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Performance, diversity analysis and character association of black pepper (*Piper nigrum* L.) accessions in the high altitude of Idukki district, Kerala

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Abstract

The experiment was conducted to evaluate black pepper accessions for growth parameters, yield attributing characters and yield. Out of the ten accessions tested, *Karimunda* recorded the highest fresh (1.61 kg) and dry (508.7 g) yield of berries plant^{-1}. Fresh weight showed significant positive genotypic correlation to dry weight and while negative correlated to 100 berry volume, 100 berry weight and number of berries spike^{-1}. Hence, selection based on number of berries spike^{-1}, 100 berry volume and 100 berry weight may not lead to the high yielding black pepper variety. The results showed that *Karimunda* is the most suitable black pepper variety for high altitude areas of Idukki district.

Keywords: black pepper, field evaluation, variability, yield

Introduction

Black pepper, *Piper nigrum* L., referred as the 'King of spices' is the most important spice in the world. Indian pepper fetches a premium price in major international markets due to its preference and intrinsic quality (Thomas 2010). In India, Kerala is famous for black pepper cultivation and export. Idukki and Wayanad are the major pepper growing districts which together contribute 90% of the Kerala production. There exists considerable variation for yield among black pepper cultivars (Ravindran & Babu 1994). Idukki has maximum genetic diversity of black pepper. Most of the pepper farmers in the Idukki district are cultivating a minimum of five cultivars. Every traditional pepper-growing tract has its own popular cultivar. Selection of cultivars for prevailing agroclimatic conditions is important for higher productivity. The diverse climatic and soil conditions in a state like Kerala necessitates the identification and popularization of location specific varieties for the enhancement of productivity of pepper (Prasannakumari *et al.* 2001). The performance of black pepper varieties varies significantly in plains and high ranges owing to the difference in environmental conditions of these two regions. For evolving high yielding varieties of any crop, knowledge on the relationship between yield and yield attributing characters as well as vegetative characters is essential. Therefore, the present study was initiated with the objective of evaluating the performance, character association and variability studies of the released varieties as well as promising selections of black pepper.

Materials and methods

The experiment was conducted as a part of All India Coordinated Research Project on Spices at Cardamom Research Station, Kerala Agricultural University, Pampadumpara, Idukki during 2010-2017 (7 years). Vines of ten high yielding accessions of black pepper were collected from Panniyur Research Station (HB 20052, PRS 88), Horticultural Research and Extension Station, Sirsi (Acc no. 53, Acc. no. 106), Horticultural Research Station, Yercaud (Acc no. 33, Acc. No. 57), IISR, Kozhikode (C-1090, HP 39) and planted along with checks (Panniyur 1 and *Karimunda*) in a randomized block design with three replications at a spacing of 2 × 2 m. Agronomical practices were followed as per the package of practices of Kerala Agricultural University. Observations were recorded on various yield components for three cropping seasons. The pooled data for three years (2014-17) were subjected to statistical analysis. The simple phenotypic correlation coefficient was estimated using the formula suggested by Al-jibouri *et al*. (1958).

Results and discussion

Performance of different cultivars

All the black pepper accessions under test, differed significantly for vegetative characters like vine column height, leaf length, leaf width and internodal length (Tables 1). Vine column height recorded highest for Acc 57 which is on par with CL 1090. Acc 33 showed highest leaf length and leaf width followed by Panniyur 1. *Karimunda* recorded lowest leaf length and leaf width.

All the yield and yield attributing characters showed significant difference among the accessions both at 1% and 5% level (Table.3). This indicates the presence of wide variability in accessions for these characters. *Karimunda* recorded highest fresh weight and dry weight of berries which is statistically on par with Panniyur 1 and HB 20052. Most of the yield attributing characters was high in Panniyur 1 except volume of 100 berries. Even though *Karimunda* was the best performed accession for the last three years, the yield attributing characters were not that much comparable with high yielding accessions except number of berries spike^{-1}. However, according to Deka *et al*. (2016), *Karimunda* recorded higher number of laterals with more spread and higher number of spikes compared to the other varieties. Ibrahim *et al.* (1985; 1987) have reported that spike yield and spike number in black pepper as important traits contributing for yield forwhich straight selection can be practiced for improvement. It may be the reason for high yielding nature of *Karimunda*.

Variance components, heritability and genetic advance

The estimates of genotypic variance (GV) ranged between 0.03-2958.02 and phenotypic variance (PV) 0.18-21930.38. The phenotypic and genotypic variances were very far to each other and this shows the high influence of environment on morphological traits. Phenotypic coefficients of variation (PCV) ranged between 1.39-68.90; and genotypic coefficients of variation (GCV) between 1.01-25.30 (Table 3). The PCV values were relatively higher than the GCV values for all the parameters indicating environmental influence on the expression of the traits [11]. However, GCV values were near to PCV values for characters like 100 berry volume, vine column height, leaf width, internodal length. Such differences indicate very low environment variance for the phenotypic expression of these characters. Heritability (h^2) values ranged between 13.48% for dry weight to 95.63% for vine column height. The genetic advance as a percentage of the mean (GAM) also ranged from 1.51 for 100 berry volume to 40.00 for spike length. The combined estimation of heritability and genetic advance gives the response of a character to selection. Characters like spike length, vine column height, leaf width and internodal length was showed high heritability and high genetic advance. This indicates the suitability of these characters for selection due to additive gene action. The influence of environment to the characters governed by additive gene action is very less.

Table 1. Pooled analysis data (2012-15) on vegetative characters

Accession	Vine columnheight (cm)	Leaf length (cm)	Leaf width (cm)	Internodal length (cm)
Acc 106	233.2^{f}	16.3^{d}	8.5^{ef}	9.0^{bc}
Acc 33	249.1^{e}	19.3^{a}	13.9^{a}	8.6^{bcd}
Acc 53	240.4^{ef}	16.6^{cd}	11.9^{b}	10.4^{a}
Acc 57	311.5^{a}	14.7^{e}	10.4^{c}	7.9^{de}
CL 1090	304.5^{ab}	13.3^{f}	9.6^{cd}	9.2^{bc}
HB 20052	288.6^{c}	17.2^{c}	11.5^{b}	8.1^{de}
HB 39	274.4^{d}	15.9^{d}	9.2^{de}	7.8^{e}
Karimunda	297.4^{bc}	13.8^{f}	8.4^{f}	9.2^{bc}
Panniyur 1	285.6^{cd}	18.5^{b}	13.6^{a}	9.3^{b}
PRS 88	196.1^{g}	15.0^{e}	9.5^{d}	8.6^{cd}
CD @ 1%	18.487	1.146	1.097	0.96
CD @ 5%	13.498	0.836	0.806	0.708

Table 2. Pooled analysis (2014-17) on yield and yield attributing characters

Accession	Fresh wt (kg vine^{-1})	Dry weight (g plant^{-1})	Spike lenth (cm)	100 berry wt (g)	100 berry volume (ml)	No. of berries spike^{-1}
Acc 106	0.95^{cd}	306.83^{de}	7.573^{f}	11.6^{cd}	111.09^{cde}	47.60^{ab}
Acc 33	0.74^{d}	332.81^{bcd}	9.52^{cde}	14.42^{a}	112.68^{ab}	35.35^{de}
Acc 53	0.99^{cd}	315.93^{cde}	12.516^{ab}	13.57^{ab}	112.27^{abc}	38.11^{cde}
Acc 57	1.16^{bc}	365.17^{bcd}	11.83^{ab}	14.05^{a}	111.31^{bcde}	44.85^{abc}
C -1090	0.97^{cd}	274.77^{de}	10.69^{bcd}	12.34^{bc}	111.63^{abcd}	45.94^{abc}
HB 20052	1.43^{ab}	440.31^{abc}	11.16^{abc}	14.38^{a}	110.49^{de}	51.33^{a}
HP 39	0.65^{d}	190.00^{e}	9.68^{cde}	13.76^{ab}	112.99^{a}	31.92^{e}
Karimunda	1.61^{a}	508.73^{a}	9.10^{def}	11.42^{cd}	110.11^{e}	41.74^{a}
Panniyur-1	1.46^{ab}	456.25^{ab}	12.67^{a}	13.63^{ab}	111.44^{bcde}	50.62^{a}
PRS88	0.93^{cd}	323.29^{cd}	8.40^{ef}	10.44^{d}	110.53^{de}	41.20^{bcd}
CD@1%	0.556	174.27	2.573	2.289	2.014	11.751
		(cm)	(g)	w t		
CD@5%	0.403	127.22	1.873	1.667	1.475	8.587

Character association

The character association studies done for both penotypic and genotypic correlation. Significant positive phenotypic correlation existed between dry weight and fresh weight of berries (0.92). The association between all other characters was not significant.

