error graphs of canopy properties and root yield of cassava

The semivariance parameters of leaf number all other growth stages except that at 160 DAP were fitted to spherical model (Table 8). Nugget effects of leaf number were very small at 40 DAP compared with all other growth stages, indicating they are highly spatially structured. The range value of the growth stage 120 DAP indicated higher value (18.11) when compared with others depicting that the observed values of leaf number are influenced by other values of leaf number over great distances according to Issaks and Srivastava (1989). Nugget to sill ratios exhibited weak spatial dependency at 40 DAP, moderate spatial dependencies at 80 and 160 DAP and weak spatial dependency at 160 DAP.

The semivariance parameters of leaf area index at different growth stages found to follow spherical model as the best fitted one (Table 8). Nugget effects were

very small for all growth stages, making them highly spatially structured. The range values of leaf area index at all growth phases varied from 2.17 to 5.59 m. The nugget to sill ratios indicated that spatial class showed weak dependencies in case of 40 and 120 DAP and moderate dependencies in case of 80 and 160 DAP.

The semivariance parameters of leaf dry matter at different growth stages of cassava which indicated spherical model as the most suited one at all growth stages. Nugget effects were very small for all growth stages showing a high spatial structure. The spatial correlation distances (range) indicated higher (36.45) in case of leaf dry matter (%) at 80 DAP which means that observed values of leaf dry matter (%) are influenced by other values of leaf dry matter (%) over great distances. The spatial class was represented by weak dependency for 40 and 80 DAP, while other two

Table 8. Semivariance parameters of plant characteristics and tuberous root yield at different growth stages of cassava

Variable	Growth stage (DAP*)	Model	Nugget	Sill (total)	Range	Nugget/Sill (%)	Spatial dependency
Plant height	40	Exponential	5.99	9.9	3.58	59.96	Moderate
	80	Spherical	254.8	320.65	9.95	79.46	Weak
	120	Spherical	232.8	391.7	9.41	59.43	Moderate
	160	Spherical	54.0	716.8	2.23	7.53	Strong
Leaf no.	40	Spherical	14.07	18.71	9.26	75.20	Weak
	80	Spherical	295.1	414.1	6.48	71.26	Moderate
	120	Spherical	670.3	1243.7	18.11	53.90	Moderate
	160	Exponential	488.0	5810.2	1.41	8.40	Strong
LAI ^a	40	Spherical	0.01	0.01	2.85	100.00	Weak
	80	Spherical	0.90	2.02	2.17	44.55	Moderate
	120	Spherical	0.54	0.70	5.59	77.14	Weak
	160	Spherical	0.84	1.31	2.17	64.12	Moderate
LDM ^b (%)	40	Spherical	5.03	6.68	7.17	75.30	Moderate
	80	Spherical	2.96	3.79	36.45	78.10	Weak
	120	Spherical	2.77	5.35	9.41	51.78	Moderate
	160	Spherical	7.44	15.52	17.12	47.94	Moderate
SDM ^c (%)	40	Spherical	3.55	5.25	28.58	67.62	Moderate
	80	Spherical	12.53	19.28	40.73	64.99	Moderate
	120	Spherical	15.20	24.19	8.70	62.84	Moderate
	160	Spherical	14.86	27.24	2.89	54.55	Moderate
TDM ^d (%)	40	-	-	-	-	-	-
	80	Spherical	104.20	111.27	4.98	93.65	Weak
	120	Spherical	9.74	15.99	10.94	60.91	Moderate
	160	Spherical	9.59	11.79	10.76	81.34	Weak
Yield	Fertilized field	Spherical	0.39	1.57	4.44	24.84	Strong
	Unfertilized field	Spherical	0.81	0.99	3.36	81.82	Weak

*DAP, days after planting; LAI^a, leaf area index; LDM^b, leaf dry matter; SDM^c, stem dry matter; TDM^d, root dry matter; R², coefficient of determination of the fit

growth stages showed moderate spatial dependency. The semivariograms of leaf dry matter (%) thus obtained are given in Fig. 2.

Spherical model best fitted stem dry matter of all growth stages studied (Table 8). Nugget effects were represented by a small value (3.55), indicating it to be highly spatially structured. The range value of 80 DAP was found to be higher compared with all other growth stages. The nugget to sill ratios of all growth stages

were found to be between 25 and 75 % exhibiting moderate dependency. The semivariograms of stem dry matter (%) at different growth stages of cassava are given in Fig. 2.

The root dry matter at 40 DAP was recorded zero because at 40 DAP growth stage there is no tuber production (Table 8). From 80 DAP till 160 DAP, spherical model was found to be the best suited one. Nugget effects recorded higher value at 80 DAP growth

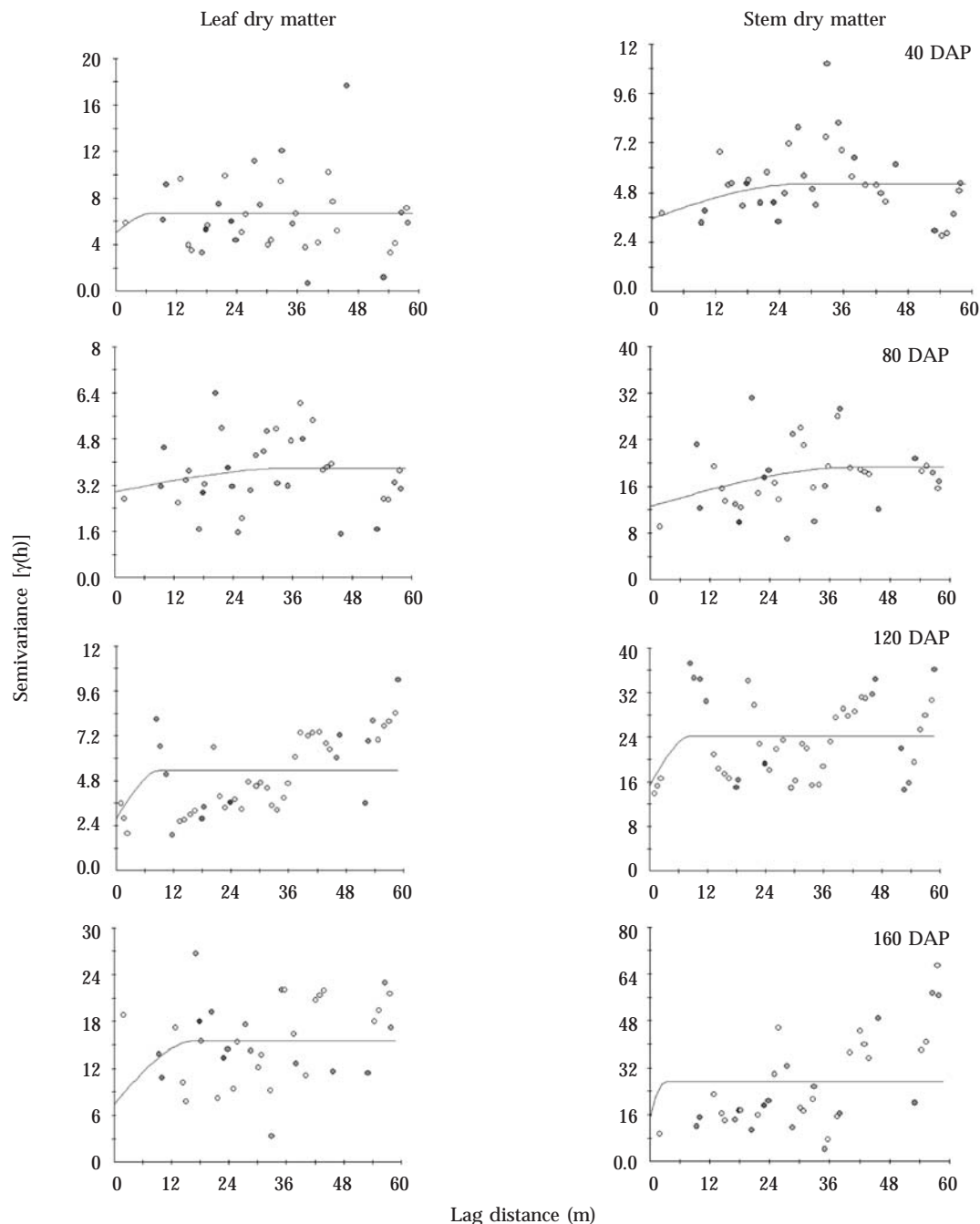


Fig. 2. Semivariograms of leaf and stem dry matter per cent at different growth stages of cassava

stage (104.20), indicating it to be low spatially structured. The spatial correlation distance, *i.e.* range varied from 4.98 to 10.94. The nugget to sill ratios of all growth stages except that at 120 DAP were found to be moderate (60.91 %).

The semivariance parameters of yield (Table 8) at the time of harvesting in fertilized and unfertilized field reveals that both fields showed spherical models. Nugget effects recorded very small values giving it highly spatially structured nature. The spatial correlation distances ranged from 3.36 to 4.44. The nugget to sill ratios were less than 25% (24.84) exhibiting strong spatial dependency and that of unfertilized field was greater than 75% (81.82) indicating weak dependency.

The spatial patterns of canopy properties and root

yield generated from kriging analysis based on their semivariogram parameters are given in Fig. 3. The kriged maps of canopy properties and root yield gives the information regarding spatial distribution over the whole field area selected for study. Kriged maps thus developed indicated almost similar distribution trends in plant height and leaf number, which showed that they were influenced by natural factors beyond human activities according to Long *et al.* (2012). Kriged maps were developed which indicated entirely different distributions exhibiting completely patchy appearance in the case of leaf area index, stem dry matter and tuberous root yield. Intrinsic factors such as soil characteristics, fertilizer application *etc.* may be the main cause of spatial distribution to some extent. There was not much patchy appearance for all other canopy

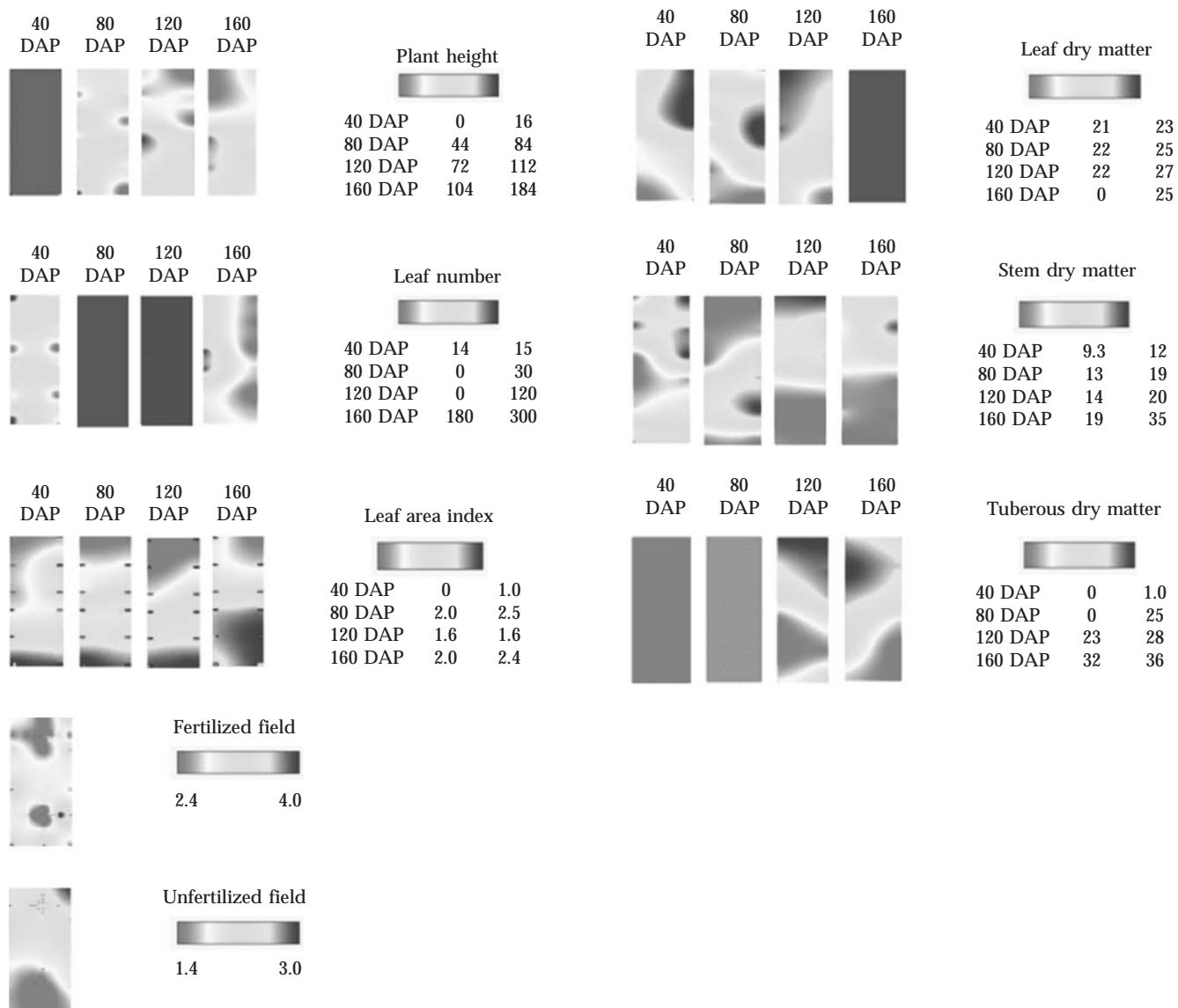


Fig. 3. Kriged maps of canopy properties and root yield of cassava

properties like plant height, total leaf number, leaf dry matter root dry matter indicating them to be influenced by natural factors beyond human activities.

CONCLUSION

Study of spatial and temporal variability of canopy properties and root yield in fertilized and unfertilized fields in an Ultisol showed that these characteristics vary at field scale. The extent of variability was affected by fertilization regimes. Plant height showed greater variability at 80 DAP (active growth stage of cassava) among two fields studied. Total leaf production showed variability in both fields. Leaf dry matter indicated higher variability at 160 days after planting in both fertilized and unfertilized fields. Among the different growth stages of fertilized field, greater variability in dry matter of stem was noted at 80 days after planting but in unfertilized field similar trend was noted at 120 days after planting. The root dry matter varied widely in unfertilized field at 80 days after planting. Leaf area index exhibited wider variability among different canopy properties studied. Leaf area index didn't show much variation between fertilized and unfertilized field which exhibited slightly higher variability (CV = 71.05%) compared with that of fertilized field (CV = 59.44%). In root yield, high variability could be observed in unfertilized field (52.29%). The results indicated that spherical model fitted best for most of the parameters studied. For plant height and leaf number, the exponential model best fitted at certain growth stages studied. Moderate spatial dependency was noted for most of the canopy properties studied at different growth stages, with a nugget accounting for 7.53 to 100 of the total variability. Strong spatial dependencies were exhibited by certain growth stages of plant height, leaf number and for root yield of fertilized field whereas weak dependencies were shown by certain growth stages of plant height, leaf number, leaf dry matter, root dry matter, leaf area index and tuberous root yield of unfertilized field. The spatial correlation distances of all the canopy properties and tuberous root yield studied varied from 1.41 to 40.73 m. Kriged maps were developed which indicated entirely different distributions exhibiting completely patchy appearance in the case of leaf area index, stem dry matter per cent and tuberous root yield. Intrinsic factors such as soil characteristics, fertilizer application etc may be the main cause of spatial distribution to some extent. There was not much patchy appearance for all other canopy properties studied indicating them to be influenced by natural factors beyond human activities. The study will further help to design kriged interpolated maps of large field area for site specific nutrient strategies to increase yield by simultaneously

minimizing environmental pollution.

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Standardization of single eye cutting in patchouli (*Pogostemon cablin*)

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ABSTRACT

An experiment was conducted to standardize single eye cutting in patchouli (*Pogostemon cablin* Besets) to reduce the use of young shoots for rooted cutting production as the shoots with five internodes are used for extraction of oil. Different leaf positions were selected for assessing the cutting success, i.e. juvenile leaf (T₁ - second node from shoot tip), immature leaf (T₂ - third leaf), mature leaf (T₃ - fourth leaf) and fully matured leaf (fifth leaf). Among four leaf types used, fourth nodal leaf (T₃) from the shoot tip had highest root and shoot growth. The root initiation started 14 days after insertion in T₃, whereas it was delayed and started 18 days after planting in T₁. Number of days taken for shoot initiation was also least (14.50 days) in T₃. Shoot emergence was delayed up to 6 days in T₁ compared to T₃. The fresh and dry weight of roots and shoot, and photosynthetic rate of single eye cutting were highest in T₃ (fourth nodal leaf). Maximum survival of plantlet was recorded in T₃ 45 days after planting. In conclusion, single eye from fourth and third nodal leaf from the shoot tip are recommended for successful vegetative propagation of patchouli using this technique.

KEY WORDS: Leaf cutting, Adventitious root formation; Source leaf age; Cutting success. Vegetative propagation

Patchouli (*Pogostemon cablin* Benth, syn. *P. patchouli* Pellet) is a valued aromatic plant belonging to Lamiaeceae family. It is the source of patchouli oil which is obtained by steam distillation of its shade-dried leaves. The oil has a characteristic woody fragrance and fixative properties, therefore scent is retained for a longer period in the skin. Synthetic substitute for patchouli oil is difficult to produce because of its complex mixture of perfumery constituents like sesquiterpenes and hydrocarbons such as, patchouli alcohol, patchouline, bunnene, guaiane, caryophyllene, elemene and copaene and other minor constituents (Sugianura *et al.* 1990). There is a growing demand for patchouli oil in the international market.

Its crop is cultivated in Indonesia, Taiwan, Malaysia, India, Singapore and other South-Asian countries. Patchouli is usually propagated by stem cuttings.

The recurrence of viral, bacterial and fungal diseases and nematode infestations during propagation limit the scope of mass production of patchouli. Meristem-tip culture for mass production of patchouli was successfully carried out which resulted in pathogen free plantlets for cultivation in the fields (Husen, 2006) and results were promising with significant increases in leaf biomass and essential oil yield. However, reinfection of virus is inevitable during successive cultivation. Clonal propagation and shoot meristem culture were also reported in patchouli. However, field establishment of plantlets obtained through these techniques remains a stumbling block for adopting these techniques in addition to the excessive cost of production. Use of adventitious bud techniques were successfully employed in other crops for plantlet production through leaf cuttings to overcome the problems related to higher input cost, virus reinfection (Broertjes *et al.* 1968).

Many plant species have the ability to form

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adventitious plantlets (Hactmann *et al.* 2002). Published reports for patchouli on this aspect are rather contradictory. Volkhovskaya (1968) first reported rooting of patchouli leaves and subsequent development of shoots.

Selvarajan and Madhava Rao (1981) reported only rooting but no shoot formation. Vasantha Kumar and Narguda (1987) reported shoot formation in leaf cuttings but subsequent growth was slow and took 80-140 days for plantlet to reach optimum size suitable for transplanting. Further, leaf with a portion of petiole was used and shoot development occurred after callus formation in the cut end of petiole. This resulted in delayed shoot initiation and low success in plantlet production. To overcome their problems associated with patchouli propagation, we have attempted for the first time the use of single eye propagation and optimum leaf stage for single leaf cutting of patchouli using low-tech environment that can be set up anywhere with minimal resources. The use of optimum leaf stage was investigated to ensure the maximum cutting success and provide healthy and vigorous plants with a cost-effective propagation system with high multiplication ratio.

MATERIALS AND METHODS

Experimental material

Field-grown patchouli (cv. Kelkar selection) plants from the experimental farm of the Directorate of Medicinal and Aromatic Plants Research, Boriavi (N 22°55', E072°66', MSL - 45m, Anand Gujarat, India) were used as source material for study. Fully-opened green leaves with nodal region and an auxiliary bud were randomly sampled from healthy shoots of one-year-old plants. Five hundred mother plants were used. Four sets of leaves with 5 mm of nodal portion retaining the auxiliary bud were prepared :

- T₁ : Leaves from second node from the top of stem (juvenile leaves)
- T₂ : Leaves from third node from the top of stem (immature leaves)
- T₃ : Leaves from fourth node from the top of stem (matured leaves)
- T₄ : Leaves from fifth node from the top of stem (fully matured leaves).