The genotypic correlation studies revealed that, fresh weight is positively and significantly correlated only with dry weight of berries however it is significantly and negatively correlated with 100 berry weight, 100 berry

Table 3. Variability parameters of black pepper accessions

Characters	Mean	Genotypic variance (GV)	Phenotypic variance (PV)	Phenotypic Coefficient of Variation (PCV)	Genotypic Coeeficient of Variation (GCV)	(Heritability) H2	Genetic Advance (GA)	Genetic advance as percentage of the mean (GAM)	Standard error (SE)	Coefficient of variation (CV)
Fresh weight	0.806	0.03	0.18	53.54	22.03	16.93	0.15	18.68	0.22	48.79
Dry weight	214.93	2958.02	21930.38	68.90	25.30	13.48	41.14	19.14	79.52	64.08
Spike length	11.15	7.78	12.91	32.22	25.01	60.25	4.46	40.00	1.30	20.31
100 Berry weight	12.76	3.51	6.52	20.00	14.69	53.94	2.83	22.23	1.00	13.57
100 Berry volume	111.33	1.27	2.42	1.39	1.01	52.44	1.68	1.51	0.61	0.96
Number of berries spike^{-1}	36.36	52.37	109.11	28.64	19.84	47.99	10.32	28.32	4.34	20.65
Vine column height	268.12	1354.44	1416.30	14.03	13.72	95.63	74.13	27.65	4.54	2.93
Leaf length	16.76	4.96	17.13	24.69	13.29	28.96	2.4	14.73	2.01	20.81
Leaf width	10.68	3.87	4.09	18.93	18.42	94.68	3.94	36.93	0.26	4.36
Internodal length	8.86	0.56	0.73	9.66	8.49	77.25	1.36	15.37	0.23	4.60

Table 4. Correlation matrix (upper half – phenotypic correlation coefficient & lower half – genotypic correlation coefficient) of yield and yield related characters in high yielding accessions of black pepper

	FW	DW	SL	100BW	100BV	NBS	VCH	LL	LW	INL
FW		**0.9239****	0.1036	-0.2579	-0.4085	0.0804	-0.1489	0.0234	-0.1056	0.2074
DW	**0.8930****		0.1003	-0.3294	-0.3637	-0.0487	-0.0216	-0.0608	-0.0566	0.2438
SL	0.2269	0.1787		0.1411	0.2906	0.0600	-0.5653	0.2488	0.1576	**0.0841****
100BW	**-0.7163***	**-0.9087****	-0.0528		0.3979	0.0566	-0.3180	0.0940	-0.2507	-0.1330
100BV	**-0.9863****	**-0.9225****	0.2581	0.3706		-0.1119	-0.1773	-0.0212	-0.1390	0.0917
NBS	**-0.0861****	-0.5639	0.1672	-0.0628	-0.2904		0.1264	-0.0664	0.0295	-0.0832
VCH	-0.2517	0.0339	**-0.7689****	-0.4781	-0.2558	0.1623		-0.2441	0.0245	-0.1647
LL	0.3775	0.4094	0.4425	-0.0180	-0.2238	-0.1976	-0.4939		0.5171	0.3599
LW	-0.3110	-0.2367	0.1998	-0.4316	-0.2466	-0.0270	0.0108	**0.9008****		0.2146
INL	0.3733	0.4739	0.2124	-0.2850	-0.0417	-0.4223	-0.2216	**0.7134***	0.1634	

5%-0.632; 1%-0.765; FW=Fresh weight; DW=Dryweight; SL=Spike length; 100 BW=100 berry weight; 100 BV=100 berry volume; NBS= Number of berries spike^{-1}; VCH=Vine coloum height; LL=Leaf length; LW=Leaf width; INL=Internodal lenght volume and number of berries spike^{-1}. However, this is not corroborates with the findings of Sainamole *et al*. (2002) in which number of berries spike^{-1} is positively correlated to fresh yield. Therefore selection programme based on of dry weight of berries would be better than selection based on size of berries and number of berries spike^{-1} in black pepper. Dry weight of berries showed a negative significant genotypic correlation with 100 berry weight and 100 berry volume. Length of spike genetically correlated with vine column height which is significant and negative in direction. Same result had been reported by Sainamole *et al.* (2002). However, Sujatha & Namboothiri (1995) reported positive and significant influence on yield with the spike length. Leaf length showed a significant positive genotypic correlation with leaf width and internodal length.

Productivity of black pepper depends on elevation, soil fertility, cultural practices, temperature, rainfall, age of the crop and climatic conditions during flowering, fruit set and development (Sivaraman *et al*. 1999). In the present study, *Karimunda*, Panniyur 1 and HB 20052 are found to be the suitable varieties for high ranges of Idukki district. The phenotypic expressions are more due to genotypic effect than environmental influence. These varieties can be utilized for further breeding programme in order to develop high yielding varieties suitable for high ranges of Idukki district. However based on the result of study conducted by Prasanna Kumari *et al* (2001) *Karimunda* did not perform well in Thodupuzha taluk. It may be due to the difference in environmental & geographical parameters like altitude, rain, temperature etc. Selection of traits which are showing high heritability and genetic gain could be effective reflecting the presence of additive gene action.

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Epidemiological parameters to delineate weather-disease interactions and host plant resistance against leaf blight in small cardamom (*Elettaria cardamomum* Maton)

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Abstract

Small cardamom, the versatile spice of Zingiberaceae is cultivated in diverse agro-climatic regions of India especially in South India. Leaf blight incited by *Colletotrichum gloeosporioides sensu lato* is one among the major challenges encountered across different cardamom growing tracts. In the present investigation, epidemiology of cardamom leaf blight was studied and an attempt was made to decipher the resistant nature of Malabar, Mysore and Vazhukka genotypes based on epidemiological parameters. The average percent disease index recorded in Malabar, Mysore and Vazhukka varied from 23.41 to 27.72, 18.79 to 20.34 and 18.74 to 20.38, respectively. The disease exhibited a positive correlation with respect to T_{max} and T_{min} in all the genotypes, however, significant correlation was observed only in Malabar and Mysore with respect to T_{max}. Whereas, rainfall and rainy days had negative correlation with leaf blight in all genotypes however found to be non-significant. The average infection rate was maximum (0.000429) in Malabar, whereas it was 0.000124 and 0.000186 in Mysore and Vazhukka, respectively. The area under disease progress curve registered the highest for Malabar (8814.15) and lowest in Vazhukka (6531.02) while, Mysore type recorded 6612.96 indicating that, Vazhukka and Mysore types might posses horizontal resistance and Malabar with vertical resistance. In the light of above results, plant protection measures could be scheduled based on the take-off level and genotypes with horizontal resistance could be promising candidates in resistance breeding programmes.