Prior to planting, basal 2 cm of cuttings were treated by dipping in 0.1% Mancozeb to prevent fungal infection. Cuttings were inserted vertically to a depth of 3-5 cm in cells filled with sand, soil and composted cow manure in a 1:1:1 ratio and are maintained in propagation platform (400 cells per platform) under climatically controlled polyhouse with 50% shade. The temperature was maintained at 28±2°C; relative humidity was 80-90%. A mist apparatus fitted with a

timer operating in playhouse generated the required humidity by a fine spray of mist for 20 seconds per five minutes. Each replication consisted of 100 leaves per treatment and each treatment was replicated four times.

Growth analysis

Observations were recorded daily on root initiation ability of different pairs of leaves from 5-15 days until all the treatments were rooted and shoot initiation ability from 10-20 days daily until all the treatments exhibited shoot formation. Remaining observations were recorded on root and shoot parameters at 15, 20, 25, 30, 35, 40 and 45 days. On each days of observation, 10 leaf cuttings from each replication were sampled. Number of leaves per plantlet and survival or presence of mother leaf with plantlet were recorded at 45 DAP.

Net photosynthesis and respiration

Net photosynthetic rate (Pn) and leaf respiratory rate in mother leaf were measured in leaves using a portable open infra-red gas analyzer (LI-6400, LI-COR Inc., Lincoln, USA) at ambient light levels in greenhouse. Measurements were made using a standard leaf chamber (2 cm × 3 cm) with a transparent top during 11.00-1.00 pm at 20, 30 and 45 DAP.

Statistical analysis

Statistical analysis was carried out using the statistical package MSTAT-C version 1.4 (Crop and Soil Science Division, Michigan State University, USA). Least significant differences (LSD) (P = 0.05) were compared between two treatment means.

RESULTS AND DISCUSSION

Root and shoot development

The single eye cuttings from different nodal positions showed significant variations for days to root and shoot initiation, root growth, shoot growth and plantlet survival. Patchouli leaves produced roots profusely at the cut ends of petiole under intermittent mist. Roots originated near the basal cut end, along the midrib and parts of the leaf in contact with sand. Early root initiation (7.17 days) was observed in single eye cuttings where the fourth nodal leaf (T₃) was used.

However, fifth nodal leaf (T₄) resulted in late root initiation (9.67 days). Number of days taken for shoot initiation was also the least (14.50 days) in T₃ which was followed by T₂ (Table I). Shoot emergence was delayed up to 6 days in T₁ compared to T₃ single eye cutting. Maximum survival of plantlet was recorded in T₃ 45 days after planting in rooting medium and more than 87% of plantlets could not survive in T₄. The other leaf positions fared better at 45 days with 55.33 and 66.00% survival in T₁ and T₂, respectively. Even though more number of juvenile leaves was present in T₃

Table 1. Root and shoot parameters of single leaf cuttings in patchouli

Parameter	Treatment				LSD-(5%)
	T ₁	T ₂	T ₃	T ₄	
Days to root initiation	8.17 ^b	8.17 ^b	7.17 ^a	9.67 ^c	0.68
Days to shoot initiation	20.50 ^d	16.33 ^b	14.50 ^a	17.33 ^c	0.37
Plantlet survival at 45 DAI (%)	50.33 ^b	66.00 ^c	72.00 ^c	12.66 ^a	12.94
Total number of leaves (plantlet ⁻¹)	4.33	4.33	4.66	4.33	N.S.
Survival of mother leaf (%)	53.33 ^c	53.33 ^c	40.00 ^b	28.50 ^a	5.90

Different letters express significantly different results among the treatments at 0.05 level. Values represent the means of four replicates

treatment at 45 days and did not vary significantly among leaf types used.

The results showed that potential for adventitious root formation and shoot growth varied markedly among single eye cuttings of patchouli from different leaf positions. The leaf age and maturity played the crucial role in adventitious root growth and shoot development. Several reasons have been assigned to decreasing rooting ability of aging and matured stock plant cuttings. The hormonal control of signals associated with root development especially auxin is known (Celenza *et al.* 1995). Auxins induced ethylene synthesis may play a role in adventitious root initiation and the associated increase in cellulase activity (Kemmerer and Tucker 1994). Decreased sensitivity of the tissue to auxins with biological aging of the stock plant, accumulation of rooting inhibitors and reduction in endogenous auxin content and/or root promoters (Hactmam, 2002; Ofori *et al.* 1997) are attributed for the variations.

Parmenter and Littlejohn (2000) also reported a close relationship between initial root weight and maximum leaf area in ginseng. Ageing of stock plant was found to reduce the rooting potential in many species (Bhardwaj and Mishra, 2005; Husen and Pal, 2006). The poor and sparse adventitious root initiation and further shoot growth of juvenile (T₁) and fully matured leaf (T₄) used for single eye cutting are possibly due to these factors. Maximum percentage of mother leaf at the end of the treatment period was observed (53.33%) in younger leaf types used (T₁ and T₂) compared to other eye cuttings. Minimum percentage of mother leaf was observed in the T₄ (28.50%), this can be a consequence of the low availability of carbohydrate, reserve tissue, and higher content of ABA (Kojima *et al.* 1993; Pressman *et al.* 1993).

Net photosynthesis (Pn) and leaf respiratory rate(R)

Leaf gas exchange parameters measured in the mother leaf exhibited a significant variation among the treatments. Maximum net photosynthetic rate was

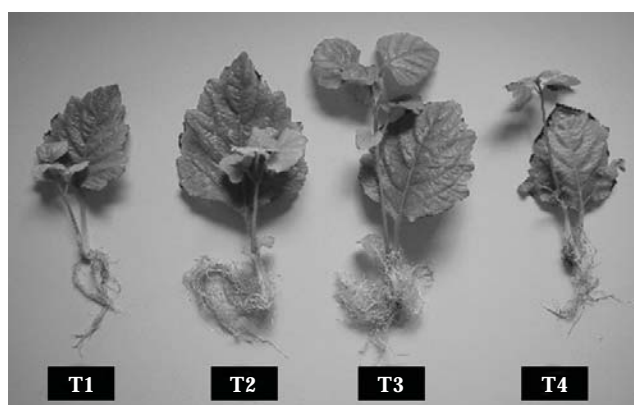


Fig. 1. Rooting and shoot development in T₁ (juvenile), T₂ (immature), T₃ (Mature) and T₄ (Fully matured and older leaf) of patchouli

observed in T₃ and minimum in T₁ which was at par with T₄ (Fig. 1-A). T₁ maintained only 39% of the Pn that of T₃ due to the juvenile nature of leaf which could not support a higher net assimilation. Lowest leaf respiration rate (R) was observed in T₃, whereas T₂ had highest R was recorded in T₂ (Fig. 1-B). Reduced leaf respiration may be one of the reasons for the higher carbon assimilation as Pn observed for T₃. The leaf with the petiole provided all the required nutrients to the developing roots. Leaves are the main source of carbohydrates in the cuttings (Leakey *et al.* 1982) and they also provide the physiological requirements to stimulate rooting apart from the supply of carbohydrate. Source leaf photosynthesis is the main source of carbon skeletons required for cellular processes and growth of cuttings.

Fresh and dry weight of single leaf cuttings

The root growth pattern in different leaf cuttings showed marked variations. The length of roots in T₁ and T₄ nodal leaves was shorter throughout the study period and growth was slower compared to other leaf cuttings (Fig. 2-A). In T₃ and T₂ cuttings, there were a

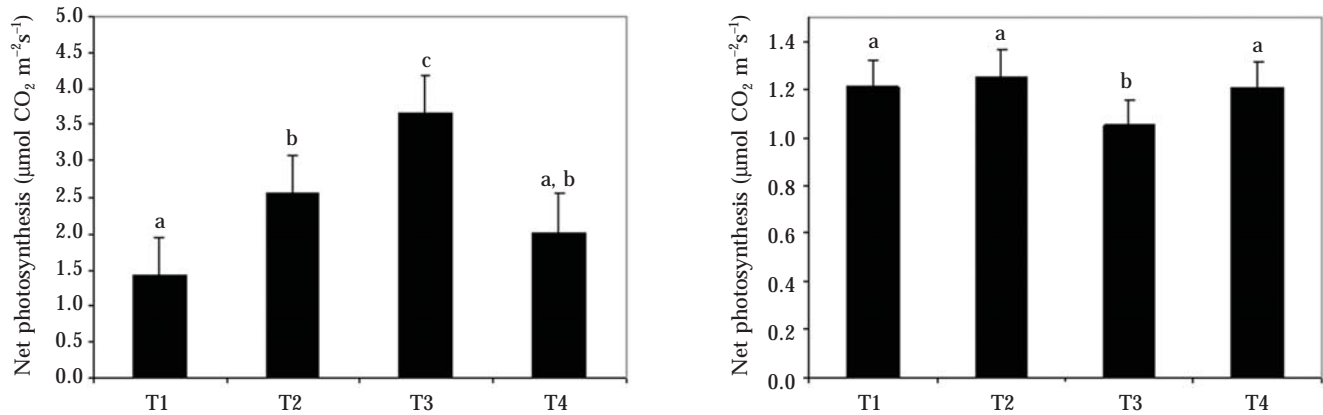


Fig. 2. Variation in net photosynthetic rate (A) and respiratory rate (B) in different treatments of single leaf cuttings of patchouli. Different letters express significantly different results among the treatments at the 0.05 level. Values are presented as mean \pm standard error of six replicates.

rapid root and root growth initially (up to 35 - days after planting in medium) and reached a plateau afterwards. However, rate of root growth

was maintained in other cuttings even at 45 DAP. Conversely, shoot growth pattern was different from root and all cuttings showed increasing trend

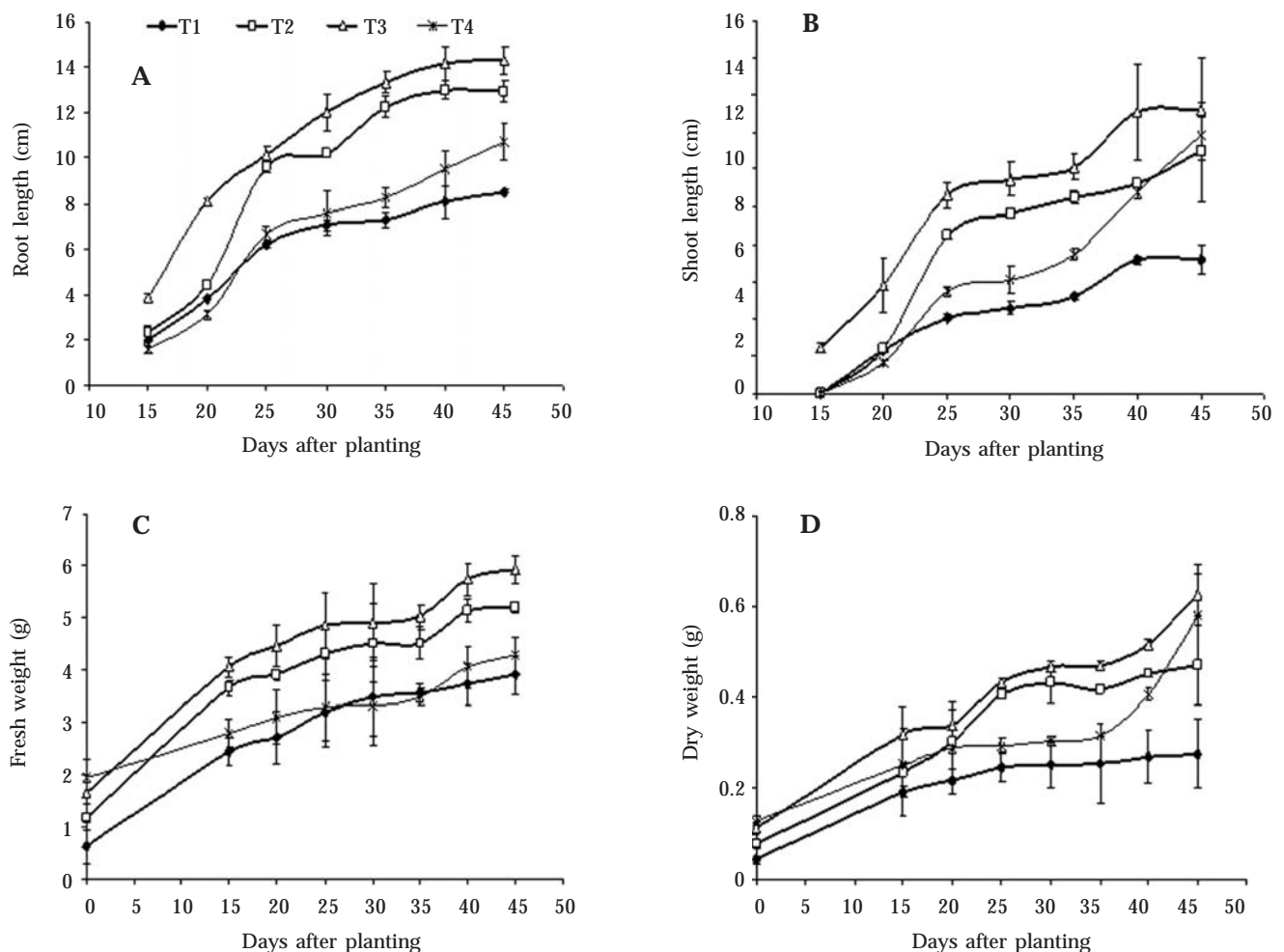


Fig. 3. Pattern of adventitious root growth (A), shoot development (B), changes in fresh weight (C) and dry weight (D) of single leaf cuttings of patchouli. (Bars indicate Std. Dev at P=0.05).

throughout the period (Fig. 2-B). Since leaves varied in their maturity, source leaf physiological stages were also different and consequently influenced the root formation and shoot growth.

The appropriate stage of cuttings is essential for rooting success and shoot development. Fresh weight and dry weight of cuttings were highest in T_4 and lowest in T_1 cuttings. The fresh weight of leaf cuttings increased rapidly in cuttings after 15 days and maintained till 40 DAP except in T_1 which showed retarded growth throughout period (Fig. 2-C). The fresh weight gain in T_4 was lower in initial period, but increased rapidly later and at the end of the treatment period, it was higher than T_2 cutting. The fresh and dry weight of cuttings increased substantially, except in T_4 . The fresh weight increase was rapid (from 1.5 to 4 g in T_3 and from 1.2 to 3.8 g in T_2 cuttings) in the first week and subsequently the increase was marginal.

The increase in fresh weight of T_4 was only marginal, i.e. from 2 to 3.7 g at 45 DAP. The dry weight increase in cuttings was similar in both T_2 and T_3 , however, cutting dry weight increased along with new shoot was substantially higher in T_3 at 45 DAP. In contrast to other cuttings, T_1 fared poorly with only marginal increase of dry weight (from 50 to 200 mg). Apical shoots are superior to basal stem regions in producing the better rooting and stem formation in patchouli (Garbuio *et al.*, 2007). The single leaf cuttings performed well when leaves were at right maturity (Fig. 2-D). The leaf position of fourth and third from the shoot tip (T_3 and T_2) were superior to their younger and older counterparts. The single eye cuttings are ready for planting in the main fields after 45 days and hence the multiplication rate is high. This technique does not require special skills compared to micro-propagation techniques which require higher investment, technical expertise and longer periods for plantlet production.

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Effect of different mulch types on canopy temperature, soil moisture content, growth, yield and quality of cherry (*Prunus avium*)

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ABSTRACT

An experiment was conducted to find out the effect of different mulches on canopy temperature, soil moisture content, growth, yield and quality of cherry (*Prunus avium* L.) during 2009-11 at CITH, Srinagar, Jammu and Kashmir. Twenty-one selections of Bigarreau Noir Grossa (Mishri), Bigarreau Napoleon (Double), Guigne Pourpera Precoca (Awal Number), Guigne Noir Hative (Makhmali), Lambert and Lapins were planted at 2.5 cm × 2.5 m spacing for evaluation. Maximum trunk circumference (47.44 cm) was reported in Makhmali (V4) and inorganic mulch (M2). Maximum tree height (2.62 m), annual shoot extension (74.88 cm), fruit weight (8.30 g) and fruit length (24.81) were observed in treatment combination of Makhmali(V4) and organic mulch (M1). The mean comparison of combined treatments of variety and mulch type showed that inorganic mulch (M2) showed positive effects on primary branch girth. The interaction effect of Stella (V1) and organic mulch resulted in highest yield/plant (13.24 kg) and total soluble solids (18.80 °Brix).

KEY WORDS: Cherry, Yield, Mulch, Growth, Fruit quality, Canopy temperature, Soil moisture, Growth

Conservation of water through use of mulches is age old practice, it is of two types, *i.e.* organic (Forge *et al.*, 2002) or inorganic (Mage, 1982), depending on composition which affects the growing medium differently. The mulching increases the specific mineral elements in soil and contribution of organic material to biological component of soil environment (Forge *et al.*, 2002). In addition, some mulches suffer changes in moisture which also have an influence on the soil biology (Arancon *et al.*, 2006). However, whether these changes are sufficient to result in consistent significant changes in nutrient status of leaves and fruits needs to be considered carefully before recommendation are made to commercial producer.

Other possible effects of mulches include suppression of weed growth (Baxter, 1970), increased soil moisture (Barzegar *et al.*, 2002), temperature moderation (Treder *et al.*, 2004) and improved root

growth (Acharya and Sharma, 1994). Therefore, one of the proposed approaches to cope up with water shortage and consequently, increase yield is application of different kinds of mulches to cover soil surface or around tree trunk. Many objectives such as soil erosion, weed invasion control along with improvement of water infiltration and water saving by decreasing evaporated water from soil surface have been followed to extend and improve mulch systems in crop production systems.

Studies on effects of mulches on yield, growth and nutrition are normally conducted on newly-established orchards (Van Schoor, 2009) or annual crops (Ekinci and Durson, 2009). However, limited information is available on the effects of organic and inorganic mulches on established orchards (Neilsen *et al.*, 2003) especially under temperate ecology of Kashmir. Therefore, an experiment was conducted to find out the effect of two different mulch types, *viz.* organic and inorganic ones on yield, growth and fruit quality in an established orchard of cherry.

MATERIALS AND METHODS

The experiment was conducted during 2009-2011 at Central Institute of Temperate Horticulture, Srinagar,

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situated at latitude of 34° 45N and longitude of 74° 50 E and an elevation of 1649 m above mean sea-level. Twenty-one selections of sweet cherry obtained from primitive varieties, i.e. Bigarreau Noir Grossa (Mishri), Bigarreau Napoleon (Double), Guigne Pourpera Precoca (Awal Number), Guigne Noir Hative (Makhmali), Lambert and Lapins, budded on *Prunus cerasus* rootstock planted at 2.5 m × 2.5 m for evaluation with regard to pomological traits. Three plants from each selections were selected for recording the observations. The morphological traits were recorded at the termination of tree growth. The tree trunk circumference was measured with the help of measuring tape and 10 cm above bud union. Tree height and annual extension growth of current season's shoots were recorded (Westwood, 1993). Tree spread north-south and east and west were also recorded by measuring tape.

Primary and secondary branch girth were measured with the help of digital Vernier caliper. Twenty ripen fruits were randomly collected for recording qualitative observations (fruit weight, fruit length, fruit diameter and TSS). Fruits from each replicate were weighed on a digital balance and average weight was determined by dividing the total weight obtained (g) by number of fruits in sample. Fruit size in terms of fruit length and diameter of each replicate was measured at the longest and widest positions with the help of a Digital Vernier calliper. Total soluble solids concentration was determined on a freshly squeezed juice sample per fruit. The data were subjected to pooled analysis. All the genotypes were grouped on the basis of generalized grouping using the Tocher's method as suggested by Rao (1952).

RESULTS AND DISCUSSION

Vegetative growth of sweet cherry

Analysis of variance for trunk circumference revealed significant difference between V4, V3 and V6, while rest of the varieties (V1, V2 and V5, V7) were statistically at par with V3 and V6 respectively (Table 1). Also, mean comparison of trunk circumference for different mulch types did not show any significant difference within themselves (M1 × M2) and with the control (M3) as well. Similarly, mean comparison of combined treatments (variety × mulch) also did not reveal much significant difference. However, maximum trunk circumference (47.44 cm) was reported in V4 and inorganic mulch (M2), followed by V3 and inorganic mulch (M2). As far as tree height is concerned, non-significant difference was reported between V3, V4, V2 and V6 which showed the height of 2.44, 2.44, 2.43 and 2.40 m respectively, whereas lowest plant height (2.15 m) was reported in V5 which

revealed significant difference with rest of the treatments. The simple mean effects of mulch types did not attain any significant difference. Maximum tree height (2.62 m) was observed in treatment combination of V4 × organic mulch (M1) followed by V3 and M1 (2.51 m).

The results indicated that maximum girth of primary branch (45.73 mm) was observed in V3, while as minimum girth of primary branch (38.21 mm) was recorded in V6. Mean comparison on simple effects of mulches on primary branch girth indicated that both organic (M1) and inorganic (M2) mulches had significant differences. Also, mean comparison of combined treatments (variety and mulch type interaction) showed that inorganic (M2) mulch had shown positive effects on primary branch girth. Similar results were obtained for secondary branch girth for individual effects of variety except that maximum girth was observed in V1 (25.56 mm).

Maximum shoot thickness (7.73 mm) was observed in V2 which showed significant difference with all other varieties. The combined interaction effects also did not indicate much significant difference. The maximum shoot extension (68.70 cm) was recorded in V1 which was significantly different to V3 (59.46 cm) and V2 (54.18 cm). The individual effects of mulching showed significant difference with that of control and maximum annual extension growth (63.10 cm) was attained under organic mulching (M1), followed by M2 (62.68 cm) and least in the control (M3) treatment. The combined effect of variety and mulch revealed that irrespective of the variety, majority of combinations showed that organic mulch (M1) was more useful for this particular trait.

Yield and quality traits

The maximum yield (11.37 kg/tree) was observed in V1 (Stella) followed by in V6 (6.00 kg/tree) and V3 (5.47 kg/tree), whereas minimum yield (2.70 kg) was recorded in V2 (Lapins) (Table 2). Mulch treatments also showed significant differences within themselves and that with the control (M3). Among various mulches, maximum yield/plant (5.79 kg) was observed in M1 (organic mulch) followed by M2 (inorganic mulch) (5.44 kg) and M3 (control) (5.06 kg), respectively. The interaction effect of varieties and mulches also showed significant differences with maximum yield (13.24 kg/tree) in V1 and organic mulch (M1), followed by V6 (8.54 kg/tree) in and inorganic mulch (M2), whereas minimum yield/plant (2.27 kg) was observed in V7M1, respectively.

Analysis of variance for fruit weight revealed that varieties showed significant differences with respect to fruit weight and maximum fruit weight (7.76 g) was observed in V4, followed by (6.58 g) in V7.

Table 1. Effect of different mulch types on growth and vigour of cherry

Treatment	Trunk circum- ference (cm)	Tree height (m)	Tree spread EW (m)	Tree spread NS (m)	Primary branch girth (mm)	Secondary branch girth (mm)	Annual shoot thickness (mm)	Annual extension growth (cm)
Main effect of varieties								
V1 (Stella)	32.07b	2.30b	2.85a	2.523de	42.13bc	25.56a	7.448ab	68.70a
V2 (Lapins)	32.37b	2.43a	2.56a	2.604bcd	44.45ab	21.02b	7.731a	54.184c
V3 (Mishri)	33.92b	2.44a	2.90a	2.851a	45.73a	22.34b	7.381ab	59.460b
V4 (Makhmali)	39.92a	2.44a	2.77a	2.680bc	39.58cd	19.30dc	6.977b	66.371a
V5 (Bing)	28.58c	2.15c	2.96b	2.567cd	39.61cd	21.03bc	6.967b	66.62a
V6 (Double)	29.33c	2.40a	2.71a	2.738ab	38.21d	20.26c	6.804b	58.436bc
V7 (Van)	29.23c	2.35b	2.43a	2.400e	38.91d	20.61b	7.507ab	59.414c
LSD (p=0.05)	2.71	0.14	0.13	0.144	2.78	1.64	0.733	4.32
Main effect of mulches								
M1 (Organic)	31.52a	2.40a	2.76a	2.689a	40.41b	20.72b	7.219a	63.10a
M2 (Inorganic)	33.27a	2.36a	2.69a	2.524b	43.67a	22.78a	7.307a	62.68b
M3 (Control)	31.82a	2.33a	2.77a	2.657a	39.61b	20.84b	7.252a	59.87b
LSD (p=0.05)		0.12		0.094	1.82	1.07	0.480	2.83
Interaction effect of variety and mulches								
Stella × Organic	33.40b	2.21d	2.76c	2.506e	37.84c	23.73b	6.560d	65.366b
Stella × Inorganic	30.80bc	2.42ab	2.74c	2.340f	46.83b	30.38a	8.113a	71.46a
Stella × Control	32.03b	2.26cd	3.04a	2.723d	41.74bc	22.58b	7.673b	69.27a
Lapins × Organic	33.36b	2.45a	2.62d	2.706d	47.52b	18.94c	8.000a	55.62c
Lapins × Inorganic	29.26c	2.41ab	2.14f	2.580e	42.01bc	24.25b	6.873cb	52.47c
Lapins × Control	34.48b	2.43ab	2.91b	2.526e	43.81b	19.86c	8.320a	54.45c
Mishri × Organic	29.49c	2.51a	3.16a	2.906a	39.07c	21.10cb	7.170b	56.64c
Mishri × Inorganic	39.44b	2.38c	2.91b	2.783c	60.36a	26.49b	8.283a	70.11a
Mishri × Control	32.84b	2.44ab	2.63d	2.863b	37.75c	19.44c	6.690c	51.63
Makhmali × Organic	35.87b	2.62a	2.63d	2.920a	39.18c	19.20c	7.083b	74.88a
Makhmali × Inorganic	47.44a	2.20d	2.89b	2.553e	40.97bc	18.46c	6.500d	62.23b
Makhmali × Control	36.45ab	2.51a	2.77c	2.560e	38.58c	20.24c	7.350b	62.00b
Bing × Organic	29.92c	2.13d	3.35a	2.836b	39.21c	21.43cb	6.960cb	68.86ba
Bing × Inorganic	28.51c	2.22d	2.66d	2.250g	40.13bc	19.84c	7.000b	64.52b
Bing × Control	27.33d	2.10d	2.88b	2.616e	39.47c	21.83cb	6.943cb	66.48b
Double × Organic	29.16c	2.50a	2.77c	2.790c	40.47bc	20.45cb	7.346b	58.79c
Double × Inorganic	29.16c	2.37c	2.84b	2.840b	36.64cd	19.53c	6.480	59.03c
Double × Control	29.66c	2.35c	2.52e	2.586e	37.54c	20.81c	6.586c	57.47c
Van × Organic	29.46c	2.37c	2.01f	2.156g	39.56c	20.19c	7.413b	61.55bc
Van × Inorganic	28.26c	2.50a	2.63d	2.326f	38.77c	20.54c	7.903b	58.92c
Van × Control	29.96c	2.19d	2.66d	2.716d	38.42c	21.10cb	7.206b	57.77c
LSD (p=0.05)	4.69	0.64	0.23	0.25	4.826	2.85	1.271	7.495

The difference between control (M3) and mulch treatments was significant and highest fruit weight (6.07 g) was observed in M1 (organic mulch) (6.06 g). Interaction effects of variety and mulch treatments also showed significant differences and maximum fruit weight (8.30 g) was observed in V4 and organic mulch, followed by V4 and inorganic mulch (7.57 g), while

minimum fruit weight (2.90 g) was observed in V6 and the control. As far as fruit length is concerned, varietal differences with respect to this trait were also significant with maximum fruit length (24.71 mm) under V4 followed by (23.17 mm) in V7.

Mulch treatments showed non-significant differences within themselves but were significantly

Table 2. Effect of different mulch types on soil moisture, canopy temperature, yield and fruit quality of cherry

Treatment	Soil moisture (%)	Canopy Temp. Inner (°C)	Canopy temp. Outer (°C)	Yield /plant (Kg)	Fruit weight (g)	Fruit length (mm)	Fruit Dia. (mm)	T.S.S. (°B)
Effect of varieties								
V1 (Stella)	11.73c	24.92d	28.91c	11.37	6.42	23.05	22.47	17.71
V2 (Lapins)	13.49b	26.25ab	29.34b	2.70	5.68	16.78	17.84	13.14
V3 (Mishri)	16.33a	26.80a	30.15a	5.47	4.71	19.95	20.96	15.50
V4 (Makhmali)	13.68b	26.00bc	29.98a	4.01	7.76	24.71	24.09	16.27
V5 (Bing)	10.28d	25.70 bc	29.79ab	3.98	5.35	15.98	19.22	13.97
V6 (Double)	16.91a	26.04 bc	29.95a	6.00	3.60	18.29	18.50	11.13
V7 (Van)	16.66a	25.49cd	29.27b	5.38	6.58	23.17	22.62	17.14
LSD (p=0.05)	0.84	0.565	0.53	0.23	0.29	0.55	0.64	0.77
Effect of mulches								
M1 (Organic)	18.24a	25.52b	29.46b	5.79	6.06	20.53	21.06	15.99
M2 (Inorganic)	15.96b	25.79b	28.92c	5.44	5.58	20.38	20.89	15.08
M3 (Control)	8.26c	26.36a	30.50a	5.06	5.12	19.93	20.18	14.18
LSD (p=0.05)	0.55	0.37	0.34	0.15	0.19	0.36	0.41	0.50
Interaction effect of varieties and mulches								
Stella × Organic	14.10	24.10	27.83	13.24	7.43	23.40	24.44	18.80
Stella × Inorganic	14.31	25.16	28.82	6.65	6.06	22.07	22.47	17.63
Stella × Control	6.78	25.52	30.07	4.24	5.76	21.05	22.26	16.70
Lapins × Organic	18.74	27.74	31.26	2.45	5.90	18.63	16.91	13.60
Lapins × Inorganic	13.54	25.66	27.86	2.76	5.83	17.93	16.46	13.30
Lapins × Control	8.20	25.36	28.92	2.90	5.33	16.97	16.99	12.53
Mishri × Organic	17.38	26.10	30.08	8.10	4.82	21.14	19.85	15.43
Mishri × Inorganic	22.12	26.63	29.61	4.50	4.75	20.15	19.36	15.40
Mishri × Control	9.49	27.66	30.76	3.81	4.55	21.61	20.65	15.06
Makhmali × Organic	15.46	25.88	28.67	3.81	8.30	24.81	25.40	17.49
Makhmali × Inorganic	18.60	26.03	29.19	3.83	7.57	23.56	24.37	17.03
Makhmali × Control	6.98	26.11	32.08	4.37	7.42	21.89	22.36	13.50
Bing × Organic	14.66	23.69	29.60	3.99	5.63	19.29	16.13	15.93
Bing × Inorganic	8.12	26.62	30.19	3.51	5.40	19.22	16.02	13.36
Bing × Control	8.04	26.78	29.57	4.45	5.03	19.17	15.79	12.63
Double × Organic	30.00	25.96	29.68	6.65	4.05	18.29	18.10	11.50
Double × Inorganic	10.31	25.44	28.63	8.54	3.86	19.44	19.18	11.13
Double × Control	10.41	26.72	31.53	2.81	2.90	17.77	17.60	10.76
Van × Organic	17.38	25.16	29.11	2.27	7.33	23.16	24.86	18.70
Van × Inorganic	24.70	24.97	28.12	7.68	6.36	21.26	21.79	17.33
Van × Control	7.90	26.34d	30.59	4.18	6.06	23.05	22.86	15.40
LSD (p=0.05)	1.46	0.97	0.92	0.41	0.50	0.95	0.95	1.33

different with respect to control (M3). The interaction effects revealed that maximum fruit length was observed in V4 with organic mulch (24.81 mm) followed by V4 and inorganic mulch (23.56 mm), whereas minimum fruit length (16.97 mm) was observed in V2 with no mulch (control). Similar results were observed

for fruit diameter, maximum fruit diameter of (24.09 mm) in V4, followed by V7 (22.62 mm). The interaction effects were also similar as that observed for fruit length and fruit weight. As far as fruit quality is concerned, the fruits under study showed significant differences with respect to total soluble solids (TSS °Brix) with

maximum T.S.S in V1 (17.71 °B). Mulching treatments also showed significant difference with control (M3) and within themselves with maximum TSS (15.99 °Brix) for organic mulch. Also, mean comparison of combined treatments (variety and mulch interactions) showed that organic mulch (M1) had been the best choice to increase yield and quality traits in cherry. Douglas *et al.* (1999) revealed that application of polyethylene mulch has been able to increase soil water content and consequently, melon yield.

These results were also confirmed by other reports as suggested by Zhiong (1998). They found that both polyethylene and straw mulches can improve soil water content, soil temperature and consequently wheat yield. Similar results have been reported for tomato and organic mulch by Mitchell and Lanini (1999). Ramakrishna *et al.* (2005) in the study of the impact of mulch treatments and exploration of economically feasible and eco-friendly mulching treatments found that mulching materials showed different effects on soil temperature. Also, it should not be forgotten that polyethylene has another advantages too, which can improve the crop yield. Scott *et al.* (2003) studied the effect of black polyethylene mulch across a wide range of conditions and found that on marginal sites, polythene mulch may provide an attractive management option in both intensive and minimal weed control applications.

Canopy temperature and soil moisture

Analysis of variance for inner canopy temperature revealed significant differences between different kinds of treatments (Table 2). Maximum canopy temperature was recorded in V3 (26.80°C) followed by V6 (26.04°C). The results further indicate that different mulch types had non-significant differences with each other. However, they showed significant difference with untreated plants, *i.e.* control as maximum inner canopy temperature of 26.36°C was recorded in M3 (control). The results for interaction effects of variety on mulch revealed that almost in all the combinations, control (M3) had maximum inner canopy temperature than both the two types of mulches M1 (organic) and M2 (inorganic).

Similar results had also been reported for outer canopy temperature in case of individual treatments as well as interaction effects of variety and mulch treatments. Analysis of variance for soil moisture (%) indicated that the samples taken from the base of each of the sample plant showed significant differences between V3, V2, V1 and V5, whereas V6 and V7 were statistically at par with V3 and V4. Mean comparison on the simple effects of mulches M1, M2 and M3 had significant difference with maximum soil moisture

percentage (18.24) at M1 followed by M2, whereas minimum soil moisture percentage (8.26) was recorded in the control.

However, mean comparison of combined treatments revealed that in most of the cases, interaction effect of M2 (inorganic mulch) had maximum soil moisture percentage except in V6 × M1 (30.00) and V2 × M1 (18.74). The improvement in nutrition and yield reported with inorganic mulch treatments may be indirectly due to changes in soil temperature and soil moisture. Mage (1982) found that the soil temperature under plastic mulch was 3°C warmer, on average, than under other mulches. There were more earth worms in the soil under the plastic mulch than in the control.

However, Pinamonti (1998) showed that the soil moisture in the composted treatment was higher than in the control (no compost) and the plastic mulch treatment which are to some extent contradictory to the present finding. Ekinci and Dusson (2009) reported that clear mulches and black mulches increase soil temperature by 8°C and 4°C, respectively. According to Smith *et al.* (2000), soil moisture is higher under a mulched area than under a non mulched area. At 30 and 60 cm depth, a wider (2 m) mulch strip contained more moisture than a narrow (1 m) strip during periods of moisture stress. The mulch caused less fluctuation in soil moisture compared to the non-mulched areas. Furthermore, Baxter (1970) reported that when mulch (15 cm thick) was applied more available water was present in the soil as compared to (non mulch) control.

CONCLUSION

The application of mulches can be effective in improving the growth and vigour of cherry fruit, besides increasing fruit yield, quality and reliability of crop. The improvement in nutrition and yield reported with mulch treatments may be indirectly due to changes in soil temperature and soil moisture. Mulching increased soil moisture conditions, temperature moderation and resulted in minimal weed competition.

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Effect of growth regulators and seaweed extract on vegetative phenology in mango (*Mangifera indica*)

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ABSTRACT

A field experiment was conducted to find out the effect of seaweed extract, Paclobutrazol, potassium nitrate, 6-benzyl amino purine and pruning on the pattern of vegetative flushing episodes and growth pattern in May-June, July-August and September-October flush in order to regulate the growth, which enhances blooming flushes in 16-year old mango trees cv. Kesar during 2010-12 at Junagadh, Gujarat. The selected shoots of mango cv. Kesar were pruned back by 10 cm and sprayed with 2% urea during last week of May, i.e. after harvesting. Different doses of Paclobutrazol (5g and 7.5g a.i) were applied as drench and 6-BA (100 and 200 ppm), seaweed extract (3 and 5%), KNO₃ (4 and 6%) and CaNO₃ (4 and 6%) were applied as foliar spray to evaluate the morphological characteristics of growth cycles (flushing episodes). 6-BA (100 ppm) exhibited maximum summer flush (May-June). However, lower flushing (September-October) was achieved with PP₃₃₃ (7.5g a.i), followed by 6-BA (200 ppm) and seaweed extract (5 and 3%). CaNO₃ (6%) exhibited maximum mean length of flush while seaweed extract (3%) exhibited minimum number of days for flush emergence and complete extension of vegetative growth with maximum number of flushes/shoot and maximum number of leaves/shoot with 6-BA (100 ppm). The P₃₃₃, 6-BA and seaweed extract showed promising effect in reducing September-October vegetative flush which modified flowering time.

KEY WORDS: Sargassum, Paclobutrazol, Mango, Potassium nitrate, 6-BA

Mango (*Mangifera indica* L.) is one of the most important tropical fruits in the world. It has been originated in the South East Asian or Indo-Burma Region having 41 recognized species of mango originating as forest trees with fibrous and resinous fruits (Mukherjee 1951 and 1967). In India, Kesar mango enjoys supreme place in Gujarat in the areas of Talala and Gir of the Junagadh zone in western Gujarat which got geographical indication tag as "Gir Kesar" by Geographical Indications Registry, Chennai. Mango is extensively grown in tropical and subtropical regions of the world. Tropical climates are conducive to year-round vegetative growth of mango, but flowering and fruit setting are usually seasonal. Flowering from one season to the next is unreliable because of environmental

signals for flower initiation are often inconsistent, subtle or poorly defined. The commercial cultivar, Kesar, however suffers from the intricate problems of alternate bearing and mango malformation, which appear mainly because of enigmatic blooming and vegetative growth behaviour. Growth in mango occurs in flushes and thus a period of growth may follow a period of quiescence, which appears essential to ensure flowering (Davenport and Nunez-Elisea, 2008). Recurrent flushes ready to bloom when they attain the maximum accumulation of starch content. Flushes of one month may re-flush during the subsequent months. Recurring vegetative flushing modifies the physiology of plant and reduces the yield. Therefore, it is essential to control the growth of shoot flushes to avoid the impact on the productivity of the trees (Shankaraswamy, 2012). Therefore, an experiment was conducted to study the effect of different levels of seaweed extract, growth regulators, pruning along with and without urea spray and chemical nutrients on the pattern of vegetative growth in May-June, July-August and September-October in

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order to regulate the growth and health of plant and in turn to enhance blooming flushes in Kesar mango.

MATERIALS AND METHODS

The field experiment was conducted during 2010-2012 on randomly selected 78 mango cv. Kesar trees in the age group of 16 years having uniform size, flowering time and intensity, maintained with recommended cultural practices in sub-block with 190 trees at Sabalpur region of Junagadh. The experiment was laid out in a randomized block design with 3 replications. In each replication, 2 trees were allotted. This trial was conducted for two mango cropping seasons (2010-2011 and 2011-2012) with 13 treatments comprising plant growth regulators, 6 BA (Benzyl Amino Purine), seaweed (*Sargassum wightii*) extract and chemical nutrients sprayed 2 times, once immediately after harvesting to study the effect of treatments on vegetative growth and second spray on new vegetative flush during second week of August and pruning immediately after harvesting of fruits of previous crop (last week of May) with an intention to induce early flowering.