Keywords: apparent infection rate, area under disease progress curve, *Colletotrichum*, epidemiology, leaf blight, small cardamom

Introduction

Small cardamom (*Elettaria cardamomum* Maton) is a commercial Zingiberaceous spice originated and evolved in the biodiversity rich forest ecosystem of Western Ghats, India. Besides its centre of origin, cardamom is widely cultivated in Sri Lanka, Guatemala, Papua New Guinea and Tanzania (Ravindran 2002). The diverse species has morphologically evolved into Malabar, Mysore and Vazhukka genotypes distinguished primarily based on plant stature, leaf, panicle and capsule characters. A myriad of biotic and abiotic factors acts as major

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impediments to cardamom cultivation consequently leading to decline in gross cropped area and productivity. Among the foliar diseases, leaf blight incited by *Colletotrichum* spp. is noticed in all cardamom growing areas, inflicting damage invariably to all the genotypes. Divergent species belonging to the hemi-biotrophic ascomycetous pathogen, *Colletotrichum* incites leaf blight (Chethana *et al*. 2016). Though the disease is prevalent during the entire cropping season, it generally exacerbates and assumes epiphytotic proportions during post-monsoon period, probably favoured by an escalation in atmospheric temperature (Thomas & Bhai 2002). The anamorphic phase (conidia) plays a pivotal role in the epidemiology of leaf blight facilitating dissemination and pathogenesis evidently favoured by conducive environmental factors. Delineating vulnerable crop stages with respect to weather factors and disease pattern helps to formulate and implement plant protection strategies economically and efficiently. Correlating the disease progression with weather variables adequately supports decision making process besides providing an indirect indication on pathogen dynamics. The apparent infection rate (r) in conjunction with area under disease progress curve (AUDPC) values could be effectively employed as epidemiological parameters to define vertical or horizontal nature of disease resistance (Van der Plank 1963; Nagarajan 1983). Adopting plant protection measures based on apparent infection rate helps targeting the initial inocula thereby checking disease spread. Definitive information on epidemiology of cardamom leaf blight and the role of r and AUDPC parameters in disease progression as well as attempts towards deciphering the nature of resistance based on epidemiological parameters is scanty in cardamom-*Colletotrichum* host-pathosystem. Hence, the present investigation was formulated to delineate the relationship between disease progression *vis-à-vis* weather variables and an attempt was made to interpret the resistant nature of Malabar, Mysore and Vazhukka genotypes based on epidemiological parameters.

Materials and methods

Recording leaf blight incidence in field gene bank accessions

The study was carried out at ICAR-Indian Institute of Spices Research Regional Station, Appangala, Madikeri, Karnataka, India ($12^{o}26'$N Latitude, $75^{o}45'$E Longitude, 920 meters above MSL) during 2015-16. The experimental materials comprised of 119 field gene bank accessions and three released varieties (Appangala 1, IISR Avinash and IISR Vijetha) representing Malabar (41 accessions), Mysore (29 accessions) and Vazhukka (52 accessions) genotypes. The accessions used in the study were collected during exploration and collection programmes undertaken at diverse agro-climatic regions of major cardamom growing tracts and maintained in the *in situ* Field Gene Bank of the experimental location. The accessions/varieties (4 to 5 years old) were established under natural vegetation of shade trees during 2011 and each accession had five clumps each. The area under the experiment was maintained under uniform shade level and recommended package of practices were adopted to raise the crop with timely adoption of recommended plant protection chemicals to manage insect pests (thrips and panicle/shoot borer) and diseases (rhizome and root rot) other than leaf blight. Since, foliar diseases like leaf blotch, Phytophthora leaf blight and rust were either totally absent or less prevalent, foliar sprays with any of the recommended chemicals were not taken up. The incidence of leaf blight invariably relied on natural inoculum was visually recorded monthly employing 1-6 disease rating scale based on severity of foliar symptoms and percent disease index (PDI) was calculated. For scoring leaf blight incidence, peripheral portion of the clump comprising of senile tillers were avoided and the scoring was based on the manifestation of foliar symptoms on the inner tillers (minimum 8-12 tillers) of the clump. The PDI of all the accessions representing each genotype was calculated and averaged to depict the monthly average PDI for each genotype. Data on different weather variables such as maximum (T_{max}) and minimum (T_{min}) atmospheric temperature, rainfall and number of rainy days were also recorded daily and the monthly average values were computed. In order to study the relationship between various weather parameters and disease incidence by correlation studies, monthly averages of these weather factors was used.

Disease rating scale for leaf blight (1 to 6 scale) (Praveena *et al*. 2013; Senthil Kumar *et al*. 2018)

Category	Symptoms on leaves
1	No symptoms
2	Isolated spots
3	Sparse elongated spots on young and mature leaves
4	Coalescing elongated spots on young and mature leaves, 25% of leaf area is affected
5	Extensive elongated spots on all leaves, upto 50% of leaf area is affected, plant appears green from a distance
6	Total infection of all leaves, plant appears blighted from a distance

Percent Disease Index (PDI) = {[Y_1 (1-1) + Y_2 (2-1) + Y_3 (3-1) + Y_4 (4-1) + Y_5 (5-1) + Y_6 (6-1)] / [N × 6]} × 100

Y_1 to Y_6 = number of infected plants in each category

N = total plants in the plot

The accessions and the varieties were further categorized into highly resistant (< 10%), resistant (11-20%), moderately resistant (21-30%), moderately susceptible (31-40%), susceptible (41-50%) and highly susceptible (> 51%) based on percent disease index.

Computing r and AUDPC values

The apparent infection rate (r) is a parameter used to analyze the momentum of epidemic development. The apparent infection rate was calculated for each genotype based on the formula suggested by Van der Plank (1963).

$$r = \frac{2.3}{t2 - t1} log \left[\frac{x2(1 - x1)}{x1\,(1 - x2)}\right]$$

where, r is the apparent infection rate, x_1 is the disease index at initial time (t_1), x_2 is the disease index at subsequent observations (t_2). The apparent infection rates were further employed to identify the highest and lowest infection periods with respect to each genotypes.

The AUDPC value was computed using the formula suggested by Wilcoxson *et al*. (1975).

$$\sum_{i=1}^{n} \left(\frac{yi + yi + 1}{2}\right)(ti + 1 - t)$$

where, y_i is the disease incidence at i[th] day of evaluation (initial observation), y_i + 1 is the observation after the successive defined period, t_{i+1} - t_i is the period between two observations and n is the number of successive evaluations.

Results and discussion

The percent disease index (PDI) observed in different cardamom genotypes along with weather variables recorded during October, 2015 to September, 2016 are presented in Table 1. Among the genotypes, Malabar comprised of 41 accessions and Mysore and Vazhukka comprised of 29 and 52 accessions, respectively. The period of observation spanned reproductive as well as vegetative phases of developmental stage and post-monsoon as well as monsoon periods as far as the weather pattern is concerned.

Leaf blight incidence in cardamom genotypes and variation in weather variables

In Malabar genotype, the maximum PDI (27.72%) was recorded during May, 2016 whereas the minimum (23.41%) was observed during October, 2015. In Mysore type, the PDI was in the range of 18.79% to 20.34% which was the minimum during July, 2016 and the disease registered as peak during April, 2016.

In Vazhukka, the variation in PDI was 18.74% to 20.38% of which the minimum was noticed during December, 2015 while; the maximum was recorded during September, 2016. The maximum atmospheric temperature (T_{max}) varied from 24.3°C to 33.7°C in which September, 2015 had the minimum and April, 2016 recorded the maximum. Whereas, the minimum atmospheric temperature (T_{min}) was in the range of 13.1°C to 18.7°C during January and May, 2016 respectively. The average monthly rainfall ranged between 0-653.4 mm. During the period of observation, the rainfall was maximum during June, 2016 and minimum during February-March 2016. The rainy days were highest during August (29 days) and no precipitation was recorded during January to March 2016 (Table 1). Crop architecture and microclimate appears to be the deciding factors which favour incidence and proliferation of various diseases in the spice ecosystem. Nevertheless, the dynamic weather variables, often manifested in the form of erratic rainfall and temperature fluctuations over a period of time have unforeseen effects which may be even pose a threat to the production system in which these spice crops are grown either as principal or component crops. Murugan *et al*. (2017) observed that, climate change as evidenced through rise in ambient temperature and erratic rainfall immensely contributed to disease outbreaks in cardamom, demanding non-judicious application of fungicides.