As per the treatment details, one spray of each treatment was taken with power sprayer on the whole crown of tree. The required concentration of solution of BA (100 and 200 ppm), seaweed extract (3 and 5%), chemical nutrients KNO₃ (4 and 6%), CaNO₃ (4 and 6%), urea (2%) about 20 litres of solution of each treatment was sprayed. Soil application of anti-gibberellin compound, paclobutrazol which acts as growth retardant (5g and 7.5g a.i./tree) was made after harvesting (last week of May) with assured irrigation and second application on 10 August 2010 and 2011 by drenching 10 litres water taken for each treatment to mix the required quantity of paclobutrazol in 15 cm deep trench made 1 m away around the trunk. Moderate pruning (10 cm) was done immediately after harvesting by using pruner. The data on experimental tree was collected by selecting 40 healthy shoots covering all sides to study the phenology of emerged flush on intensity of flushing episodes (May-June, July-August and September-October), number of vegetative flush/shoot, mean length of shoots, number of days taken for emergence of new vegetative flush from the date of operation and days required for complete

Table 1. Effect of plant growth regulators, chemical nutrients, seaweed and pruning on flushing episodes in mango cv. Kesar

Treatment	Intensity of flush at each flushing episode								
	May-June			July-August			September-October		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
T ₁ - BA (100 ppm)	57.92	63.33	60.63	32.50	37.50	35.00	5.42	11.67	8.54
T ₂ - BA (200 ppm)	52.50	60.33	56.42	37.91	32.91	35.42	5.00	11.25	8.13
T ₃ - CaNO ₃ (4%)	59.50	58.83	59.17	49.16	48.33	48.75	26.66	25.42	26.04
T ₄ - CaNO ₃ (6%)	53.33	42.00	47.67	49.58	39.58	44.58	31.25	25.83	28.54
T ₅ - KNO ₃ (4%)	47.08	52.08	49.58	49.16	36.66	42.92	26.67	23.75	25.21
T ₆ - KNO ₃ (6%)	45.83	57.08	51.46	55.00	46.66	50.83	22.50	22.00	22.25
T ₇ - unpruned+urea (2%)	40.75	54.17	47.46	56.25	33.33	44.79	35.42	22.50	28.96
T ₈ - moderate pruning (10 cm) + urea (2%)	25.50	17.84	21.67	47.83	27.50	37.67	27.50	21.67	24.58
T ₉ - seaweed (3% <i>Sargassum wightii</i>)	43.75	45.45	44.60	40.25	25.41	32.83	21.25	13.33	17.29
T ₁₀ - seaweed (5% <i>Sargassum wightii</i>)	33.33	51.25	42.29	59.16	69.16	64.17	13.33	8.75	11.04
T ₁₁ - paclobutrazol (5g a.i. per tree)	55.08	60.00	57.54	58.00	63.33	60.67	10.42	9.25	9.83
T ₁₂ - paclobutrazol (7.5g a.i. per tree)	57.08	49.58	53.33	35.41	39.00	37.21	5.42	5.83	5.63
T ₁₃ - control	32.08	39.08	35.58	37.33	54.16	45.75	51.17	49.58	50.38
Mean	46.44	50.07	48.26	46.74	42.58	44.66	21.69	19.69	20.49
SEm±	2.91	3.05	6.40	2.73	2.86	6.01	2.09	2.13	2.63
CD (5% level)	8.50	8.91	19.72	7.97	8.36	18.53	6.12	6.23	8.10
CV (%)	11.31	10.18	10.71	10.13	11.66	10.86	16.76	19.19	17.9

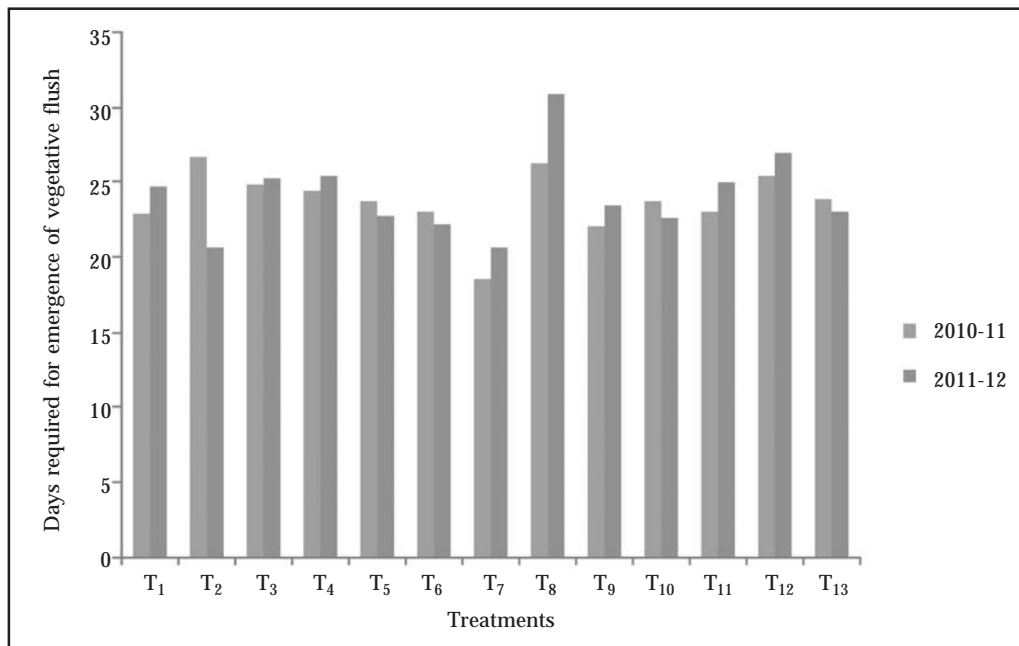
extension of vegetative growth. The data were statistically analysed following the method of Panse and Sukhatme (1989).

RESULTS AND DISCUSSION

The data on intensity of the flush at each flushing episode revealed that summer flush (May-June) was maximum (60.63%) in trees sprayed with 6-BA (100 ppm) but it was par with KNO_3 (6%), unpruned + urea (47.46%) and paclobutrazol (5g a.i) (57.54%), while minimum (21.67%) was noticed in moderate pruning (10 cm) + urea (2%) (Table 1). Application of 6-BA (100 and 200 ppm) reduced the intensity of July-August flush (35 and 35.42%) and September-October flush (8.54 and 8.13%) respectively and it was at par with seaweed (5%) and paclobutrazol (5g a.i./tree). When compared to other chemicals (6-BA and paclobutrazol),

exploitation of seaweed extract is cost-effective in reduction of July-August flush and September-October flush. More September-October flush undesirable for regular cropping in mango and March-April and May-June are most important periods for emergence of new shoots. However, stray shoots and sporadic extension growth may emerge any time between July and October (Singh 1958) cause irregularity in cropping. This can be minimized by use of seaweed extract by elimination of costly chemicals, growth regulators spray.

Seaweed extract (*Sargassum wightii*) at 3% level has profound effect (Table 2) in increasing the number of vegetative flush/shoot (5.63) in mango cv. Kesar. Seaweed increases the vegetative growth and photosynthetic rate leads to increased plant biomass, particularly shoot dry matter which is most useful to differentiate vegetative bud to floral bud



Treatments

- T₁ - BA (100 ppm)
- T₂ - BA (200 ppm)
- T₃ - CaNO_3 (4%)
- T₄ - CaNO_3 (6%)
- T₅ - KNO_3 (4%)
- T₆ - KNO_3 (6%)
- T₇ - Unpruned + urea (2%)
- T₈ - Moderate pruning (10 cm) + urea (2%)
- T₉ - Seaweed (3% *Sargassum wightii*)
- T₁₀ - Seaweed (5% *Sargassum wightii*)
- T₁₁ - Paclobutrazol (5g. a.i./tree)
- T₁₂ - Paclobutrazol (7.5g. a.i./tree)
- T₁₃ - Control

SEm±

CD (5%)

2010-11

2011-12

1.07

1.40

3.14

4.09

Fig. 1. Effect of plant growth regulators and seaweed on growth of vegetative flush of mango cv. Kesar

Table 2. Effect of plant growth regulators, chemical nutrients, seaweed and pruning on vegetative flush of mango cv. Kesar.

Treatment	Intensity of flush at each flushing episode								
	Number of vegetative flushes/shoot			Mean length of shoots			Days required for complete extension of vegetative growth		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
T ₁ - BA (100 ppm)	4.48	4.61	4.55	16.96	17.66	17.31	24.10	28.24	26.17
T ₂ - BA (200 ppm)	4.30	4.08	4.19	14.11	13.99	14.05	18.08	18.85	18.47
T ₃ - CaNO ₃ (4%)	4.03	4.46	4.24	19.56	22.45	21.01	15.88	16.89	16.39
T ₄ - CaNO ₃ (6%)	4.45	4.25	4.35	22.59	24.59	23.59	15.18	16.12	15.65
T ₅ - KNO ₃ (4%)	3.23	3.23	3.23	13.88	15.48	14.68	13.00	13.67	13.34
T ₆ - KNO ₃ (6%)	4.61	4.58	4.59	21.65	20.22	20.94	17.94	18.77	18.35
T ₇ - unpruned+urea (2%)	4.46	4.46	4.46	22.04	23.84	22.94	19.13	20.44	19.78
T ₈ - moderate pruning (10 cm) + urea (2%)	4.28	4.28	4.28	20.63	20.63	20.63	24.61	27.76	26.18
T ₉ - seaweed (3% <i>Sargassum wightii</i>)	5.63	5.63	5.63	22.38	20.38	21.38	16.57	15.27	15.92
T ₁₀ - seaweed (5% <i>Sargassum wightii</i>)	4.24	4.51	4.38	18.89	17.49	18.19	17.66	19.55	18.61
T ₁₁ - paclobutrazol (5g a.i. per tree)	3.76	3.76	3.76	17.75	16.88	17.32	26.63	26.65	26.64
T ₁₂ - Paclobutrazol (7.5g a.i. per tree)	2.86	2.87	2.86	15.63	14.23	14.93	24.70	29.82	27.26
T ₁₃ - control	4.34	4.30	4.32	18.79	18.79	18.79	21.58	24.76	23.17
Mean	4.21	4.23	4.22	18.84	18.97	18.90	19.62	21.29	20.46
SEm±	0.21	0.17	0.14	1.06	1.57	0.95	1.56	1.30	1.02
CD 5%	0.62	0.50	0.39	3.08	4.60	2.70	4.55	3.80	2.89
CV (%)	8.80	7.99	8.94	9.70	14.37	12.28	13.76	10.60	12.16

(Spinelli 2010). While soil application of paclobutrazol (7g a.i./tree) exhibited less number of vegetative flushes/shoot, checking vegetative growth with paclobutrazol by inhibiting the biosynthesis of gibberellins in plants by blocking the conversion of kaurene and kaurenoic acid is possible reason for restricting the more vegetative flush per shoots (Davis *et al.* 1986).

Mean length of flush (Table 2) was observed to be minimum on post-harvest vegetative flush with 6-BA at 200 ppm as foliar spray immediate after harvesting. Days required for complete extension of vegetative growth (Table 2) revealed that soil application of paclobutrazol (7g a.i) took maximum number of days (27.26) for complete extension of vegetative flush. The effect of paclobutrazol on suppression of growth has been reported in mango by Burondkar and Gunjate, 1993, Hiller, 1993 as well as in other fruit crops (Arun *et al.*, 1983).

The data on number of days required for new vegetative flush emergence (Table 3) revealed that

moderate pruning (10 cm) + urea (2%) spray as post-harvest spray required highest number (28.55) of days from the date of application of treatment and less number days (19.57) with urea (2%) spray alone. The results indicate that application of 6-BA has promising effect on reducing September-October flush and reduced growth rate of vegetative flush with paclobutrazol which has profound effect in regulating post-harvest vegetative growth with proper distribution of assimilates and increase in vegetative shoots number by seaweed extract in order to get regular cropping in subsequent year.

CONCLUSION

Seaweed extract exhibited minimum number of days for flush emergence and complete extension of vegetative growth with maximum number of flushes/shoot and maximum number of leaves/shoot with 6-BA. P₃₃₃, 6-BA and seaweed extract showing promising effect in modifying the flowering time in mango.

Table 3. Effect of plant growth regulators, chemical nutrients, seaweed and pruning on vegetative flush of mango cv. Kesar.

Treatment	Days required for new vegetative flush emergence		
	2010-11	2011-12	Pooled
T ₁ - BA (100 ppm)	22.83	24.73	23.78
T ₂ - BA (200 ppm)	26.64	20.68	23.66
T ₃ - CaNO ₃ (4%)	24.85	25.28	25.07
T ₄ - CaNO ₃ (6%)	24.40	25.40	24.90
T ₅ - KNO ₃ (4%)	23.64	22.72	23.18
T ₆ - KNO ₃ (6%)	23.07	22.12	23.18
T ₇ - unpruned+urea (2%)	18.56	20.58	19.57
T ₈ - moderate pruning (10 cm) + urea (2%)	26.20	30.91	28.55
T ₉ - seaweed (3% <i>Sargassum wightii</i>)	22.01	23.39	22.70
T ₁₀ - seaweed (5% <i>Sargassum wightii</i>)	23.63	22.61	23.12
T ₁₁ - paclobutrazol (5g a.i./tree)	23.07	24.94	24.01
T ₁₂ - Paclobutrazol (7.5g a.i./tree)	25.41	26.91	26.16
T ₁₃ - control	23.85	22.96	23.41
Mean	23.55	24.62	23.90
SEm±	1.07	1.40	0.94
CD 5%	3.14	4.09	2.67
CV (%)	7.90	9.85	9.62

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Character association and path coefficient analysis among quantitative traits in China aster (*Callistephus chinensis*)

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ABSTRACT

Twenty genotypes of China aster [*Callistephus chinensis* (L.) Nees] were evaluated for 12 quantitative traits to study the character association and path coefficient analysis in a randomized complete block design with three replications during 2012-13. Analysis of variance showed significant differences among genotypes for all the characters. In correlation studies, number and weight of flowers/plant were significant and positively correlated with plant height, number of branches/plant, number of leaves/plant and flower stalk length. Path coefficient analysis was carried out using correlation coefficients to know the yield-contributing traits having true associations with flower yield/plant. In path coefficient analysis, days to 50% flowering recorded maximum positive direct effect on weight of flowers/plant, followed by flower stalk length, flowering duration, number of branches/plant, plant height and number of flowers/plant, revealing that indirect selection for these traits would be effective in improving flower yield/plant. Days to 50% flowering showed highest positive indirect effect on yield of flowers, followed by flower stalk length, plant height, flowering duration, number of branches and flowers/plant. There was a direct positive influence on weight of flowers/plant from duration of flowering, days taken to 50% flowering, flower diameter and number of ray florets/flower.

KEY WORDS: China aster, Character association, Correlation, Path coefficient analysis

China aster [*Callistephus chinensis* (L.) Nees], belonging to the family Asteraceae, is most popular annual flowering plant grown throughout the world. In India, it is grown traditionally for its loose flowers, cut flowers, in arranging in vase, floral decorations, making garlands and venis. It is extensively grown in Karnataka, Tamil Nadu, West Bengal and Maharashtra,

by marginal and small farmers. Dwarf cultivars are used as potted plants, suitable for edges and window boxes (Rao *et al.*, 2012). Correlation analysis is a biometrical technique used to find out the nature and degree of association among various traits. Knowledge of association among the traits is necessary for making indirect selection for improvement of economically important traits. Character association as correlation is a measure of degree of association prevailing between highly heritable characters with most economic characters and gives better understanding of the contribution of each trait in building up of the genetic make-up of the crop. High positive correlation between the traits indicates that selection for improvement of one character leads to the simultaneous improvement in the other character. Hence, it is of greater significance and could be effectively utilized in formulating effective selection scheme.

When indirect associations become complex, path coefficient analysis is most effective means to find out

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direct and indirect causes of association among different variables. Path coefficient analysis can discriminate between the realistic (genetic effects) and inflated (environmental effects) correlations. Hence, the knowledge of direct and indirect effects of different components on yield is of prime importance in selection of high-yielding genotypes. Several flower traits in China aster have been examined using quantitative genetic approaches (Rao 1982; Negi *et al.* 1983 and Ravikumar and Patil 2003). Keeping the above facts in view, present investigation was undertaken with 20 genotypes of China aster.

MATERIALS AND METHODS

The present study was carried out at experimental field of the Division of Ornamental Crops, Indian Institute of Horticultural Research, Bengaluru, during 2012-13 in a randomized complete block design with three replications. The experimental site was geographically located at 13° 58' N Latitude, 78° E longitude and at an elevation of 890 m above mean sea-level. Experimental material comprised 20 genotypes of China aster, viz., Kamini, Poornima, Shashank, Violet Cushion, Phule Ganesh Pink, Phule Ganesh White, Phule Ganesh Purple, Matsumoto Apricot, Matsumoto Red, Matsumoto Rose, Matsumoto Scarlet, Matsumoto Pink, Matsumoto White, Matsumoto Yellow, Local White, IIHR-H13A, IIHR-C 1, IIHR-H 3, IIHR-I 1 and IIHR-G 13.

Thirty two plants per genotype per replication were planted at a spacing of 30 cm × 30 cm during second week of October 2012. Uniform cultural practices were imposed on all genotypes to ensure good growth. Five uniformly grown plants per replication were tagged for recording various biometric observations on plant height (cm), number of branches/plant, number of leaves/plant, plant spread (cm), days to first flower opening, days to 50% flowering, flower diameter (cm), number of ray florets/flower head, number of disc florets/flower head, flower stalk length (cm), flowering duration (days), vase-life (days), shelf-life (days), number of flowers/plant and weight of flowers/plant. The genotypic and phenotypic coefficient of correlation were estimated as suggested by Al-Jibouri *et al.* (1958). The path analysis was done as per Dewey and Lu (1959). Statistical package 'Biostat IIHR, Version 1.0' was used for analysis of the data.

RESULTS AND DISCUSSION

Correlation coefficient

The phenotypic and genotypic correlation coefficient among different characters in China aster is presented in Table 1. The results indicated that

genotypic correlations were of higher magnitude to the corresponding phenotypic ones, thereby establishing strong inherent relationship among the characters (Table 1). Higher magnitude of genetic correlation coefficient was also reported by Baweja (2000) in China aster and Kumar *et al.* (2012) in gerbera. The low phenotypic value might be due to appreciable interaction of genotypes with environments. The genotypic correlation provided a measure of genetic association between the characters and normally used in selection, while environmental as well as genetic architecture of a genotype plays a great role in achieving higher yield combined with better quality.

The results of correlation coefficient revealed that plant height had highly significant and positive correlation with number of leaves/plant, days to 50% flowering, flower stalk length, number and weight of flowers/plant. Raghava *et al.* (1992) also reported positive significant correlation of plant height with flower size, number and yield of flowers/plant in chrysanthemum. This leads to the conclusion that the selection of taller plants results in wider canopy, longer flower stalk and higher flower yield owing to increase in photosynthetic area. Therefore, direct selection of this character results in quality flowers.

The number of branches/plant was highly significant and positively correlated with number and weight of flowers/plant. This leads to increase in flower yield both in terms of number and weight. Therefore, direct selection of this character improves flower yield. The number of leaves/plant was highly significant and positively correlated with plant height, flower diameter, flower stalk length, flowering duration, number and weight of flowers/plant. This leads to improvement in flower quality characters such as flower diameter, flower stalk length, flowering duration and flower yield. This reveals that flower production can be increased by indirectly selecting for increased number of leaves as reported by Anuradha and Gowda (2002), and Nair and Shiva (2003) in gerbera.

Days to first flower opening exhibited positive and highly significant correlation with days to 50% flowering, flower diameter and weight of flowers/plant. Negi *et al.* (1983) also reported that positive significant association of days to first flower opening with weight of flowers/plant in China aster. The days to 50% flowering was recorded highly significant and positively correlated with plant height, days to first flower opening, flower diameter and weight of flowers/plant. The days to first flower opening and days to 50% flowering can be used in selection since it improves flower yield.

The flower diameter showed highly significant and positive correlation with number of leaves/plant, days

Table 1. Estimates of phenotypic (r_p) and genotypic (r_g) correlation among different characters in China aster

Character	Plant height (cm)	No. of branches/ plant	No. of leaves/ plant	Days to first flower opening	Days to 50% flower-ing	Flower dia-meter (cm)	No. of florets/ flower head	No. of disc florets/ flower head	Flower stalk length (cm)	Flower-ing duration (days)	No. of flowers/ plant	Weight of flowers/ plant (g)
Plant height (cm)	r_p 1.000	0.411	0.698**	0.534*	0.559*	0.500*	0.238	0.418	0.657**	0.120	0.744**	0.679**
	r_g 1.000	0.435	0.723**	0.557*	0.579**	0.513*	0.255	0.434	0.673**	0.223	0.787**	0.698**
No. of branches/ plant	r_p	1.000	0.407	0.316	0.427	0.373	0.005	0.291	0.199	0.077	0.668**	0.634**
	r_g	1.000	0.412	0.322	0.442	0.376	0.005	0.299	0.200	0.134	0.694**	0.645**
No. of leaves/ plant	r_p		1.000	0.358	0.487*	0.474*	0.273	0.312	0.754**	0.316	0.786**	0.742**
	r_g		1.000	0.364	0.499*	0.482**	0.283	0.325	0.766**	0.625**	0.818**	0.753**
Days to first flower opening	r_p			1.000	0.960**	0.839**	0.351	0.131	0.331	-0.037	0.389	0.501*
	r_g			1.000	0.977**	0.855**	0.371	0.133	0.333	-0.032	0.405	0.515*
Days to 50% flowering	r_p				1.000	0.848**	0.309	0.211	0.407	0.032	0.517**	0.612**
	r_g				1.000	0.866**	0.317	0.224	0.419	0.072	0.533*	0.630**
Flower diameter (cm)	r_p					1.000	0.540*	0.158	0.523*	0.074	0.418	0.539*
	r_g					1.000	0.550*	0.162	0.526*	0.132	0.437	0.540**
No. of ray florets/ flower head	r_p						1.000	-0.280	0.496*	0.105	0.190	0.237
	r_g						1.000	-0.290	0.509*	0.179	0.202	0.241
No. of disc florets/ flower head	r_p							1.000	0.112	0.255	0.374	0.376
	r_g							1.000	0.107	0.552*	0.391	0.384
Flower stalk length (cm)	r_p								1.000	0.184	0.689**	0.712**
	r_g								1.000	0.308	0.721**	0.719**
Flowering duration (days)	r_p									1.000	0.250	0.220
	r_g									1.000	0.511*	0.392
No. of flowers/ plant	r_p										1.000	0.889**
	r_g										1.000	0.933**
Weight of flowers/ plant (g)	r_p											1.000
	r_g											1.000

*, **Significant at 5 and 1%, respectively

to first flower opening and days to 50% flowering. Results are in agreement with Negi *et al.* (1983) and Ravikumar and Patil (2003) in China aster. The flower stalk length was found highly significant and positively correlated with plant height, number of leaves/plant, number and weight of flowers/plant. Improvement in flower stalk length leads to simultaneous improved flower yield/plant. Further, genotypes with long flower stalk with more flowers are found most suitable for cut flowers. There is a scope for direct selection of this character. Ravikumar and Patil (2003) have also reported similar results.

The number and weight of flowers/plant is paramount importance in production of loose flowers in China aster. The number of flowers/plant was highly significant and positively correlated with plant height, number of branches and leaves/plant, flower stalk length and weight of flowers/plant. Sreenivasulu *et al.* (2007) has also reported significant and positive correlation of number of flowers/plant with plant height, number of branches and fresh weight of flowers in China aster. The direct selection of this character results in quality flowers with higher yield.

The weight of flowers/plant was highly significant and positively correlated with plant height, number of branches and leaves/plant, days to 50% flowering, flower diameter, flower stalk length and number of flowers/plant. Ravikumar and Patil (2003) have also reported significant positive correlation of weight of flowers with flower diameter and number of flowers/plant in China aster. Baweja (2000) in China aster also reported highly significant and positive correlation of yield with number of flowers and branches/plant. Therefore, direct selection of this character results in quality flowers with higher yield.

Path co-efficient analysis

An association between two traits is product of the interaction of direct and indirect causes. Correlation coefficient measures only the extent of association between any two characteristics but fails to give a complete picture of other characters involved in complicated pathway leading to the end point. Thus, correlation coefficients together with path coefficients values will be more useful in finding out the character association. Path coefficient analysis furnishes a means of partitioning the direct and the indirect effects through variables and measures, the relative importance of causal factor involved.

The phenotypic and genotypic path coefficient among different characters in China aster is presented in Table 2. The results of genotypic path analysis revealed that days to 50% flowering exhibited maximum positive direct effect on weight of flowers/plant,

followed by flower stalk length, flowering duration, number of branches/plant, plant height and number of flowers/plant, indicating direct selection based on these traits will be rewarding for crop improvement.

Plant height had positive direct effect on weight of flowers/plant at genotypic and phenotypic levels, however, its correlation with weight of flowers/plant was positive and highly significant. This character indirectly contributed to weight of flowers/plant via number of branches/plant, flower stalk length, flowering duration and number of flowers/plant.

Number of branches/plant had positive direct effect and highly significant correlation with weight of flowers/plant. It had indirect effect via flower stalk length, flowering duration and number of flowers/plant.

Number of leaves/plant, days to first flower opening and flower diameter had significant positive correlation on weight of flowers/plant, but its direct effects on weight of flowers/plant was negative mainly because of high negative indirect effect via days to first flower opening. Hence, direct selection based on these characters is not effective. These results are in accordance with the findings of Raghava *et al.* (1992). The days to first flower opening and days to 50% flowering indirectly positively influences weight of flowers/plant via number of number of branches/plant, flower stalk length and number of flowers/plant.

Flower diameter had negative direct effect but its correlation with weight of flowers/plant was positive and highly significant. This character indirectly contributed to weight of flowers/plant via number of branches/plant, flower stalk length, flowering duration and number of flowers/plant.

Flower stalk length showed direct positive effect and its correlation was positive and highly significant. However, its indirect effect on weight of flowers/plant via number of branches/plant, flowering duration and number of flowers/plant. Flowering duration had positive direct effects on weight of flowers/plant, its indirect effects via number of branches/plant, flower stalk length and number of flowers/plant.

Path coefficients analysis for weight of flowers/plant revealed that significant positive correlation between weight of flowers/plant and plant height, number of leaves/plant, number of branches/plant, flower diameter, days to first flower opening, days to 50% flowering are mainly due to their direct effects. Therefore, plant height, number of leaves/plant, number of branches/plant, flower diameter, days to first flower opening, days to 50% flowering are important traits from breeding point of view. The number of ray florets and disc florets/flower head had negative direct effect on weight of flowers/plant. Similar

Table 2. Phenotypic and genotypic direct (diagonal bold) and indirect effects among different quantitative traits in China aster

Character	Plant height (cm)	No. of branches/plant	No. of leaves/plant	Days to first flower opening	Days to 50% flowering	Flower diameter (cm)	No. of florets/flower head	No. of disc florets/flower head	Flower stalk length (cm)	Flowering duration (days)	No. of flowers/plant	Correlation with weight of flowers/plant
Plant height (cm)	P -0.239	0.101	0.017	0.233	-0.043	-0.100	-0.002	0.066	0.303	0.002	0.339	0.679**
	G 0.253	0.134	-0.398	-0.396	0.740	-0.146	-0.028	-0.071	0.407	0.092	0.111	0.698**
No. of branches/plant	P -0.098	0.248	0.010	0.137	-0.033	-0.074	0.000	0.046	0.092	0.001	0.304	0.634**
	G 0.110	0.308	-0.226	-0.228	0.564	-0.107	-6E-04	-0.049	0.121	0.055	0.097	0.645**
No. of leaves/plant	P -0.167	0.100	0.025	0.156	-0.037	-0.095	-0.002	0.049	0.348	0.005	0.358	0.742**
	G 0.183	0.127	-0.550	-0.259	0.636	-0.137	-0.0316	-0.053	0.464	0.258	0.115	0.753**
Days to first flower opening	P -0.128	0.078	0.009	0.436	-0.074	-0.168	-0.003	0.020	0.153	-0.0007	0.177	0.501*
	G 0.141	0.099	-0.200	-0.711	1.248	-0.243	-0.041	-0.022	0.201	-0.013	0.057	0.515*
Days to 50% flowering	P -0.134	0.106	0.012	0.419	-0.077	-0.170	-0.002	0.033	0.188	0.0006	0.236	0.612**
	G 0.146	0.136	-0.274	-0.695	1.277	-0.246	-0.035	-0.037	0.253	0.029	0.075	0.630**
Flower diameter (cm)	P -0.119	0.092	0.011	0.366	-0.065	-0.200	-0.004	0.025	0.241	0.001	0.190	0.539*
	G 0.130	0.116	-0.265	-0.608	1.106	-0.284	-0.061	-0.026	0.318	0.054	0.061	0.540**
No. of ray florets/flower head	P -0.057	0.001	0.006	0.153	-0.023	-0.108	-0.008	-0.044	0.229	0.001	0.086	0.237
	G 0.064	0.001	-0.155	-0.264	0.405	-0.156	-0.111	0.047	0.308	0.073	0.028	0.241
No. of disc florets/flower head	P -0.100	0.072	0.007	0.057	-0.016	-0.031	0.002	0.158	0.051	0.004	0.170	0.376
	G 0.109	0.092	-0.178	-0.095	0.286	-0.046	0.032	-0.165	0.064	0.228	0.055	0.384
Flower stalk length (cm)	P -0.157	0.049	0.018	0.144	-0.031	-0.105	-0.004	0.017	0.462	0.003	0.314	0.712**
	G 0.170	0.061	-0.421	-0.237	0.535	-0.149	-0.056	-0.017	0.605	0.127	0.101	0.719**
Flowering duration (days)	P -0.028	0.019	0.007	-0.016	-0.002	-0.014	-0.0009	0.040	0.084	0.017	0.113	0.220
	G 0.056	0.041	-0.344	0.022	0.092	-0.037	-0.020	-0.091	0.186	0.413	0.072	0.392
No. of flowers/plant	P -0.178	0.165	0.019	0.170	-0.040	-0.083	-0.001	0.059	0.318	0.004	0.456	0.889**
	G 0.199	0.214	-0.450	-0.288	0.680	-0.124	-0.022	-0.064	0.436	0.211	0.141	0.933**

Residual value: 0.116 and 0.127 phenotypic and genotypic, respectively

results were also reported in chrysanthemum (Sirohi and Behera 1999) and in gerbera (Anuradha and Gowda 2000).

SUMMARY

Twenty genotypes of China aster were evaluated for 12 quantitative traits to study the character association and path coefficient analysis in RCBD with three replications during 2012-13. The number and weight of flowers/plant was significant and positively correlated with plant height, number of branches/plant, number of leaves/plant and flower stalk length. These characters contributing in improvement in yield of flowers in China aster (number and weight of flowers/plant). In path coefficient analysis, days to 50% flowering recorded maximum positive direct effect on weight of flowers/plant, followed by flower stalk length, flowering duration, number of branches/plant, plant height and number of flowers/plant, revealing that indirect selection for these traits would be effective in improving flower yield/plant.

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Evaluation of indigenous genotypes for yield, quality and storage of garlic (*Allium sativum*) bulbs

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ABSTRACT

The studies were carried out to evaluate the genotypes of garlic (*Allium sativum* L.) at the National Horticultural Research and Development Foundation, Nasik. About 300 germplasms were collected. Of them, 19 advanced lines including four checks, Yamuna Safed (G-1), Agrifound White (G-41), Yamuna Safed-2 (G-50) and Yamuna Safed 3 (G-282), were planted in a randomized block design with three replications. The results of first year showed highest gross (160.25 q/ha) and marketable yields (139.51 q/ha) for check G-41 and were at par with G-4 (146.17 q/ha) (127.16 q/ha) and G-189 (157.28 q/ha) (130.12 q/ha), while for second year, highest gross (179.63 q/ha) and marketable yields (177.28 q/ha) for check variety G-41 and was at par with G-324 (179.01 q/ha) (176.42 q/ha) and G-264 (164.69 q/ha), (162.72 q/ha). These yield showed that the lines which have high gross as well as marketable yield can be utilized breeders in crop improvement for higher yield production. The significant and lowest total loss (4.67%) was noted for G-200 and was at par with G-4, G-264, G-189, G-176, G-324, G-305, G-366, G-255 and G-50. On the basis of both years the genotypes G-189 and G-324, are promising and can be selected for higher yield with quality bulbs and good keeping quality. The advanced line, G-200, performed better and it can be utilized for storage.

KEY WORDS: *Allium sativum*, Garlic, Performance, Selection, Storage

Garlic (*Allium sativum* L.), an important bulbous crop, is widely cultivated throughout country. It is highly placed for its flavour enhancing capacity (Roy and Chakraborti, 2002) and having higher nutritive values, can also be used for preparation of pickle (Pandey and Singh, 1987). China, India, Korea, Russia, Myanmar, Ethiopia, the USA and Egypt are major garlic-growing countries. Egypt tops on the list in productivity (23.83 t/ha), followed by China (23.06 t/ha), USA (18.94 t/ha), Uzbekistan (16.33 t/ha) and Republic of Korea (12.67 t/ha).

The annual area under garlic during 2012-13 was 2.42 lakh ha with a total production of 12.28 lakh tonnes. Madhya Pradesh is the leading state in India, accounting for more than 27% of area and 21% of production with an average yield of 4.47 t/ha. In India, its yield is highest in Kerala (19 t/ha), followed by Manipur (11.91 t/ha), Punjab (10.96 t/ha), Andhra

Pradesh (10.38 t/ha) and West Bengal (9.79 t/ha) (Bhonde *et al.* 2012).

The average productivity of garlic in India is 5.07 t/ha, which is very low compared to other garlic-growing countries. Lack of high-yielding and better storage varieties for garlic are main constraints in limiting its production and productivity. Garlic exhibits greater susceptibility to agro-techniques and environmental condition and a wide range of variability in bulb traits and yield attributes as well as the storability in spite of being vegetatively propagated crop. To meet out the domestic as well as export requirement, selection of suitable genotypes for growing under different agroclimatic condition and better shelf-life is required. Sprouting, physiological loss in weight (PLW) and rotting are the main causes of loss during storage. These losses depend on varieties, type of storage and weather conditions. Thus, it is essential to increase the storage ability of garlic without deterioration of their quality. Therefore, a large number of germplasms were evaluated for performance and 19 advanced lines were selected.

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MATERIALS AND METHODS

The present study was carried out at National Horticultural Research and Development Foundation, Regional Research Station, Karnal, Haryana, during 2007-08 and 2008-09. Nineteen advanced lines including four checks, Yamuna Safed (G-1), Agrifound White (G-41), Yamuna Safed 2 (G-50) and Yamuna Safed 3 (G-282) selected from more than 300 germplasm evaluated. Planting of cloves of selected lines was done every year during first fortnight of October in beds of 3.0 m × 1.5 m size. Recommended package of cultural practices was followed to ensure a healthy crop. The climate of Karnal is subtropical, minimum and maximum temperature ranging between 5°C to 45°C respectively. Both field as well as storage studies were arranged in a randomized block design with three replications.

The data were recorded on ten randomly selected plants in each lines for all the traits, viz. plant height (cm), leaves/plant, neck thickness (cm), bulb diameter (cm), bulb size index (cm²), weight of 20 bulbs (kg), clove diameter (cm), clove size index (cm²), weight of 50 cloves (g), cloves/bulbs, bolting (%), total soluble solid (%), dry-matter content (%), gross yield (q/ha), marketable yield (q/ha), disease and insect pest infestation.

After proper field curing and neck cutting well cured and representative bulbs of the same advanced lines were kept in storage to identify superior clones for storage under ambient conditions in perforated plastic crates. The observations were recorded on losses due to sprouting, physiological loss in weight (PLW), rotting and total loss at monthly basis for four months. Total soluble solids were measured with hand refractometer field data as well as storage data as analyzed separately to identify high-yielding, processing as well as good keeping quality genotypes.

RESULTS AND DISCUSSIONS

The data showed that highest gross (160.25 q/ha) and marketable yield (139.51 q/ha) were noted for the control G-41 and were at par with G-4 (146.17 q/ha) (127.16 q/ha) and G-189 (157.28 q/ha) (130.12 q/ha). These ranges showed, lines which have high gross as well as marketable yield can be utilized in crop improvement for higher yield production. The highest and significant weight of 10 bulbs (0.350 kg) and bulb diameter (4.78 cm) were noted for control G-41 and was at par with G-189 (0.340 kg) (4.68 cm), G-192 (0.330 kg) (4.56 cm) and G-1 (0.340 kg) and (4.64 cm) respectively. The control G-41 also showed higher and significant bulb size index (16.72 cm²) among all genotypes. The clove diameter, clove size index and

weight of 50 cloves ranges from 0.83 cm-1.70 cm, 2.34 cm²-3.98 cm² and 40.33-93.33 g respectively.

Highest and significant clove diameter (1.70 cm), clove size index (3.98 cm²) and 50 cloves weight (93.33 g), were noted for G-282 and significantly different from other genotypes. Significant lowest cloves/bulb (18) were noted for control G-282 and highest number of cloves/bulb was noted for G-192 (43.67). It is reported that increase in bulb weight was associated with increase in plant height, leaves/plant, bulb diameter, bulb size index, number of cloves/bulbs and cloves weight. This is in consonance with the finding (Singh, *et al.* 2012; Singh, *et al.* 2012; Dubey and Singh, 2010; Singh *et al.* 2011; Islam *et al.* 2004; Ahmed and Hoque, 1986 and Thompson and Kelly 1976). Total soluble solids and dry-matter content ranged from 36.83-41.50% and 38.97-43.29%. Highest and significant total soluble solids and dry-matter content 41.50% and 43.29% were noted for G-200 and which was at par with G-264 (40.83%) (42.94%), G-324 (41.00%) (42.89%), G-305 (40.57%) (42.45%) G-304 (40.67%) (42.50%), G-255 (40.83%) (42.57%) and G-222 (40.50%) (42.04%).

Genotypes which have higher total soluble solids and dry-matter content can be utilized for processing purpose. The minimum bolter (7.77%) was indicated by G-366 and maximum (29.77%) in G-324. Plant height, leaves/plant and neck thickness ranged (82.27-98.57 cm), (6.67-7.67) and (1.40 cm-1.58 cm). Higher plant height (98.57 cm), leaves/plant (7.67) and minimum neck thickness (1.40 cm) were observed in G-255, G-192 and G-50 respectively. Minimum stemphylium blight incidence (93.33%) was noted in G-200 and G-324 but it showed non-significant differences. The intensity of stemphylium blight ranged from 13.30% to 18.60%. Lowest intensity was recorded in G-200. Thrips incidence and nymphs/plant ranges from 83.33-100% and 3.20-4.57%. Lowest thrips incidence (83.33%) and nymphs/plant (3.20) was noted in G-41 and G-200.