Patterns in disease progression and correlation with weather variables

The disease exhibited a positive correlation with respect to T_{max} and T_{min} in all the genotypes, however, significant correlation was observed only in Malabar and Mysore with respect to T_{max}. Whereas, rainfall and rainy days had negative correlation with the disease in all genotypes however found to be non-significant (Table 2). In Malabar, the disease progression followed a high-low-high pattern. The disease exhibited increasing trends during November, December, January, March, April, May, August

Table 1. Percent disease index in cardamom genotypes and weather variables during October 2015 to September 2016

Month	PDI in different genotypes			Maximum atmospheric temperature (°C)	Minimum atmospheric temperature (°C)	Weather variables	
	Malabar	Mysore	Vazhukka			Rainfall (mm)	Rainy days
October	23.41	18.79	19.26	26.0	18.2	94.3	7
November	25.28	20.34	19.32	26.1	17.7	75.2	4
December	25.65	20.11	18.74	28.2	16.9	5.9	1
January	26.13	19.36	19.03	28.2	13.1	1.0	0
February	26.09	19.36	19.51	32.9	14.8	0	0
March	26.99	20.17	19.93	33.6	18.2	0	0
April	27.64	20.34	19.74	33.7	18.2	13.4	2
May	27.72	20.11	19.93	32.9	18.7	161.2	11
June	26.74	19.88	19.87	27.5	17.2	653.4	25
July	25.40	18.79	18.94	25.2	16.4	537.2	27
August	25.89	18.90	19.00	25.8	16.0	440.0	29
September	26.42	19.54	20.38	24.3	16.0	251.4	19

Table 2. Simple correlation between leaf blight incidence in cardamom genotypes with weather variables

Weather variables	Correlation coefficient		
	Malabar	Mysore	Vazhukka
Maximum atmospheric temperature (^oC)	*0.695	*0.668	0.37063^{NS}
Minimum atmospheric temperature (^oC)	0.182^{NS}	0.559^{NS}	0.19754^{NS}
Monthly rainfall (mm)	-0.055^{NS}	-0.481^{NS}	-0.25195^{NS}
Number of rainy days	-0.098^{NS}	-0.630^{NS}	-0.28827^{NS}

* = 5% level of significance; NS = non significant

and September, whereas, decreasing trends were observed during October, February and June-July. In Mysore genotype, leaf blight incidence registered peaks during November, March-April and August-September. While, the lowest incidence was noticed during October, December-February and May-July. In Vazhukka, decreasing trends in the PDI was observed during October-November, June-July and increasing pattern was noticed during November, January-March, May and August-September. In general, increasing as well as decreasing trends in disease progression were observed in all the genotypes during different months with a uniform increase during November, August and September whereas, a uniform decreasing trend was noticed during October, June and July. Though the impact of weather on diseases incited by *Colletotrichum* are well described by earlier workers, deciphering disease progression and host plant resistance through epidemiological parameters are not attempted in cardamom-*Colletotrichum* host-pathosystem. Alterations in temperature and moisture regimes influence population dynamics and pathogenicity of infectious agents and also might impact host physiology (Coakley *et al*. 1999; Chakraborty & Datta 2003; Mina & Sinha 2008). Physiological changes in host plants might result in increased resistance, leading to evolution of pathogens to prevail over host-plant resistance (Caffarra *et al*. 2012).

Foliar diseases incited by *Colletotrichum* species are generally favoured by temperature in the range of 25 to 35^{o}C, atmospheric humidity of 80-90% and rainfall. Singh *et al*. (2009) reported that, anthracnose of guava incited by *C. gloeosporioides* attained a peak during September which had a negative correlation with maximum and minimum temperatures. The disease also exhibited a positive correlation with precipitation defined in terms of rainfall and number of rainy days. The minimum and maximum temperature regime for development of guava anthracnose was found to be 10 and 35^{o}C, respectively with an optimum of 30^{o}C (Tandon & Singh 1969). Bainik *et al*. (1998) reported the temperature range 28-34.2^{o}C favours development of mango anthracnose. Though relative humidity had positive correlation with disease development, rainfall and number of rainy days had non-significant correlation (Ann *et al*. 1994). The sporulation in *Colletotrichum* is favoured by temperatures in the range of 20-25^{o}C, while temperatures above 30^{o}C have an inhibitory effect (Kendrick & Walker 1948; Slade *et al*. 1987; Mello *et al*. 2004). Cowger & Mundt (2002) illustrated that, interaction of components conferring genotypic resistance with environmental factors is required to modify the effects of host diversity with respect to disease progression.

In cardamom system, it is speculated that *Colletotrichum* might have remained as cryptic dormant endophyte during anti-epidemic phase and subsequently activated during post-monsoon period particularly favoured by temperature. *C. gloeosporioides* colonized the internal foliar niche as endophyte in sweet orange which served as inoculum reservoirs

Table 3. Categorization of cardamom accessions/varieties in each genotype based on reaction towards leaf blight

Percent Disease Index (%)	Classification	Genotypes		
		Malabar	Mysore	Vazhukka
< 10%	Highly resistant (HR)	Nil	Nil	Nil
11-20%	Resistant (R)	FGB 1, FGB 9, FGB 10, FGB 39, FGB 70, FGB 71, FGB 84,FGB 87, FGB 89, FGB 95 FGB 96, FGB 118, FGB 119, Appangala 1, IISR Avinash	FGB 4, FGB 7, FGB 13, FGB 21, FGB 23, FGB 29, FGB 34, FGB 40, FGB 42, FGB 44, FGB 46, FGB 50, FGB 56, FGB 57, FGB 58, FGB 59, FGB 60, FGB 61, FGB 72, FGB 73, FGB 86, FGB 90, FGB 97, FGB 120	FGB 2, FGB 3, FGB 5, FGB 6, FGB 8, FGB 11, FGB 12, FGB 14, FGB 15,FGB 16, FGB 17, FGB 18, FGB 19, FGB 20, FGB 22, FGB 24, FGB 25,FGB 26, FGB 27, FGB 28, FGB 30,FGB 31, FGB 32, FGB 33, FGB 35, FGB 36, FGB 41, FGB 43, FGB 45,FGB 47, FGB 48, FGB 49, FGB 51,FGB 54, FGB 55, FGB 62, FGB 63,FGB 64, FGB 65, FGB 69, FGB 75
21 – 30%	Moderately resistant (MR)	FGB 77, FGB 78, FGB 85, FGB 88, FGB 92, FGB 93,FGB 98, FGB 100, FGB 102, FGB 107, FGB 113, FGB 116	FGB 66, FGB 67, FGB 68, FGB 94	FGB 37, FGB 38, FGB 52, FGB 53,FGB 76, FGB 80, FGB 99, FGB 114, FGB 115, FGB 117
31 – 40%	Moderately susceptible (MS)	FGB 79, FGB 81, FGB 82, FGB 83, FGB 101, FGB 103, FGB 104, FGB 105, FGB 108, FGB 109, FGB 110, FGB 111, FGB 112, IISR Vijetha	FGB 91	FGB 106
41 – 50%	Susceptible (S)	Nil	Nil	Nil
> 51%	Highly susceptible (HS)	Nil	Nil	Nil

causing post blossom fruit drop during favourable weather (Andrade *et al.* 2017).