Storage data of the same year revealed that after one month of storage nil sprouting and decay losses were noted in all genotypes. Lowest physiological loss of weight (0.33%) and total loss (4.00%) were noted for G-4 and G-302 (Table 2). After two months of storage, no sprouting was noted and only three genotypes, G-368, G-302 and G-282, showed decay loss (1.33%) (3.33%) and (1.67%). Minimum and significant physiological loss of weight 2.00% were recorded in G-4. Lowest total loss 2.00% and maximum 10.00% were recorded in G-4 and G-302 and it showed non-significant differences. After three months of storage only three genotypes, viz. -G-192, G-302 and G-222, showed sprouting. Highest decay loss (3.33%) was noted in G-302. Physiological loss of weight and total loss were (4.00-13.33%) and (4.00-16.67%). Lowest and

Table 1. Evaluation of garlic advanced lines during 2007-08

Advanced line	Gross yield (q/ha)	Marketable yield (q/ha)	Weight of 10 bulbs (kg)	Bulb dia-meter (cm)	Bulb size index (cm ²)	Bulb cloves/ bulb size index (cm ²)	Cloves dia-meter (cm)	Clove size index (cm ²)	Weight of 50 cloves (g)	Bolters (%)	Plant height (cm)	Neck thick-ness (cm)	Leaves/ plant	TSS (%)	DM (%)	Thrips			Stemphylium Blight	
																Inc. (%)	Nym. /plant	Inc. (%)	Int. (%)	(%)
G-4	146.17	127.16	0.300	4.38	13.19	40.33	0.93	2.47	40.33	20.00	86.10	1.45	7.47	38.00	40.08	100	4.50	100.0	100.0	14.07
G-176	137.53	120.25	0.330	4.49	12.69	40.00	0.93	2.36	40.33	19.10	90.87	1.47	6.93	38.33	40.14	100	4.50	100.0	100.0	15.47
G-189	157.28	130.12	0.340	4.68	15.81	42.67	0.83	2.36	50.00	18.83	92.67	1.54	7.00	39.83	41.83	100	3.90	100.0	100.0	16.10
G-192	137.28	125.43	0.330	4.56	12.48	43.67	1.10	2.72	44.67	20.87	93.30	1.55	7.67	38.33	40.31	100	4.57	100.0	100.0	15.30
G-200	126.67	112.35	0.300	4.54	12.57	39.00	1.07	2.76	44.33	26.80	95.87	1.53	6.93	41.50	43.29	100	3.20	93.33	93.33	13.30
G-222	134.57	93.58	0.290	4.52	12.26	37.67	1.23	2.46	50.67	15.10	94.80	1.43	7.20	40.50	42.45	100	4.07	100.0	100.0	16.23
G-255	115.56	98.02	0.320	4.58	13.00	39.67	1.13	2.73	44.33	29.53	98.57	1.50	7.07	40.83	42.57	100	4.20	100.0	100.0	18.60
G-264	124.69	109.38	0.310	4.35	13.08	38.33	1.03	2.34	38.67	28.57	95.63	1.51	7.47	40.83	42.94	100	4.17	100.0	100.0	14.77
G-302	86.42	51.85	0.290	4.47	12.66	26.33	1.13	3.03	57.67	9.53	90.00	1.55	6.77	38.00	39.98	100	3.93	100.0	100.0	15.00
G-304	140.74	116.54	0.310	4.53	12.90	40.33	1.10	2.57	46.00	29.00	97.47	1.49	7.40	40.67	42.52	100	4.10	100.0	100.0	17.60
G-305	128.64	109.63	0.230	4.18	11.85	28.67	1.47	2.68	58.33	10.33	82.27	1.49	7.60	40.57	42.45	96.67	3.90	100.0	100.0	15.97
G-324	140.74	109.38	0.320	4.50	13.29	40.33	1.13	3.00	54.33	29.77	94.00	1.58	7.50	41.00	42.89	100	4.17	93.33	93.33	14.13
G-366	132.84	98.77	0.290	4.33	12.22	26.67	1.33	3.21	58.67	7.77	95.43	1.43	6.93	39.67	41.73	100	3.93	100.0	100.0	17.17
G-368	94.57	78.52	0.290	4.13	13.07	34.00	1.17	2.70	43.00	20.70	90.43	1.58	7.17	36.83	38.97	100	4.53	100.0	100.0	16.20
G-369	92.59	74.81	0.250	4.14	10.65	39.00	1.17	3.12	57.33	12.20	85.67	1.49	6.67	37.33	39.55	90.0	4.07	100.0	100.0	16.57
G-1(C)	147.65	117.28	0.340	4.64	13.39	41.00	1.00	2.38	45.67	16.03	97.53	1.54	7.27	39.83	41.93	100	4.47	100.0	100.0	15.70
G-41(C)	160.25	139.51	0.350	4.78	16.72	35.00	1.07	2.63	39.67	16.03	82.80	1.45	7.13	40.00	42.19	83.33	3.70	100.0	100.0	15.07
G-50(C)	128.40	108.15	0.310	4.53	13.20	39.67	1.03	2.79	46.33	10.67	91.73	1.40	6.87	39.83	42.04	100	4.00	100.0	100.0	16.80
G-282(C)	129.63	86.91	0.350	4.52	13.04	18.00	1.70	3.98	93.33	13.33	90.57	1.48	7.20	38.33	40.50	100	4.37	100.0	100.0	16.10
Min.	86.42	51.85	0.330	4.13	10.65	18.00	0.83	2.34	40.33	7.77	82.27	1.40	6.67	36.83	38.97	83.33	3.20	93.33	93.33	13.30
Max.	160.25	139.51	0.350	4.78	16.72	43.67	1.70	3.98	93.33	29.77	98.57	1.58	7.67	41.50	43.29	100.0	4.57	100.0	100.0	18.60
SEm±	7.16	9.38	0.01	0.12	0.28	1.36	0.06	0.06	2.71	1.46	2.85	0.03	0.19	0.67	0.64	3.50	0.54	3.10	3.10	0.89
CD (5%)	14.57	19.01	0.02	0.24	0.57	2.76	0.12	0.12	5.50	2.96	5.78	0.06	0.39	1.36	1.30	7.10	NS	NS	NS	1.81

Table 2. Storage performance of garlic advanced lines during 2007-08

Advance lines	Gross yield (q/ha)	Market-able yield (q/ha)	After one month of storage			After two months of storage			After three months of storage			After four months of storage		
			Sprouting (%)	Decay loss (%)	PLW (%)	Total loss (%)	Sprouting (%)	Decay loss (%)	PLW (%)	Total loss (%)	Sprouting (%)	Decay loss (%)	PLW (%)	Total Loss (%)
G-4	146.17	127.16	0.00	0.00	0.33	0.33	0.00	0.00	2.00	2.00	0.00	0.00	4.33	4.33
G-176	137.53	120.25	0.00	0.00	1.67	1.67	0.00	0.00	3.00	3.00	0.00	0.00	5.67	5.67
G-189	157.28	130.12	0.00	0.00	1.33	1.33	0.00	0.00	3.67	3.67	0.00	0.00	5.67	5.67
G-192	137.28	125.43	0.00	0.00	0.67	0.67	0.00	0.00	3.00	3.00	0.67	0.00	7.67	7.67
G-200	126.67	112.35	0.00	0.00	2.00	2.00	0.00	0.00	3.33	3.33	0.00	0.00	4.00	4.00
G-222	134.57	93.58	0.00	0.00	2.00	2.00	0.00	0.00	3.67	3.67	0.67	0.00	8.33	8.33
G-255	115.56	98.02	0.00	0.00	1.00	1.00	0.00	0.00	2.67	2.67	0.00	0.00	4.67	4.67
G-264	124.69	109.38	0.00	0.00	0.67	0.67	0.00	0.00	3.00	3.00	0.00	0.00	5.83	5.83
G-302	86.42	51.85	0.00	0.00	4.00	4.00	0.00	3.33	6.67	10.00	1.33	3.33	10.00	14.67
G-304	140.74	116.54	0.00	0.00	1.33	1.33	0.00	0.00	3.67	3.67	1.00	0.00	7.67	8.67
G-305	128.64	109.63	0.00	0.00	0.67	0.67	0.00	0.00	3.00	3.00	0.00	0.00	5.67	5.67
G-324	140.74	109.38	0.00	0.00	1.33	1.33	0.00	0.00	3.00	3.00	0.00	0.00	6.00	6.00
G-366	132.84	98.77	0.00	0.00	2.00	2.00	0.00	0.00	3.00	3.00	0.00	0.00	8.00	8.00
G-368	94.57	78.52	0.00	0.00	3.00	3.00	0.00	1.33	5.33	6.67	0.00	1.33	9.00	10.33
G-369	92.59	74.81	0.00	0.00	3.00	3.00	0.00	0.00	7.67	7.67	0.00	0.00	13.33	13.33
G-1 (C)	147.65	117.28	0.00	0.00	0.67	0.67	0.00	0.00	3.67	3.67	0.00	0.00	8.33	8.33
G-41 (C)	160.25	139.51	0.00	0.00	1.67	1.67	0.00	0.00	7.33	7.33	0.00	0.00	11.33	11.33
G-50 (C)	128.40	108.15	0.00	0.00	0.67	0.67	0.00	0.00	2.33	2.33	0.00	0.00	6.67	6.67
G-282 (C)	129.63	86.91	0.00	0.00	1.67	1.67	0.00	1.67	4.00	5.67	0.00	1.67	7.67	9.33
Min.	86.42	51.58	0.00	0.00	0.33	0.33	0.00	0.00	2.00	2.00	0.00	0.00	4.00	4.00
Max.	160.25	139.51	0.00	0.00	4.00	4.00	0.00	3.33	6.67	10.00	1.33	3.33	13.33	14.67
SEm±	7.16	9.38	-	-	1.18	1.18	-	1.04	1.63	2.23	0.62	1.04	1.72	2.45
CD (5%)	14.57	19.01	-	-	NS	NS	-	NS	3.31	NS	NS	NS	3.49	4.97

Table 3. Performance evaluation of garlic advanced lines during 2008-09

Advanced lines	Gross yield (q/ha)	Marketable yield (q/ha)	Weight of 20 bulbs (kg)	Bulb dia-meter (cm)	Bulb size index (cm ²)	Cloves/ bulb	Cloves dia-meter (cm)	Clove size index (cm ²)	Weight of 50 cloves (g)	Plant height (cm)	Neck thick-ness (cm)	Leaves/ plant	TSS (%)	DM (%)	Thrips		Stemphylium Blight	
															Inc. (%)	Nym. /plant	Inc. (%)	Int. (%)
G-4	149.26	147.53	0.710	4.51	14.65	40.47	1.25	3.31	61.67	90.65	1.44	8.13	35.83	37.93	100	7.97	21.41	8.57
G-176	156.79	154.44	0.700	4.73	15.44	24.23	1.25	3.24	64.67	88.91	1.42	9.20	35.40	37.53	100	10.73	21.37	7.83
G-189	155.56	152.35	0.720	4.56	15.18	28.97	1.09	2.75	56.67	91.47	1.48	8.90	37.90	39.80	100	8.50	20.77	9.60
G-192	150.12	148.27	0.720	4.73	16.16	36.50	1.02	2.62	51.67	89.20	1.47	8.77	35.70	37.77	100	8.07	20.57	10.67
G-200	133.70	129.01	0.660	4.27	13.38	21.23	1.30	3.46	66.67	92.59	1.45	8.13	37.00	38.90	100	9.60	20.17	10.84
G-222	141.23	138.77	0.680	4.53	14.50	28.23	1.18	3.24	60.67	90.95	1.43	8.07	36.20	37.97	100	9.63	15.83	8.97
G-255	149.51	145.56	0.690	4.45	14.03	40.47	1.15	2.71	53.33	91.24	1.52	8.37	37.47	39.40	100	10.70	26.81	6.03
G-264	164.69	162.72	0.710	4.47	14.60	35.50	1.11	2.64	53.33	92.69	1.46	9.87	35.33	37.37	100	11.73	24.20	9.77
G-302	143.09	138.52	0.730	4.75	16.49	24.00	1.37	3.77	86.67	91.96	1.53	8.60	37.43	39.67	100	8.97	21.91	11.57
G-304	152.47	149.14	0.720	4.55	15.22	38.70	1.25	2.96	55.00	91.69	1.48	8.33	37.30	39.37	100	10.20	15.80	5.13
G-305	150.49	148.77	0.730	4.84	17.55	29.17	1.24	3.10	60.00	90.43	1.50	8.93	37.80	39.83	100	9.83	15.80	5.80
G-324	179.01	176.42	0.750	5.18	17.81	32.87	1.23	3.18	63.33	106.45	1.49	9.95	37.00	39.23	100	7.77	14.14	4.93
G-366	141.11	136.30	0.720	4.37	15.89	25.93	1.31	3.57	76.67	93.44	1.42	7.73	36.90	39.03	100	7.97	14.57	5.87
G-368	121.23	115.43	0.680	4.33	13.86	33.10	1.26	3.27	66.00	108.14	1.53	10.13	36.57	38.57	100	11.30	19.80	5.63
G-369	106.91	98.27	0.630	4.25	13.10	20.10	1.25	3.27	65.67	91.85	1.48	8.87	37.00	38.73	100	11.43	16.40	6.00
G-1 (C)	139.75	137.16	0.660	4.63	15.87	39.73	0.97	2.63	54.33	90.30	1.39	9.03	37.33	38.30	100	10.30	20.17	7.90
G-41 (C)	179.63	177.28	0.720	4.74	17.17	35.17	1.21	3.76	76.67	95.06	1.51	9.63	36.90	38.57	100	11.67	27.68	13.73
G-50 (C)	145.56	142.35	0.650	4.25	13.32	40.90	1.13	2.90	51.67	89.02	1.45	9.07	37.10	38.83	100	10.77	16.33	10.03
G-282 (C)	153.95	149.88	0.730	4.79	16.97	17.07	1.53	4.35	96.67	97.42	1.55	9.53	36.33	38.47	100	10.30	25.17	12.37
Min.	106.91	98.27	0.680	4.25	13.10	17.07	0.97	2.62	51.67	88.91	1.39	7.73	35.33	37.37	100	7.77	14.14	4.93
Max.	179.63	177.28	0.750	5.18	17.81	40.90	1.53	4.35	96.67	108.14	1.55	10.13	37.90	39.80	100	11.43	27.67	13.73
SEm±	10.29	10.71	0.02	0.13	0.47	2.13	0.04	0.13	2.75	1.02	0.04	0.12	0.42	0.37	-	1.09	2.33	1.06
CD (5%)	20.84	21.69	0.04	0.26	0.95	4.31	0.08	0.26	5.57	2.07	0.08	0.24	0.85	0.75	-	2.21	4.72	2.15

Table 4. Storage performance of garlic advance lines during 2008-09

Advanced lines	Gross yield (q/ha)	Market-able yield (q/ha)	After one month of storage			After two months of storage			After three months of storage			After four months of storage		
			Sprouting (%)	Decay loss (%)	PLW (%)	Total loss (%)	Sprouting (%)	Decay loss (%)	PLW (%)	Total loss (%)	Sprouting (%)	Decay loss (%)	PLW (%)	Total Loss (%)
G-4	149.26	147.53	0.00	0.00	2.33	2.33	0.00	0.00	3.00	3.00	0.00	0.00	4.00	5.00
G-176	156.79	154.44	0.00	0.00	1.67	1.67	0.00	0.00	2.00	2.00	0.00	0.00	2.00	5.00
G-189	155.56	152.35	0.00	0.00	1.67	1.67	0.00	0.00	2.33	2.33	0.00	0.00	2.33	5.33
G-192	150.12	148.27	0.00	0.00	1.33	1.33	0.00	0.00	2.00	2.00	0.00	0.00	3.67	5.00
G-200	133.70	129.01	0.00	0.00	2.33	2.33	0.00	0.00	3.33	3.33	0.00	0.00	3.33	4.33
G-222	141.23	138.77	0.00	0.00	2.33	2.33	0.00	0.00	2.67	2.67	0.00	0.00	4.00	5.67
G-255	149.51	145.56	0.00	0.00	2.67	2.67	0.00	0.00	3.33	3.33	0.00	0.00	4.00	5.33
G-264	164.69	162.72	0.00	0.00	2.33	2.33	0.00	0.00	3.00	3.00	0.00	0.00	3.00	5.33
G-302	143.09	138.52	0.00	0.00	2.33	2.33	0.00	0.00	2.67	2.67	0.00	0.00	4.67	6.67
G-304	152.47	149.14	0.00	0.00	2.33	2.33	0.00	0.00	3.00	3.00	0.00	0.00	4.00	5.67
G-305	150.49	148.77	0.00	0.00	2.33	2.33	0.00	0.00	3.00	3.00	0.00	0.00	4.00	5.67
G-324	179.01	176.42	0.00	0.00	2.33	2.33	0.00	0.00	2.67	2.67	0.00	0.00	5.00	6.00
G-366	141.11	136.30	0.00	0.00	2.67	2.67	0.00	0.00	3.33	3.33	0.00	0.00	4.00	5.00
G-368	121.23	115.43	0.00	0.00	2.33	2.33	0.00	0.00	2.33	2.33	0.00	0.00	2.33	5.00
G-369	106.91	98.27	0.00	0.00	2.67	2.67	0.00	0.00	4.33	4.33	0.00	3.00	7.00	15.17
G-1 (C)	139.75	137.16	0.00	0.00	3.33	3.33	0.00	0.00	4.33	4.33	0.00	0.00	4.33	5.33
G-41 (C)	179.63	177.28	0.00	0.00	3.33	3.33	0.00	0.00	4.00	4.00	0.00	0.00	4.00	10.67
G-50 (C)	145.56	142.35	0.00	0.00	3.67	3.67	0.00	0.00	4.33	4.33	0.00	0.00	4.33	5.33
G-282 (C)	153.95	149.88	0.00	0.00	3.33	3.33	0.00	0.00	5.67	5.67	0.00	0.00	10.00	13.17
Min.	106.91	98.27	0.00	0.00	1.33	1.33	0.00	0.00	2.00	2.00	0.00	0.00	2.00	4.33
Max.	179.63	177.28	0.00	0.00	3.67	3.67	0.00	0.00	5.67	5.67	0.00	3.00	10.00	15.17
S Em \pm	10.29	10.71	-	-	0.44	0.44	-	-	0.77	0.77	-	-	0.88	1.01
C.D (5%)	20.84	21.69	-	-	0.89	0.89	-	-	1.56	1.56	-	-	1.78	2.05

significant total loss (4.00%) were noted in genotypes G-200 but maximum losses (14.67%) in G-302.

After four months of storage, sprouting and decay loss did not vary significantly. Physiological loss of weight minimum (4.67%) was recorded for G-200 and highest loss (15.33%) was noted in G-369. Total loss ranges from 4.67%-17.33%. Significant and lowest total loss (4.67%) were noted in G-200 and was at par with G-4, G-264, G-189, G-176, G-324, G-305, G-366, G-255 and G-50. The highest total loss 17.33% was observed in genotype G-302. The result is in consonance with Patil and Kale (1989). The non-significant variation indicates variables performance from year to year, which may be influence of climatic variation.

The results exhibited that highest gross yield (179.63 q/ha) and marketable yield (177.28 q/ha) were noted for control variety G-41 and was at par with G-324 (179.01 q/ha) (176.42%) and G-264 (164.69 q/ha), (162.72 q/ha) (Table 3). G-324 showed higher bulb diameter (5.18 cm) and ranges from 4.25 to 5.18 cm. Maximum and significant bulb size index (17.81 cm²) were also noted in G-324 and it was at par with G-305 (17.55 cm²), G-41 (17.17 cm²) and G-282 (16.97 cm²). The 20 bulb weights ranged from (0.680-0.750 kg) and highest 20 bulb weight (0.750 kg) was noted in G-324 and at par with G-302 (0.730 kg), G-366 (0.720 kg), G-305 (0.730 kg), G-192 (0.720 kg), G-264 (0.710 kg), G-189 (0.720 kg), G-41 (0.720 kg) and G-282 (0.730 kg).

Minimum cloves per bulb (17.07) were recorded in G-282 and maximum in G-41 (40.90). Significant differences were noticed among the lines pertaining to clove diameter, clove size index and weight of 50 cloves varied (0.97-1.53 cm) (2.62-4.35 cm²) and (51.67-96.67 g), in this cases G-282 performed better among all genotypes. This indicates that yield potentialities of the genotypes and which supported by (Singh *et al.* 2011; Korla and Rastogi 1979; Hari Om and Shrivastava 1976 and Singh and Chand, 2003) compared with selected varieties.

Plant height and leaves/plant varied from 88.91 to 108.14 cm and (7.73-10.13) in both cases. G-368 performed well. Lowest neck thickness (1.39 cm) was observed for G-1. Total soluble solids and dry-matter content an important traits in this regard. G-189 showed highest and significant (37.90%) and (39.80%) respectively and was at par with G-304 (37.30%) (39.37%), G-255 (37.47%) (39.40%), G-302 (37.43) (39.67%) and G-305 (37.80%) (39.43%) respectively. These variations mentioned above could be utilized by the plant breeder for the improvement of desired traits. The lowest and significant stemphylium blight incidence (14.14%) and intensity (4.93%) was noted for G-324. A 100% thrips incidence was noted for all genotypes but minimum thrips/plant (7.77) was also

noted in G-324. The genotypes which indicated low stemphylium and thrips intensity percent can be utilized for resistant breeding.

Results on storage of same year revealed that after one month of storage no sprouting and decay loss was observed for any genotypes (Table 4). The lowest and significant physiological loss of weight and total loss (1.33%) were noted in G-192. Highest (3.67%) physiological loss of weight and total loss was recorded in G-50. After two months of storage nil sprouting and decay loss noted. Minimum 2 % physiological loss of weight and total loss was recorded for genotypes G-192 and G-176. G-282 showed highest 5.67% total losses. After three months of storage the minimum and significant 2 % physiological loss of weight and total loss was noted for G-176 and maximum 10.0% showed by G-282.