Categorization of accessions based on resistance towards leaf blight

The reaction exhibited by the genotypes and their categorization based on resistance/ susceptibility levels towards leaf blight are presented in Table 3. Based on the percent disease index recorded in different accessions, different categories were evolved in which the accessions were placed based on average monthly PDI. Among the accessions representing different genotypes, none exhibited highly resistant, susceptible or highly susceptible reactions towards leaf blight. In Malabar type, the average PDI ranged from 16.66 to 33.88%. Of the 41 accessions evaluated, 24 exhibited resistant reaction and 12 and 14 accessions were categorized under moderately resistant and moderately susceptible categories. In Mysore genotype, of the 29 accessions evaluated, resistant reaction was exhibited by 24 accessions. Whereas, 4 accessions were grouped under moderately resistant category and one under moderately susceptible group wherein, the average PDI varied between 16.66 to 31.08%. In Vazhukka with an average PDI range of 16.66 to 31.08% in which 41 accessions were grouped under resistant category and 10 and one accession exhibited moderately resistant and moderately susceptible reactions, respectively. Evolving genotypes possessing inherent resistance towards the invading pathogens is the most economical and eco-friendly approach to combat diseases. Identification of resistant sources and their subsequent incorporation in the breeding programmes are indispensible in the development of resistant varieties and considered as the most economical and sustainable strategy to combat diseases. The sources of resistant genes may be well distributed among elite cultivars, adopted non-elite germplasm, improved elite germplasm, land races, primitive varieties or wild related species as depicted in genetic diversity pyramid (Carson 1997). Earlier efforts to identify leaf blight resistance in cardamom germplasm resulted in the identification of glabrous selections of Malabar type *viz*., MA-15, MA-18 and MA-20 as moderately resistant and the compound panicle types, CP-2 and CP-9 as well as the land race Njallani Green Gold as resistant to the disease (Anon. 2004-05) besides, 22 leaf blight resistant accessions (Anon. 2006-07). Further, two accessions *viz*., IC-349588 and IC-349613 which exhibited highly resistant reaction were found promising against leaf blight disease (Praveena e*t al*. 2013). Concerted efforts in the direction to carry out extensive surveys in the hot spots of genetic diversity, collection and conservation of germplasm by establishing field gene banks, their subsequent characterization to identify desirable traits are essential in resistant breeding programmes for harnessing the existing genetic diversity within a diverse population.

Trends in r and AUDPC values

The rate of disease spread as expressed in terms of r-value exhibited an erratic pattern irrespective of the genotypes. However, in general, the occurrence of anti-epidemics (where the r value attained a negative phase) was found to be uniform in all the genotypes during June-July. The average r-value was the highest (0.000429) for Malabar and least in Mysore (0.000124), whereas in Vazhukka it was 0.000186 (Table 4). The take-off level (an increase in r-value after attaining the anti-epidemic phase) was generally observed during July-August which coincided with an average T_{max} of 24.5°C, T_{min} of 16.2°C and rainfall and rainy days of 448.6 mm and 28 days. The AUDPC value was the maximum (8814.15) for Malabar and minimum (6531.02) in Vazhukka while it was 6612.96 in Mysore (Table 4). Critical analysis of the epiphytotics with respect to time, space and weather variables and its interpretation in terms of infection rate helps identifying the pattern of disease progression in a population and formulating diversified strategies to combat diseases with comparatively lesser efforts. Further, employing the epidemiological parameters including apparent infection rate and AUDPC values to identify resistant nature of the crop species have more implications besides merely deciphering the interaction of genotypes with weather variables on a time scale. The r and AUDPC values derived from disease progression have been used to identify resistance nature of genotypes in several economically important crops like wheat, rice, potato, sunflower etc. against a variety of pathogens. Slow blighting cultivars are widely gaining acceptance in plant disease management as they reduce the momentum of disease spread, check the probable occurrence of epiphytotics without adversely affecting the potential yield. Genotypes possessing slow rusting/slow blighting quality governed by horizontal resistance mechanism exert less selection pressure on the invading pathogenic microbes resulting in preferential development of previously undetected virulent strains (Van der Plank 1963; Hooker 1967). Results from the present study indicated that, the apparent infection rate varied throughout the period of observation and remained inconsistent for a particular genotype and also did not exhibit a particular trend which might be attributed to genetic makeup of the genotype. Wilcoxson *et al*. (1975) and Nagesha & Nargund (2005) observed the similar trends in wheat and sunflower, respectively. The area under disease progress curve is considered as a promising parameter to evaluate development of epidemics of foliar diseases considering genetic architecture of the genotypes. The experimental results suggested that, leaf blight severity primarily depends on prevailing weather conditions and resistance levels of the genotypes. The genotype which recorded higher AUDPC value exhibited severe leaf blight symptoms. The results indicated that, in this system climatic conditions could be a vital determinant favouring infection, as variation in PDI in all the genotypes was not drastic and toward resistance/susceptibility components. The AUDPC values differed considerably among the genotypes. The highest AUDPC value was observed in Malabar (8814.15) followed by Mysore (6612.96) and Vazhukka (6531.02). Based on the analyses of epidemiological parameters *vis-à-vis* host plant resistance, it is

Table 4. Apparent infection rate (r) and area under disease progress curve (AUDPC) in cardamom genotypes

	r-value during different months											r-value (average)	AUDPC
	October to November	November to December	December to January	January to February	February to March	March to April	April to May	May to June	June to July	July to August	August to September		
Malabar	0.0032	0.000649	0.0008	0	0.00159	0.001	0.00013	-0.00159	-0.00232	0.00082	0.00088	0.000429	8814.15
Mysore	0.00317	-0.00047	-0.00153	0	0.0017	0.00033	-0.00047	-0.00046	-0.00233	0.00023	0.00132	0.000124	6612.96
Vazhukka	0.000124	-0.00125	0.00061	0.000994	0.000914	-0.00039	0.000398	-0.00012	-0.00198	0.000126	0.002813	0.000186	6531.02

hypothesized that, resistance in Malabar types is governed by mono/oligo genes (vertical resistance) and Mysore as well as Vazhukka might possess horizontal resistance (governed by polygenes). Deciphering the nature of resistance based on r and AUDPC values have been attempted by earlier workers in crops *viz*., wheat, potato and sunflower. Nagesha & Nargund (2005) also reported lower AUDPC values in slow rusting varieties and higher values in susceptible varieties of sunflower. Hence, based on the AUDPC values, Malabar genotype could be considered as fast blighter and highly susceptible and Mysore as well as Vazhukka genotypes as slow blighters. Paraschivu *et al*. (2013) suggested that, there is a correlation between susceptibility of genotypes and AUDPC indicating that, highly susceptible wheat cultivars recorded high AUDPC values against *Septoria tritici*.

Non-judicious application of synthetic molecules might lead to several far-reaching consequences as it contributes immensely to the evolution of novel races of pathogens with fungicide resistance and pesticide residues in the produce. Besides deciphering the speed at which the disease spreads in a population, the r-value could be effectively employed to identify the stages at which the plant protection measures can be adopted, primarily targeting the initial inoculum (X_o). In the present study it is observed that, in general, the r-value exhibited the trend of anti-epidemic phase during May-June and a take-off phase during July-August. Hence, undertaking plant protection measures with recommended fungicides before the commencement of monsoon (May-June) and during July-September targeting the low inoculum levels would have significant adverse effect on the disease progression.

From the perspectives of epidemiology and host plant resistance it is concluded that, an increase in temperature during post-monsoon and precipitation have significant implications on disease progression. The trends observed with r and AUDPC values indirectly indicated that, resistance in Malabar types may be governed by strong genes (vertical resistance) and weak genes (horizontal resistance) in Vazhukka and Mysore types. Further, based on the results, plant protection measures could be scheduled based on take-off phase of the disease to realize better management of the disease under field conditions.

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Effect of drip irrigation on growth and yield of onion (*Allium cepa* L.)

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Abstract

Drip irrigation is one of the essential, advanced and innovative irrigation methods over surface irrigation. In view of this, an experiment was conducted to study the efficiency of drip irrigation system over surface irrigation in onion during *Rabi* 2013-14 and 2014-15 and *Kharif* 2014 and 2015. The results revealed that drip irrigation system performed superior over surface irrigation system in terms of superior plant morphology, yield and quality of bulb. Drip irrigation recorded maximum plant height (66.37 cm & 61.88), number of leaves (9.23 & 8.00) and neck thickness (1.62 cm & 1.30 cm) in both *Rabi* and *Kharif* seasons. The bulb equatorial and polar diameter, higher gross yield as well as marketable yield obtained in drip irrigation system. In drip, gross yield and marketable yield increased 18.16% and 24.49%, respectively over surface irrigation method and better water use efficiency and also saved 29.36% and 27.12% water during *Rabi* and *Kharif* seasons, respectively.

Keywords: onion, drip irrigation, surface, yield, water use efficiency

Introduction

India is the second largest producer of onion next to China. Maharashtra state is the leading producing state in India. Onion is cultivated in three distinct seasons namely *Kharif*, late *Kharif* and *Rabi*. The soil moisture affect the quality of bulb and yield which is greatly influenced by the irrigation system. Onion is a shallow rooted crop needs light but frequent irrigation either by flood, sprinkler, or drip. The productivity of onion in India is 17.33 ton ha^{-1} which is low compared to world average. Managing the amount of applied irrigation water is critical to achieve optimum yield and quality. Most of the onion grown in India is under surface irrigation, which is relatively inexpensive, but inefficient in the amount of water use. Irrigation through drip is a new technique to increase agricultural production and to enhancing the efficiency of water use (Kusçu *et al*. 2009; Shock 2013; Enciso *et al*. 2015). Drip irrigation lends itself to automation, more so than either surface or sprinkler irrigation. Keeping this in mind, an experiment was planned on onion to study the feasibility of onion cultivation under drip irrigation.

Materials and methods

A field trial was conducted during *Rabi*, 2013-14 and 2014-15 and *Kharif* 2014 and 2015 under "All India Network Research Project on Onion and Garlic" programme to study the feasibility of onion under drip irrigation system over surface irrigation on variety *Agrifound Light Red* for *Rabi* and *Agrifound Dark Red* for *Kharif* at the research farm of National Horticultural Research and Development Foundation, Nashik, Maharashtra. During experimental period meteorological data has given in Fig. 1. Soil of the experimental area was deep heavy clay with pH (7.60), organic carbon (0.75 mg g^{-1}), available N (374.0 kg ha^{-1}), available P (49. 05 kg ha^{-1}), available K (414.4 kg ha^{-1}), water holding capacity (62.8%), field capacity (38.9%) and permanent wilting point (24.6%). The 55-60 days aged seedlings were transplanted in the month of December for *Rabi* and for *Kharif* 45-50 days old seedlings were transplanted in August.

The drip irrigation system was arranged in broad based furrow (BBF) system at spacing of 10 × 15 cm in both drip and surface irrigation systems (farmers practice). BBF of 1.20 m top width with 0.45 m furrow maintaining 15 cm height, each BBF consists of two drip laterals (16 mm size) with inbuilt emitters. The distance between two inbuilt emitters was 50 cm and the discharge rate is 4 L/hr. The BBF system was prepared with a BBF former mounted behind a tractor. Single bed size was kept as 45.0 m x 1.2 m in 6 replications and laid down in RBD design. The width of each bed and furrow was 1.2 and 0.45 m, respectively; thus the width of one unit of BBF was 1.65 m simultaneously the crop raised under surface irrigation method was arranged in flat bed system in three rows, single bed size was 5.0 x 2.0 m, single row contains 7 beds.

Before transplanting of seedlings organic manures *i.e.* vermicompost @10 t ha^{-1} along with *Tricoderma viride* 5 kg ha^{-1}mixed with *Azotobacter* 10 kg ha^{-1} applied in soil in both BBF and flat beds. The recommended dose of chemical fertilizers NPKS was 100:50:50:30 kg ha^{-1}. Fifty percent of N and 100% P, K and S applied at basal remaining 50% N applied in two splits at 30 & 45 days after transplanting in flood irrigation flat bed system. Whereas, in drip

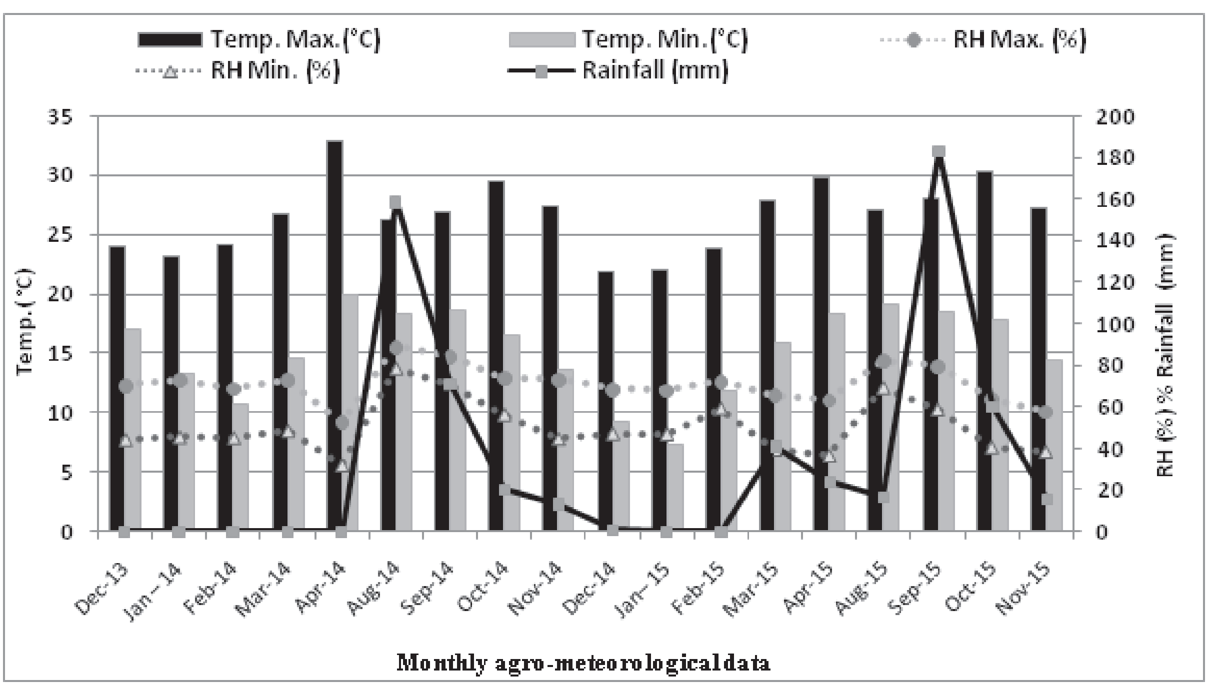

Fig. 1. Agro-meteorological data during crop growing period

system fertigation was done with drip tank in 7 splits with 7 days intervals per day 2-3 hr. First irrigation was operated immediately after transplanting and light irrigation was done three days after transplanting for better and uniform initial establishment of crop. Recommended crop production and protection practices were followed as and when required to get good healthy crop. Following critical precautions were taken while conducting the experiment *viz.* irrigation interval followed uniformly; the operating pressure of drip system was 1.0 -1.5 kg cm^{-2}. In both the systems, irrigation was stopped at 15-20 days before crop harvesting. The bulbs were harvested at full maturity stage. After proper curing and neck cutting, the observations on yield and yield contributing characters and marketable bulb yield, percent of A (>6.5 cm), B (4.5- 6.5 cm) and C (< 4.5 cm) grade bulbs on weight basis separately recorded and quantity of water applied was also measured.