After four months of storage nil sprouting and only one genotype G-369 (3.0%) showed decay loss. Physiological loss of weight and total loss ranges from 4.33%-13.17% and 4.33%-15.17%. Lowest and significant physiological loss of weight and total loss 4.33% was noted for G-200 and maximum physiological loss of weight 13.17% and total loss 15.17% was observed for genotypes G-282 and G-369 respectively. Thus, genotypes, G-189 and G-324, are identified as promising and can be selected for high yield and quality. For good keeping quality advanced line, G-200, performed better and it can be utilized for storage.

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Correlation studies on insect pest and disease management in mango (*Mangifera indica*) cultivars

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ABSTRACT

A field experiment was conducted at Fruit Research Station, Kuthulia, College of Agriculture, Rewa (Madhya Pradesh) during December - June 2011-12. Climatic factor, viz. temperature, humidity, winds and sunshine affect the growth, flowering, fruiting and quality of mango (*Mangifera indica* L.) fruits. The fruit yield was positively correlated with plant height, canopy height, spread (N-S and E-W), average fruit weight and other quality parameter. Mature fruits were positively and significantly correlated with number of fruits/tree and weight of fruit/tree. However, it was negatively correlated with fruit drop. The maximum incidence of malformation, mangohopper and leaffolder was observed in Langra. The remaining varieties showed lesser infection than other varieties. The variation in incidence of malformation amongst varieties may probably be related to genetic characters of variety. The variation in incidence of mangohopper and leaffolder may be related to the temperature, humidity, wind and sunshine. Maximum incidence of mangohopper was noted in March in Langra. It is really interesting to note that Dashehari gave higher yield than other variety may be due to "off-year" season in last year and they reserves the carbohydrate synthesis that increase higher yield. The maximum number of fruits and weight were recorded in Dashehari (328.38) and (87.01kg). Dashehari, Mallika and Totapari gave significant higher fruit weight as compared to Sundarja and Langra.

KEY WORDS: Correlation, Insect pest, Disease, Mango cultivars

Mango (*Mangifera indica* L.) trees perform well both under tropical and subtropical climatic conditions. Mango is a highly nutritive fruit. Ripe mangoes are excellent table fruits and also can be transformed into a variety of products. Mango pulp is the most important which is utilized for human consumption; fruit pulp predominates in water, carbohydrates, organic acids, fats, minerals, pigments, tannin and vitamins. The ripe fruit pulp contains about 11.8% carbohydrates 4800 IU of vitamin A, and 13 mg/100 mg ascorbic acid. The pulp is a rich source of beta carotene, sucrose, glucose and fructose. It requires good rainfall during its growing season (June - October) and rainless dry weather from

November onwards. Cultivation of mango faces so many problems due to environmental conditions. Climatic factor, viz. temperature, humidity, wind and sunshine affect the growth, flowering fruiting and quality of fruits. The varieties of north, south and central region are found suitable for this region. Temperature is one of the most important environmental factors, which effect the flowering, pollination and fruit setting. Cloudy weather may also act as one of the factors for unfruitfulness. Hence, an experiment was conducted on correlation studies on insect pest and disease management in mango.

MATERIALS AND METHODS

A field experiment was conducted at Fruit Research Station, Kuthulia, College of Agriculture, Rewa, during December - June 2011-12. The experiment was laid out in a randomized block design having four replications. The climate condition of Rewa is subtropical climate, hot and dry summer and cold winter. In general, highest and lowest temperature gave above 43°C and below 5°C, respectively. The annual rainfall varies from 900 to

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1150 mm which is received mainly from July to September. The soil pH (5.70) and EC (0.12 mmhos/cm²). The experiment consisted of 5 treatments (varieties), Dashehari, Mallika, Sundarja, Totapari and Langra.

Observations were correlated for morphological characters, tree height (m), tree spread (N-S) and (E-W) (m), girth of rootstock (m), girth of scion (m), canopy height (m) and volume of tree (m³), phenological characters (date of first appearing flower, date of 50% flowering, date of 100% flowering, size of panicle (cm), number of male flowers (%), number of hermaphrodite flowers (%), number of hermaphrodite flowers in N.S.E.W. direction, total number of flowers and sex ratio), fruit setting (mustard-size of fruits/panicle, pea-size fruits/panicle, marble-sized fruits/panicle, mature fruits/panicle, fruit drop (%) and harvesting period (days) and yield attributing characters (number of fruits/tree and weight of fruits/tree (kg)) and fruit quality parameters, physical quality- fruit weight (g), fruit breadth (cm), peel (%), pulp (%) and stone (%), chemical quality-TSS (°Brix) and acidity (%), respectively.

RESULTS AND DISCUSSION

The tree height was positively and significantly correlated with tree spread (N-S) (0.910), tree spread (E-W) (0.939), girth of rootstock (0.904), girth of scion (0.961), canopy height (0.966), volume of tree (0.945), sex ratio (0.575) and fruit drop (0.643). However, it was negative correlated with size of panicle (-0.718), number of male flowers (-0.318), mustard-sized fruits (-0.029), pea-sized fruits (-0.098), and marble-sized fruits (-0.013). The plant spread (N-S) was positively and significantly correlated with tree spread (E-S) (0.993), girth of root stock (0.849), girth of scion (0.917), canopy height (0.960) and volume of tree (0.994). The tree spread (E-W) was positively and significantly correlated with girth of root stock (0.900), girth of scion (0.955) canopy height (0.983) and volume of tree (0.998) and negative correlated with size of panicle (-0.438) and number of male flowers (-0.080). Girth of rootstock was positively and significantly correlated with girth of scion (0.983), canopy height (0.955), volume of tree (0.886), number of hermaphrodite flowers (0.677), sex ratio (0.789) and fruit drop (0.755). However, it was negative correlated with size of panicle (-0.550), number of male flowers (-0.378), pea-sized fruits (-0.264) and marble-sized fruits (-0.143). Girth of scion was positively and significantly correlated with canopy height (0.989), volume of tree (0.948), number of hermaphrodite flowers (0.618), sex ratio (0.713), and fruit drop (0.699).

However, it was negative correlated with size of panicle (-0.583), number of male flowers (-0.301) and

pea-sized fruits (-0.143). Canopy height was positively and significantly correlated with volume of tree (0.980), sex ratio (0.610) and fruit drop (0.593). Size of panicle was positively and significantly correlated with number of male flowers (0.713). The number of male flowers was positively and significantly correlated with pea-sized fruits (0.955), marble-sized fruits (0.943), mature-fruits (0.744), number of fruits/tree (0.686) and weight of fruits/tree (0.585). The number of hermaphrodite flowers was positively and significantly correlated with sex ratio (0.962), mustard-size fruits (0.846) and fruit drop (0.847).

Sex ratio was positively and significantly correlated with mustard-sized fruits (0.723) and fruit drop (0.934). Pea-sized fruits were positively and significantly correlated with marble-sized fruits (0.986), mature fruits (0.904), number of fruits/tree (0.840) and weight of fruits/tree (0.783). Marble-sized fruits were positively and significantly correlated with mature fruits (0.902). The number of fruits/tree (0.820), weight of fruits/tree (kg.) (0.759). Mature fruits were positively and significantly correlated with number of fruits/tree (0.958) and weight of fruits/tree (0.958). The number of fruits/tree was positively and significantly correlated with weight of fruit/tree (0.981) (Table 1). Similar correlation along with various parameters of mango was observed by Oppenheimer (1960), Pongsomboon *et al.* (1997), Chakrabarti *et al.* (1997), Chakrawar and Jature (1980) reported that correlation was positive between yield and number of fruits/plant. Prasad (1987) reported that positive significant association between the number of fruits, their size with TSS, fruit weight.

The number of mango hoppers/panicle/month was counted in each treatment. The mean data indicates that Dashehari, Mallika and Langra gave significant higher mango hopper, compared to Sundarja and Totapari (Table 2). The maximum incidence was observed under (January - 1.67, 1.29, 1.18), (February - 6.45, 6.13, 6.00), (March - 20.73, 20.14, 19.85) and (April - 3.13, 12.25, 11.88).

The number of web mass/tree was counted in each treatment. The mean values are highlighted (Table 2). Thus, it is clear that leaf folder of mango varieties did not differ significantly except Langra. The maximum web mass was noted under Langra (25.45mass). The minimum web mass noted under Totapari (11.95 mass), followed by Sundarja (13.71 mass), Mallika (18.83 mass) and Dashehari (19.79 mass).

Malformation in mango trees was observed in percentage in each treatment. The mean data indicates that variety Sundarja and Langra gave significant higher malformation as compared to Totapari, followed by Dashehari and Mallika (Table 3). The maximum incidence was observed under Langra (47.79%) and

Table 1. Correlation among various morphological, flowering, fruiting and yield-contributing characters

Character	Tree height (m)	Tree spread (N-S) (m)	Tree spread (E-W) (m)	Girth of root (m)	Girth of scion (m)	Girth of stock (m)	Canopy height (m)	Canopy volume (m ³)	Size of panicle (cm)	No. of male flowers	No. of hermaphrodite flowers	Sex ratio	Mustard sized fruits/panicle	Pea sized fruits/panicle	Marble size fruits/panicle	Mature fruits/panicle	Fruit drop (%)	No. of fruits/tree	Weight of fruit /tree (kg)
Tree height (m)	0.910**	0.939**	0.904**	0.961**	0.966**	0.945**	-0.718	-0.318	0.478	0.575**	-0.029	-0.098	-0.013	0.296	0.643**	0.329	0.408		
Tree spread (N-S) (m)		0.993**	0.849**	0.917**	0.960**	0.994**	-0.378	-0.018	0.388	0.431	0.002	0.167	0.286	0.469	0.375	0.415	0.465		
Tree spread (E-W) (m)			0.900**	0.955**	0.983**	0.998**	-0.438	-0.080	0.476	0.528	0.070	0.100	0.219	0.416	0.480	0.391	0.436		
Girth of rootstock (m)				0.983**	0.955**	0.886**	-0.550	-0.378	0.677**	0.789**	0.265	-0.264	-0.143	0.036	0.755**	0.088	0.110		
Girth of scion (m)					0.989**	0.948**	-0.583	-0.301	0.618**	0.713**	0.173	-0.143	-0.030	0.191	0.699**	0.229	0.267		
Canopy height (m)						0.980**	-0.548	-0.251	0.518	0.610**	0.073	-0.076	0.040	0.261	0.593**	0.261	0.313		
Volume of tree (m ³)							-0.458	-0.089	0.437	0.493	0.020	0.1.2	0.217	0.427	0.459	0.396	0.450		
Size of panicle (cm)								0.713**	-0.244	-0.411	0.267	0.501	0.514**	0.102	-0.690	-0.017	-0.143		
No. of male flowers									-0.029	-0.289	0.286	0.955**	0.943**	0.744**	-0.506	0.686**	0.585**		
No. of hermaphrodite flowers										0.962**	0.846**	-0.051	0.006	0.055	0.847**	0.260	0.160		
Sex ratio											0.723**	-0.295	-0.225	-0.133	0.934**	0.063	-0.004		
Mustard-sized fruits/panicle														0.128	0.165	0.496	0.171	-0.0001	
Pea-sized fruits/panicle															0.986**	0.904**	-0.449	0.840**	0.783**
Marble-sized fruits/panicle																0.902**	-0.414	0.820**	0.759**
Mature fruits/panicle																	-0.194	0.958**	0.958**
Fruit drop (%)																		0.026	0.013
No. of fruits/tree																			0.981**

** Significant at 5%

Table 2. Insect pests of mango cultivars

Variety	Mango hopper				Mealy bug	Leaf folder (October)
	Jan.	Feb.	March	April		
Dashehari	1.18	6.00	19.85	11.88	-	19.79
Mallika	1.29	6.13	20.14	12.25	-	18.83
Sundarja	0.50	1.69	9.23	11.16	-	13.71
Totapari	0.38	1.45	8.25	9.88	-	11.95
Langra	1.67	6.45	20.73	13.13	-	25.45
SEM +	0.17	0.20	0.33	0.44	-	0.51
CD (5%)	0.53	0.62	1.02	1.36	-	1.59

Table 3. Disease on mango cultivars

Variety	Malformation	Powdery mildew
Dashehari	7.32 (2.70)	-
Mallika	21.14 (4.59)	-
Sundarja	42.56 (6.52)	-
Totapari	2.99 (1.72)	-
Langra	47.79 (6.91)	-
SEM+	5.35	-
CD (5%)	16.51	-

(), root transformation value

Sundarja (42.56%), whereas minimum incidence was noted under Totapari (2.99%), followed by Dashehari (7.32) and Mallika (21.14%). Kumar (1999), Singh (2002), Pandey *et al.* (2003) Kundan and Syamal (2004) was also reported these insect-pest and disease incidence findings.

The powdery mildew was not recorded in this location.

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Preparation of leaf venation skeletons of leaves for dry flower arrangement

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ABSTRACT

The experiment was conducted to find out the effect of bakers yeast fermentation on leaf maturity to find out the particular age group of leaves suitable for fermentation, using *Ficus religiosa* L. leaves as the model substrate and to study the optimal fermentation time on other plant species to skeletonize, viz. leaves of *Bauhinia purpurea*, *Tectona grandis*, *Ficus benjamina* and *Hiptage bengalensis*. The study of the preparation of venation leaf skeletons was carried out by using bakers yeast (*Saccharomyces cerevisiae*) to standardize the optimum yeast concentration required for the formation of venation skeletons. Various formulations of aqueous yeast solution were prepared. Among all the concentrations prepared, 2.0% was found to be the optimum yeast concentration for the formation of undamaged network of veins. The duration required by leaves to form the complete network of veins was also studied and the selected leaves showed some variation in time to form a complete network of veins. The study of effect of bakers yeast fermentation was carried on different age groups (maturity) of leaves and only matured leaves of 4 - 5 months old were found to be suitable under reaction conditions.

KEY WORDS: Leaf venation, Dry flower, Fermentation Skelton, Presservation, Ficus, Yeast Concertation

Preservation of flowers and plant materials is a form of artistic expression. It was hugely popular during the Victorian age. This craft form has once again begun to gain popularity. Dried or dehydrated parts of plants, such as flowers, leaves, stems and sometimes even entire plants can be used for interior decoration. Be it summer, winter or autumn, these elements add charm to the surroundings with their long lasting beauty, being cheap and everlasting makes them more popular among flower lovers. Dried flowers are extremely popular because of their advantages. They are tolerant of extremes of temperatures and offer a wide range of striking colours which could not be seen in cut flowers. Dried flowers are beautiful and are becoming favorites among adventurous flower lovers across the globe.

Dried flowers are good substitutes for the florists, since designs can be made up during the slack periods and arrangements can be displayed where fresh flowers are unsuitable from the growers' point of view and the price is less than for equivalent fresh flowers (Salinger 1987). Earlier, dried flowers were in practice in the form of herbaria made by botanists for the purpose of identification of various species (Prasad *et al.* 1997). In 1860, techniques of drying red roses, pansies, stock and

other single flowers in sand have been described. Though drying of flowers was well-known even in the past, but for the first time, in 1982, the flowers were dried commercially in Germany (Jean and Lesley, 1982).

Dried flowers can be used for making decorative floral items and for commercial exploitation. The industry has grown rapidly with over 60% share of profits belonging to the floriculture industry (Ranjan and Misra, 2002). The industry projected annual turnover of 2003 was more than 150 crores (Singh, 2009). In recent floriculture trade, the exports from India grew from ₹ 266 crore during 2002-2003 to ₹ 302 crore during 2003-2004 and ₹ 273 crore during 2004-2005 to achieve a growth rate of 2.66%.

The Indian export basket comprises 71% of dry flowers which are exported to USA, Europe, Japan, Australia and Russia. Dry flowers constitute more than two-thirds of the total floriculture exports. The demand for dry flowers is increasing, offering a lot of opportunities for the Indian entrepreneurs to enter in the global floricultural trade (Singh, 2009). The value of dry flower industry can be increased more by developing new techniques including skeleton leaf preparation (Mir, 2014). Skeletonized leaves nowadays

have become popular way to make jewellery, in which leaves are skeletonised, and then somehow either plated with gold or silver (Chiolero, 2007). There are reports of skeletonised leaves as old as a hundred years, they can be of various shapes and can also be ironed, just like a fabric.

The venation pattern of leaves offers great beauty, this results from the visual combination of their complexity and regularity. Usually leaf venation of dicotyledonous plants form complex patterns even though their variations in morphology have some common features. The veins form developed structures which are connected to form reticulum. What follows is a step by step explanation of techniques involved in the preparation of vein skeletons.

MATERIALS AND METHODS

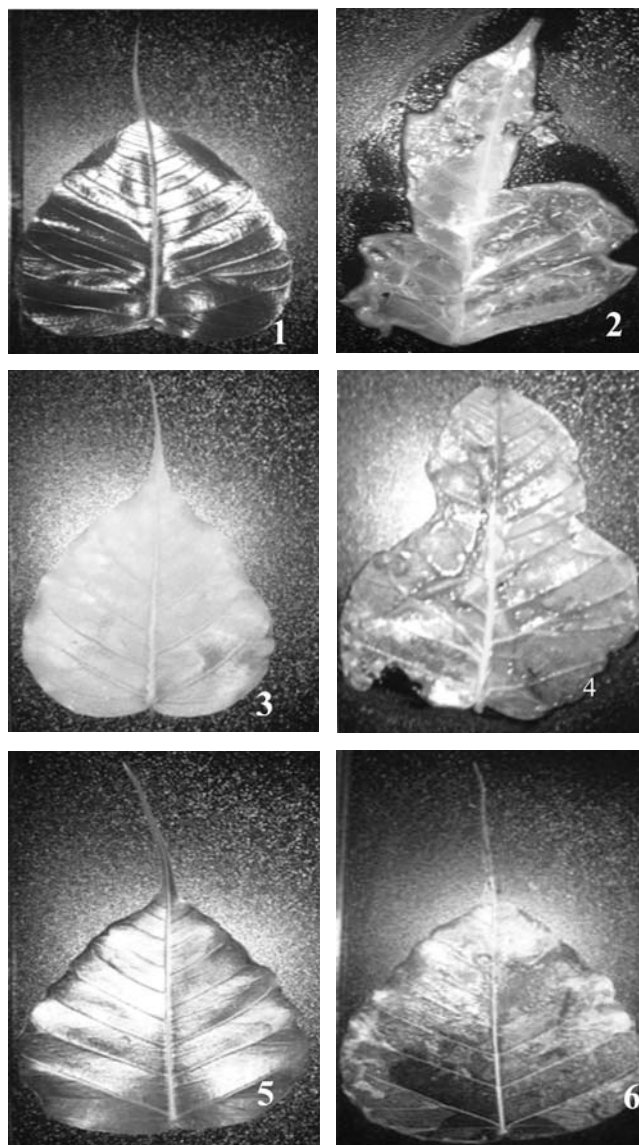
The collection of plant material was done from the National Chemical Laboratory garden of Pune. The plant material initially selected were the leaves of *Ficus religiosa* (Moraceae family) from an elite tree. In subsequent experiment, leaves of other plant species, viz. *Bauhinia purpurea*, *Ficus benjamina*, *Tectona grandis* and *Hiptage bengalensis*, were also considered for fermentation. In skeletonizing leaves, it is important to select leaves that are naturally perfect and without any damage by insects or by environmental conditions. The leaves of fully-grown plants having firm texture were taken. The selected leaves were thoroughly rinsed with water very carefully to clean dirt and dust if any. The material was dried properly (set drying) then the selected material was immersed in an aqueous yeast solution at the standardized concentration. The method of anaerobic fermentation was used for isolation of chlorophyll and other green cells from leaves, this anaerobic fermentation was established in an air tight plastic trays.

Fermentation

Fermentation was done by using yeast (*Saccharomyces cerevisiae*). Various aqueous yeast solutions were tried and prepared concentration of 2.0% was found to be the optimal formulation for the formation of complete and undamaged network of veins. Bakers yeast at the standardized concentration of 2.0% was prepared to study the effect of yeast fermentation on leaf maturity. Leaves of various age groups were selected for this experiment, viz. young leaves (10 days old), middle-aged leaves (a month old) and fully-grown matured leaves (four months old) (Table 1), in order to find out the suitable age group of leaves for fermentation. No satisfactory results were obtained in young leaves as shown in before and after (Figs 1 and 2). The middle-aged leaves also failed to

Table 1. Effect of bakers yeast fermentation on leaf age (maturity)

Leaf age	Figures	Results
Young leaves (10 days old)	1 and 2	Not suitable for fermentation
Middle-aged leaves (1 month old)	3 and 4	Not suitable for fermentation
Mature leaves (4 months old)	5 and 6	Suitable for fermentation



ferment as shown in, before and after treated (Figs 3 and 4). The good results were obtained in matured leaves as shown in before and after treated (Figs 5 and 6).