Results and discussion

The results revealed that all growth and yield parameters of onion are significantly influenced by irrigation methods. The highest plant height *i.e.* 66.37 cm and 61.88 cm was recorded in drip irrigation raised bed system during *Rabi* and *Kharif* seasons, respectively, where as in surface irrigation flat bed system plant height was 65.00 cm and 51.52 cm. Number of leaves and neck thickness were also higher in drip irrigation method in both *Rabi* (9.23/ plant and 1.62 cm) and *Kharif* (8.0/ plant and 1.30 cm) seasons (Table 1) that indicated that in drip irrigation raised bed system plant receive favourable conditions for enlargement of root system thereby plant growth and vigour is high. The results are in line with the results of Bhonde *et al.* (2003); Kumar *et al.* (2007) and Bangali *et al.* (2012) for plant growth. Drip provided require amount of water to the crop in small amounts delivered at frequent intervals as needed by the plant, and water losses to evaporation are less than with surface irrigation and also water is delivered at or below ground level, so that wetting of the foliage is not a problem. The drip irrigation affected the size of onion bulb, highest bulb equatorial (6.15 cm & 5.15 cm) as well as polar bulb diameter (5.15 cm & 3.35 cm) were recorded in drip irrigation and the lowest bulb diameter were recorded from the surface irrigation during *Rabi* and *Kharif*, respectively. Frequent amount of soil moisture application leads to large

Table 1. Effect of drip irrigation and surface irrigation systems on plant growth, yield and quality of onion cv. *Agrifound Light Red* for *Rabi* 2013-14 and 2014-15, and *Agrifound Dark Red* for *Kharif* season 2014 and 2015

Growth and yield parameters	*Rabi*			*Kharif*		
	Drip	Surface	CD (P<0.05)	Drip	Surface	CD (P<0.05)
Plant height (cm)	66.37	65.00	1.16	61.88	51.52	5.92
Number of Leaf $plant^{-1}$	9.23	8.18	0.93	8.00	6.77	0.96
Neck thickness (cm)	1.62	1.04	0.39	1.30	0.95	0.05
Bolting (%)	0.56	2.22	0.22	0	0	0
Doubles (%)	2.28	6.34	0.70	0	0.47	0.077
Bulb equatorial diameter (cm)	6.15	5.36	0.33	5.15	4.66	0.26
Bulb polar diameter (cm)	4.64	4.13	0.017	3.35	2.99	N.S.
Gross yield (t ha^{-1})	33.93	29.86	1.71	23.30	20.39	1.22
Marketable yield (t ha^{-1})	31.96	26.07	2.95	20.03	16.93	0.75
A grade bulb (%)	63.07	53.68	1.72	28.96	15.98	3.39
B grade bulb (%)	24.82	22.46	2.40	36.28	34.16	1.21
C grade bulb (%)	12.11	23.86	6.32	34.76	49.86	2.29

photosynthesis area resulted highest plant height and large number of leaves leads to large bulb diameter and yield. The highest total bulb yield (33.93 & 23.30 t ha^{-1}) and marketable yield (31.96 & 20.03 t ha^{-1}) were recorded in drip irrigation system in both *Rabi* and *Kharif* seasons, whereas as in flood irrigation lowest gross yield (29.86 & 23.30 t ha^{-1}) as well as marketable yield (26.07 & 16.93 t ha^{-1}) were recorded. The gross yield and marketable yield increased 18.16% and 24.49%, respectively over surface irrigation. Drip irrigation with fertigation of NPK nutrients with regular intervals enables better plant growth caused higher photosynthesis levels and higher carbohydrates accumulation in sink region. It is evidenced from the results presented in this study is inclusive and similar with previous researchers (Balasubramanyan *et al*. 2001; Quadir *et al*. 2005; Tripathi *et al*. 2010; Bangali *et al*. 2012). The results further revealed that drip irrigation provided lower bolting (0.56%) and doubles (2.28%) as compared with surface system and it was observed that during *Kharif* season bolting did not record in any treatments because the average minimum temperature is above 17ºC is not favourable to initiate bolting, however doubles were recorded (Table 2).

Nashik comes under shadow of a southwest monsoon; hence the erratic summer monsoon experienced by this region sets in last part of June and extends till the 2nd week of October. The mean average rainfall varied from 548.0 mm to 862.0 mm during 2013 to 2015. Rainfall was coincided with bulb initiation and bulb development phases, due to heavy rain fall during *Kharif* season poor bulb development was observed. This is the reason and other climatic reasons during *Kharif* season 36.32% yield decreased as compared with *Rabi*, however by adopting drip irrigation system in *Kharif* season considerable yield was increased over surface irrigation method because drip irrigation raised bed system up to some extent remove excess water and avoid water logging due to slow and steady runoff water as compared with surface flat bed system where crop was affected. Over all during *Kharif* season in drip irrigation, the gross yield and marketable yield increased 14.27% and 18.30%, respectively. It is evidenced from the results, properly designed and managed drip irrigation raised bed has many advantages over surface irrigation including: elimination of surface runoff, high uniformity of water distribution, high water usage efficiency, flexibility in fertilization, prevention of weed growth and plant disease during rainy season. The results further revealed that highest 'A' grade (>6.0 cm) bulb (63.07%), 'B' grade (4.0-6.0 cm) bulb (24.82%) and lower 'C' grade (<4.0 cm) bulb (12.10%) were recorded in drip irrigation system during *Rabi* season and in *Kharif* also higher 'A' grade bulb (28.97%), 'B' grade bulb (36.28%) and lower 'C' grade bulb (34.76%) recorded in drip irrigation system (Table 3). Drip irrigation ensures optimum growth, better bulbing and early maturity of crops by assuring optimum soil moisture, water, air and nutrients throughout the crop growing period resulting uniform bulb obtained is directly correlated to the highest bulb size and productivity, whereas in surface irrigation yield decreased due to deep percolation and water is lost beyond the active absorption zone of the root system as an onion is shallow rooted crop. These results are in line with the results of Hanson & May (2005) and Tripathi *et al*. (2010).

Table 2. Benefits of drip irrigation system over surface irrigation system during *Rabi* and *Kharif* seasons at Nasik region of Maharashtra

Parameters	*Rabi*	*Kharif*
Gross yield (%)	13.64	14.27
Marketable yield (%)	22.61	18.30
A grade bulb (%)	17.49	81.24
B grade bulb (%)	10.51	5.94
C grade bulb (- %)*	49.84	30.29
Water saving (%)	29.36	27.12
Water use efficiency (%)	60.87	56.79

*Per cent decreased over surface irrigation

The benefits of drip irrigation system over surface irrigation are illustrated in Table 4, that applied water in drip system is very lower in two seasons as compare with surface irrigation system. The 60.29 ha cm^{-1} and 55.65 ha cm^{-1} quantity of water was applied in drip system during *Rabi* and *Kharif*, respectively where as in flood system 85.35 ha cm^{-1} and 76.35 ha cm^{-1}, respectively. Thus, the drip system could save 29.36% and 27.12% water during *Rabi* and *Kharif*, respectively. The primary reasons attributed for the water savings include irrigation of a smaller portion of the soil volume, decreased surface evaporation, reduced irrigation runoff from the drip field and controlled deep percolation losses below the crop root zone, which enables higher water use efficiency in drip irrigation raised bed system, which was 562.79 kg ha^{-1} mm for *Rabi* and 418.69 kg ha^{-1} mm for *Kharif* (Fig. 2). The results were similar in line with results of Halim & Ener (2001) and Nagaz *et al*. (2012). Based on water consumption of crop calculated that during *Rabi* season 1000 lit of water is utilized for production of 5.62 kg and 3.49 kg of onion in drip and surface irrigation, respectively. Whereas in *Kharif* season 1000 litre of water by drip produces 4.18 kg, while in surface it is 2.67 kg, therefore drip irrigation system well suited for shallow rooted onion. The Cost: Benefits ratio also high in drip (1:2.69) while in surface irrigation it is 1: 1.68. The Cost: Benefits ratio in drip suggests that despite higher initial cost of the drip system, the drip irrigation is more profitable than the surface irrigation.