The leaf materials of plant species, viz. *Ficus religiosa*, *Bauhinia purpurea*, *Tectona grandis*, *Ficus benjamina* and *Hiptage bengalensis* were taken (Table 2). This experiment was aimed to find out the maximum duration required by each leaf material to skeletonize. The leaves showed some variation in time in the formation of venation skeletons. Time duration of 15 days was required by leaves of *Ficus religiosa* and *Bauhinia purpurea* to skeletonize completely as shown in before and after treated (Figs 7, 8, 9 and 10). For *Tectona grandis*, 12 days were required for the leaves to skeletonize (Figs 11 and 12). For *Ficus benjamina*, duration of 20 days were required (Figs 13 and 14) and 25 days were required by the leaves of *Hiptage bengalensis* to show complete skeleton formation (Figs 15 and 16).

RESULTS AND DISCUSSION

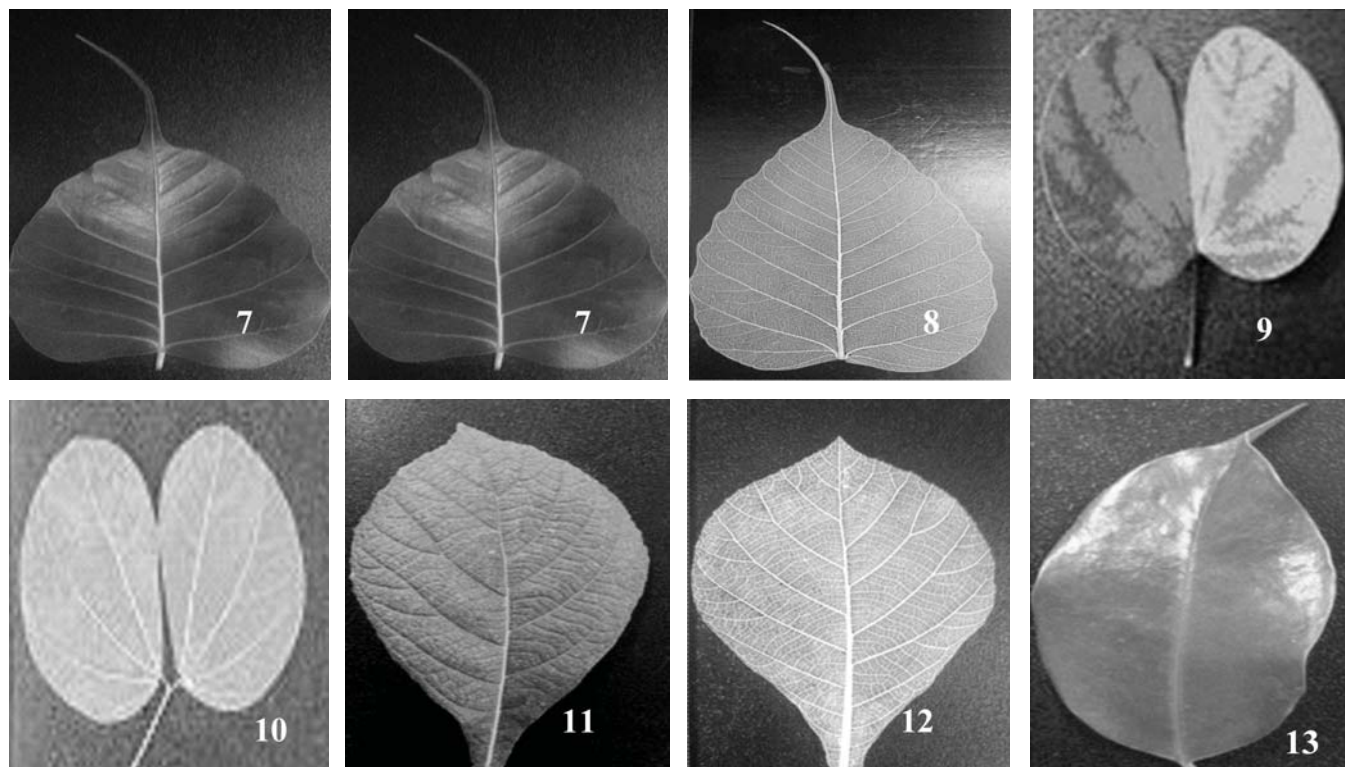
The leaves of different age groups were taken into

Table 2. Effect of fermentation time using bakers yeast on different species

Plant	Figures	Time (days)
<i>Ficus religiosa</i>	7 and 8	15
<i>Bauhinia purpureae</i>	9 and 10	15
<i>Tectona grandis</i>	11 and 12	12
<i>Ficus benjamina</i>	13 and 14	20
<i>Hiptage benghalensis</i>	14 and 16	25

consideration for the formation of venation skeletons. The selected leaves were of young-aged (10 days old), middle-aged (a month old) and fully-grown mature leaves (4 months old). It was practically observed that both young and middle-aged leaves failed to ferment and were torn completely even at the fifth day of fermentation. It was found to be very difficult to take out the leaves from the solution. The reason being tearing and not forming the venation skeleton, was due to the under-developed venation system in both young and middle-aged leaves. The matured leaves were only suitable for this process. This experiment was designed to find out the leaf material suitable for the formation of venation skeletons. It was found that only matured leaves were suitable for the formation of venation skeletons (Fig. 6).

Whittenberger and Naghski (1948) reported that the time required for the completion of fermentation varies with the type of leaf, although 2-3 days are sufficient for leaf skeletonization. The preparation of vein skeletons from leaves of a number of species with *Clostridium roseum* was reported. They also mentioned that thick xeromorphic leaves require longer period than loosely compacted mesomorphic ones. The selected leaves showed sometime variation to form a complete network of veins. For *Ficus religiosa* and *Bauhinia purpurea* complete network of veins were observed at the 15th day of fermentation. In *Tectona grandis*, complete network of veins was observed at 12th day of



fermentation. In *Ficus benjamina*, complete skeletonization of leaves were observed at 20th day of fermentation, for *Hiptage bengalensis*, complete skeletonization of leaves were seen at the 25th day of fermentation.

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Evaluation of bio-efficacy and selectivity of herbicides for weed control in tuberose (*Polianthes tuberosa*) cv. Prajwal

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ABSTRACT

A field experiment was conducted to study the bio-efficacy on weeds and selectivity of herbicides on growth, flowering and bulb yield of tuberose (*Polianthes tuberosa* Linn.) cv. Prajwal at the Division of Floriculture and Landscaping, Indian Agricultural Research Institute, New Delhi, during 2012-13. Ten different combinations of herbicides, particularly pre-emergence tank-mix herbicides application treatments were laid out in a randomized block design with three replications. The herbicidal treatments significantly reduced the density, and fresh and weight of weeds compared to the unweeded control. Maximum bulb sprouting (98.15%), and highest plant density (35.33) were observed with Pendimethalin (1 kg /ha) + rice residue (5t/ha). Maximum average plant height (70.50 cm), spike length (30.75 cm), number of florets (29.56), and number of flowers (8.79) opened at a time were associated with the combination of atrazine (1.0 kg /ha)+ rice residue (5t/ha). Lowest weed fresh (12.52g/m²) and dry weight (5.76g/m²), weed density/m² (37.32) and weed control index (98.15%) were also observed with atrazine (1.0 kg /ha)+rice residue (5t/ha). Maximum bulb yield/m² (268.77g) was observed with atrazine (1.0 kg /ha)+ one hand-weeding 30 days after planting, but atrazine (1.0 kg /ha) +rice residue (5t/ha) was at par. However, effect of herbicides was not significant on bulblet yield/plant, bulb weight and diameter. Thus, application of atrazine (1.0 kg/ha) + rice residue (5t/ha) resulted in better weed control, higher growth, flowering and bulb yield.

KEY WORDS: Bulb yield, Cut flower, Herbicide, Tuberose, Weed

Tuberose (*Polianthes tuberosa* Linn.) is one of the popular and commercially-grown bulbous flower crops. It is cultivated for cut and loose flowers. Prajwal is commercial cultivar for both loose and cut flowers which fetch good price in market. One of the main constraints in the commercial cultivation of flower crops is weeds. Weeds cause irreparable damage to its crop by competing for water, nutrients, light and space, besides acting as alternate hosts to a number of pathogens and insect pests (Shalini and Patil, 2006). Manual weeding is time-consuming and costly as the labour is scarce. Hence, it is imperative to employ alternate methods of weed control in flower cultivation irrespective of size of land holdings. Herbicides are the best alternate method of weed control in flower crops, but, hardly investigated for weed control. Selectivity of

herbicides to tuberose or its varieties needs to be studied for safe recommendation. The repeated applications of herbicides may result in reduction of crop growth (Sorkin, 1981) and development of herbicide resistance in weeds. However, repeated emergence and rapid growth of weed lead to severe weed competition in its initial growth phases, which can cause a reduction in yield by 50-100%. Pre-emergence herbicides are viable option to control weeds at this initial growth phase, since the choice of herbicides for post-emergence applications are limited in tuberose. Herbicides are economical and effective alternative to age-old back-breaking manual weeding for weed control. Manual weeding is costlier and has become impracticable due to non-availability of labourers during peak period of weeding and ever-escalating cost of labour. Therefore, an experiment was conducted to evaluate the comparative performance of herbicides alone and in combination on weed control and growth, flower and bulb yield in tuberose .

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MATERIALS AND METHODS

A field experiment was conducted at the Indian Agricultural Research Institute, New Delhi, during 2012- 13 in a randomized block design with ten weed control treatments (Table 1) replicated three times. Four herbicides, namely Atrazine, Pendimethalin, Imazathapyr and Metribuzin alone and in combination and with rice residue were studied for their bioefficacy on weeds and selectivity for growth and flowering in tuberose cv. Prajwal.

Uniform sized bulbs were planted at 40 cm (row-to-row) × 30 cm (plant-to-plant) spacing, in a bed of 2 m × 2.5 m, accommodating 36 plants in each plot. A weed-free control and a weedy check treatment were adopted for comparison with herbicidal treatments. Readily available rice residue was used for mulching immediately after pre-emergence Atrazine treatment less. A uniform dose of 100 kg N, 50 kg P₂O₅, and 50 kg K₂O/ha was applied in the form of urea, single superphosphate and muriate of potash, respectively. Half dose of N and whole amount of P and K were applied as basal before planting. Remaining dose of N was applied 45 days after planting. All recommended

cultural practices were followed for raising tuberose. All pre-emergence herbicides were applied two days after planting with a volume rate of 400 l/ha of water, using a knapsack sprayer fitted with flat fan nozzle. Weed density, fresh and dry weight were recorded 30 and 60 days after planting from each plot, using a 50 cm × 50 cm quadrat. Similarly, growth, flowering and bulb parameters were recorded. Weed control index (WCI) was calculated using the formula suggested by Das (2008)).

$$\text{Weed control index} = \frac{a - b}{a} \times 100$$

where, a, weed biomass of unweeded plot; b, weed biomass of treated plot. Data on weed population were transformed through square-root method by using the formula $\sqrt{x + 0.5}$. The data were subjected to analysis of variance for a randomized block design at 5 % level of significance.

RESULTS AND DISCUSSIONS

Effect on weed growth: Tuberose was infested with *Cyperus rotundus*, *Polygonum aviculair*, *Rumex dentatus*,

Table 1. Effect of different herbicides on bulb sprouting, plant population and weed growth

Treatment	Bulb sprouting (%)	Plant density/plot	Weed density/m ²	Fresh weight of weeds (g/m ²)	Dry weight of weeds (g/m ²)	Weed control index (%)
Atrazine 1 kg/ha (T ₁)	96.29	34.66	352.00 (37.28)	286.60 (33.76)	55.40 (15.28)	82.72
Atrazine 1 kg/ha+ residue 5 t/ha (T ₂)	94.44	34.00	37.32 (12.72)	12.52 (7.52)	5.76 (4.68)	99.24
Atrazine 1kg + one hand weeding 30 DAP (T ₃)	97.22	35.00	230.68 (29.20)	146.92 (21.40)	45.32 (12.32)	98.70
Pendimethalin1kg/ha (T ₄)	95.37	34.33	280.00 (32.32)	340.80 (36.20)	61.88 (15.96)	79.44
Pendimethalin1kg + residue 5 t/ha (T ₅)	98.15	35.33	292.00 (30.84)	462.80 (34.76)	68.12 (15.28)	72.09
Pendimethalin 0.75 kg + atrazine 0.75 kg/ha (T ₆)	95.37	34.33	304.00 (33.84)	285.08 (30.96)	56.28 (15.00)	82.80
Pendimethalin (PE) 0.75 kg + Imazithapyr (PoE) 0.10 kg/ha (T ₇)	93.52	33.67	310.68 (35.12)	522.92 (44.24)	76.40 (17.32)	68.46
Pendimethalin (PE)0.75 kg + metribuzin (PoE) 0.20 kg/ha (T ₈)	92.59	33.33	301.32 (34.52)	660.68 (46.36)	81.60 (17.96)	60.15
Control (T ₉)	96.30	34.66	408.00 (40.32)	1658.28 (77.56)	168.28 (25.64)	0.00
Weed free check (T ₁₀)	96.29	34.67	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	100
CD (0.05)	NS	NS	16.44	32.52	(9.48)	23.17

Amaranthus viridis, *Dactyloctenium aegyptium*, *Acrachne racemosa*, *Dinebra retroflexa*, *Chenopodium murale*, *Leptochloa chinensis*, *Parthenium hysterophorus*, *Phyllanthus neruri*, *Trianthema portulacastrum*, *Cormopu sdidymus*, *Euphorbia hirta* and *Cynodon dactylon* weeds. Among these, *C. rotundus*, *T. portulacastrum* and *D. aegyptium* were most dominant weeds due to their frequent occurrence. The occurrence of other species was sporadic with low density.

The data indicated that application of herbicides did not affect sprouting of bulbs and plant population/plot significantly. Maximum bulb sprouting (98.1%) and maximum plant population/plot (35.3) were observed with T_5 , i.e. Pendimethalin 1.0 kg + rice residue 5 t/ha, while lowest plant density and per cent sprouting was observed under treatment T_8 (Table 1). All herbicide treatments (T_1 – T_8) resulted in a significant reduction in their density, fresh weight and dry weight of weeds (Table 1) compared to the control (T_9), which had the highest density of weeds/m² (408), fresh weight (1658.3g/m²) and dry weight (168.3g/m²).

The density (12.7), fresh weight (7.5g/m²) and dry weight (4.78 g/m²) of weeds were significantly lower when pre-emergent Atrazine was applied @1 kg /ha and plot was covered with rice residue @5 t/ha (T_2) immediately after Atrazine application. Probably, combined or dual action of Atrazine and organic mulch reduced weed growth. Atrazine functions by binding

to plastoquinone-binding protein in photosystem II, which causes starvation and oxidative damage by breakdown in the electron transport process and ultimately, plant death (Apelby *et al.*, 2001). Singh and Singh (2010) observed similar reduction in weed growth due to herbicides indirect-seeded rice. Highest weed control index (99.2%) was recorded with the application of Atrazine 1.0 kg/ha pre-emergence + residue @ 5 t/ha (T_2), which was statistically at par with all the treatments except T_5 , T_7 , T_8 and T_9 . Similar results have also been reported in tuberose cv. Double (Anandamurthy and Narayanagowda, 1993) and in China aster (Basavaraju *et al.* 1992).

Both vegetative and flowering traits were significantly affected by the application of herbicides. The data indicate that average maximum plant height (70.50 cm) was observed in plants treated with Atrazine 1 kg/ha+ residue 5t/ha, which was at par with weed-free check (T_{10}), T_3 , T_4 , T_7 and T_8 , while minimum plant height (53.25 cm) was observed in unweeded control (Table 2). Longest spikes (33.34 cm) were obtained with treatment T_2 and were at par with T_3 , T_4 , T_5 and T_7 . Maximum number of florets (29.56) were recorded in plants sprayed with Atrazine (1 kg/ha) and covered with residue @5t/ha (T_2), which was at par with many treatments including weed-free check, however, minimum number (16.87) was observed in unweeded control. Similar results were obtained by Yadav and

Table 2. Effect of herbicides on growth and flowering traits of tuberose cv. Prajwal

Treatment	Plant height (cm)	Spike length (cm)	No. of florets	Flower size (cm)	Flower duration (days)	No. of flowers open at a time
Atrazine 1 kg/ha (T_1)	62.25	24.40	22.58	3.42	11.78	6.00
Atrazine 1 kg/ha + residue 5 ton/ha (T_2)	70.50	33.34	29.56	3.57	11.17	8.79
Atrazine 1 kg + one hand weeding 30 DAP (T_3)	69.67	29.83	28.02	3.54	10.63	8.10
Pendimethalin 1 kg/ha (T_4)	67.94	27.17	25.47	3.52	9.22	7.39
Pendimethalin 1 kg + residue 5 t/ha (T_5)	67.25	30.75	28.33	3.52	11.00	8.42
Pendimethalin 0.75 kg + atrazine 0.75 kg/ha (T_6)	62.25	22.00	21.87	3.52	9.50	8.25
Pendimethalin (PE)0.75 kg + Imazithapyr (PoE) 0.10 kg/ha (T_7)	65.39	29.00	26.67	3.52	11.20	7.20
Pendimethalin (PE) 0.75 kg + metribuzin (PoE) 0.20 kg/ha (T_8)	65.09	26.88	28.90	3.54	11.67	7.50
Unweeded control (T_9)	53.25	23.33	16.87	3.47	9.17	6.12
Weed free Check (T_{10})	66.89	32.47	28.50	3.53	11.75	7.84
CD (0.05)	6.70	6.92	6.88	NS	NS	1.76

Table 3. Effect of herbicides on bulb production parameters of tuberose cv. Prajwal

Treatment	Average yield of bulbs/plant (g)	Average bulblet yield/plant (No.)	Average weight of single bulb (g)	Average bulb diameter (cm)
Atrazine 1 kg/ha (T ₁)	230.33	27.73	20.61	2.40
Atrazine 1 kg/ha+ residue 5 t/ha (T ₂)	268.77	33.53	20.72	2.58
Atrazine 1 kg + one hand-weeding 30 DAP (T ₃)	268.80	30.53	19.11	2.49
Pendimethalin 1 kg/ha (T ₄)	199.00	31.33	14.70	2.27
Pendimethalin 1 kg + residue 5 t/ha (T ₅)	179.00	25.67	14.51	2.22
Pendimethalin 0.75 kg + Atrazine 0.75 kg/ha (T ₆)	171.83	28.03	15.26	2.19
Pendimethalin (PE) 0.75 kg + Imazithapyr (PoE) 0.10 kg/ha (T ₇)	137.00	24.03	15.21	2.16
Pendimethalin (PE) 0.75 kg + metribuzin (PoE) 0.20 kg/ha (T ₈)	142.67	19.13	16.38	2.30
Control (T ₉)	146.00	16.87	12.94	1.99
Weed free check (T ₁₀)	275.00	33.80	18.03	2.40
CD 0.05	69.96	NS	NS	NS

Bose (1987) by using 2 and 3 kg a.i/ha of Atrazine in tuberose. Flower size and flower duration were not significantly affected with herbicide application, whereas maximum flower opening at one time (8.72) was observed with treatment T₂ and was statistically at par with all the treatments except T₁ and T₉. It means application of atrazine might have reduced the germination of both broad leaf and annual grass weeds and on the same time application of mulch might have reduced the weed growth but also have conserved soil moisture and might have reduced soil temperature, thus resulted in better growth and flowering.

Out of four bulb parameter, only bulb yield/plant showed significant difference with application of herbicides, whereas bulb weight, bulb diameter and bulblet yield were not affected significantly. Maximum bulb yield/plant (275.00 g/plant) was observed under weed-free check and was at par with T₁, T₂ and T₃, while minimum yield (137.00g) was recorded with treatment T₇ and was at par with T₄, T₅, T₆, T₈ and T₉.

Thus, it is concluded that pre-emergence application of Atrazine 1kg/ha + residue (5t/ha) is more effective than other herbicides for controlling weeds. It gave highest vegetative growth, flowering and bulb yield in tuberose.

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