Based on the obtained results of *Rabi and Kharif* seasons of the effect of drip irrigation on yield, yield components and morphological characteristics of onion, as well as water use efficiency and water saving it concluded that drip irrigation is highly significant effect on all studied parameters. To achieve a high production potential of onion, adopting drip irrigation should be maintained during the both *Rabi* and *Kharif* seasons.

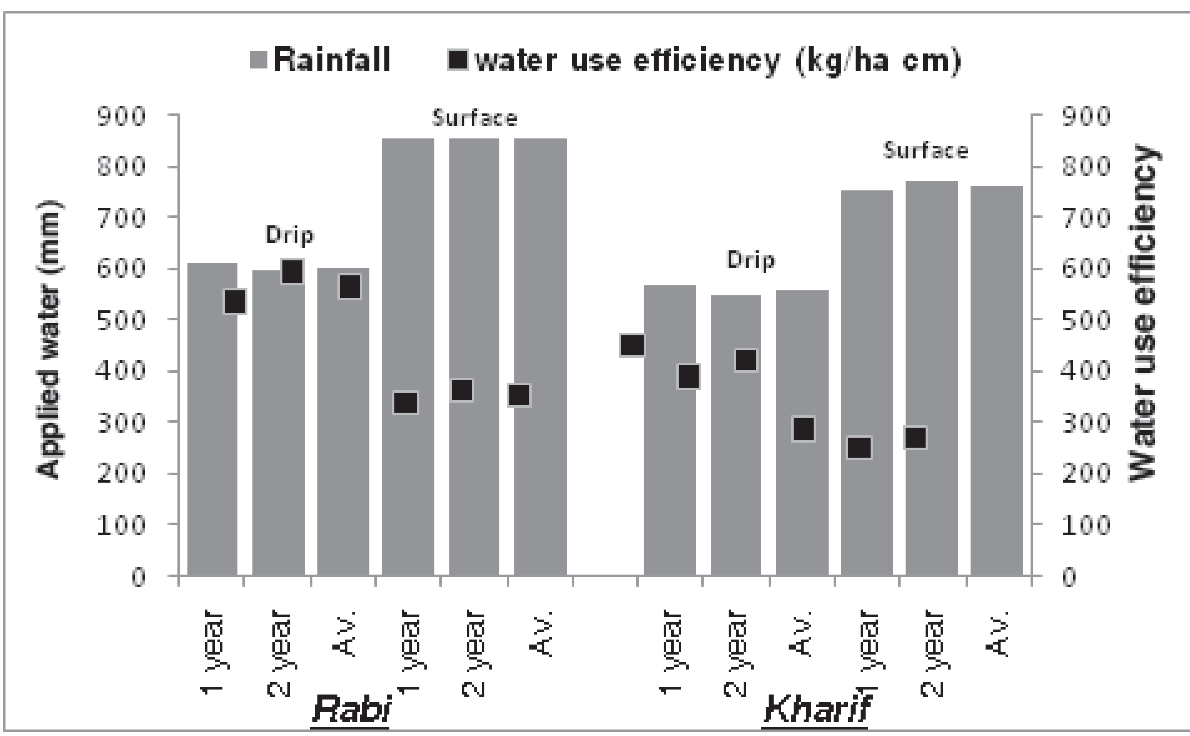

Fig. 2. Effect of drip irrigation and surface irrigation systems on water consumption and water use efficiency of onion cv. *Agrifound Light Red* for *Rabi* 2013-14 and 2014-15, and *Agrifound Dark Red* for *Kharif* season 2014 and 2015

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Influence of organic and inorganic fertilizers on yield and quality of sweet basil (*Ocimum basilicum* L.)

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Abstract

Field experiments were carried out during *Kharif* season of 2015 and 2016 to study the influence of FYM, inorganic fertilizers and bio-fertilizers on fresh herbage yield, quantity and quality of essential oil of sweet basil (*Ocimum basilicum*). Nine treatments with three replications were adopted in a randomized block design to find out the effect of different levels of N applied through FYM (100, 75 and 50% of the recommended N along with and without bio-fertilizers), recommended dose of NPK (160:80:80 kg ha^{-1}), recommended FYM (10 t ha^{-1}) + NPK (160:80:80 kg ha^{-1}) and control (recommended FYM (10 t ha^{-1}) on fresh herbage and oil yield, oil content and oil quality of sweet basil (*Ocimum basilicum* L.). Pooled results revealed that application of recommended FYM (10 t ha^{-1}) along with recommended NPK (160:80:80 kg ha^{-1}) recorded the highest fresh herbage yield (39.95 and 19.37 t ha^{-1}), essential oil content (0.48 and 0.45%) and essential oil yield (199.7 and 107.58 kg ha^{-1}) in the main crop and ratoon, respectively. With respect to oil quality, bio-fertilizer has a good impact on oil quality, that highest percentage of Methyl chavicol was recorded with application of recommended FYM (10 t ha^{-1}) + recommended N through FYM along with bio fertilizers in the main crop of 2016 (63.78%) and in the ratoon (59.39 and 59.67%) of 2015 and 2016, respectively.

Keywords: bio-fertilizer, FYM, herbage, inorganic fertilizer, oil quality and basil

Introduction

Sweet basil (*Ocimum basilicum* L.) is one of the most important essential oil producing aromatic plant, is grown worldwide for its medicinal, flavoring and industrial properties. The economic parts of the plant include leaves, flowers and seeds. The medicinal impact of basil results from the presence of phenolic compounds, flavonoids and other substances in its essential oil which have antibacterial (Nour *et al*. 2009), anti-mycotic and antioxidant activities (Sekar *et al*. 2009).

Basil is considered as a species with substantial nutritional and fertilization needs. It responds extremely well to nitrogen fertilization. The yield of basil increases when the dose of

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nitrogen increases (Daneshian *et al*. 2009; Biesiada & Ku 2010), but intensive farming that need high input of mineral fertilizers is considered as serious damage that may affect soil health, sustained production and balanced environment (Anwar *et al*. 2007). Taking into consideration of the deleterious effect of continuous applying of mineral fertilizer on the soil structure, organic farming could consider as a suitable replacement of inorganic fertilizer for improving microbial population, and soil organic matter (Shahram & Ordookhani 2011). Reza *et al.* (2015) claimed that substituting chemical fertilizers by organic manures and bio-fertilizers, could consider as a good farming system improve the ecosystem and soil health as a step for achieving sustainability in agriculture.

Besides this, for medicinal and aromatic plants (MAPs), the real value is given to the quality rather than quantity, so that organic farming is considered as a suitable approach that enhances the performance of these crops. However, complete replacement of inorganic fertilizers by the organic manures is not advisable owing to their very low nutrient concentration and in turn requirement in huge quantities which may not be possible due to scarcity of such materials. In this endeavor, a blend of organic and inorganic fertilizers is important for improving the yield, maintaining soil health and keeping favorable ecological conditions on long-term basis. Amran (2013) and El-khyat (2013) revealed that application of organic manure along with half dose of chemical fertilizer had a positive impact on the oil yield of *Pelargonium graveolens* and *Rosmarinus officinalis*. The quality of the essential oil in basil is determined by the percentage of its volatile molecules which is affected by soil and climate conditions. Combined application of organic manure and inorganic fertilizer is considering the best tool that can be used to improve the yield and quality of these plants. Despite the importance of the basil crop, information on different aspects of growth, development, influence of organic manure and inorganic fertilizers on herbage and oil yield is very meager. In this context, this study was aimed to find out the "Influence of FYM, inorganic fertilizer and bio-fertilizers on herbage, oil yield, essential oil content and oil quality of sweet basil.

Material and methods

Field experiments were conducted in the experimental field at ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bangalore during the *kharif* season of 2015 and 2016. The experimental station is located at an altitude of 890 m above mean sea level and 13^{o}58" N latitude and 77^{0}29" E longitudes. The nine treatments of experiment contain T_1 (FYM (10 t ha^{-1}) + 100% recommended N through FYM), T_2 (FYM (10 t ha^{-1}) + 100% recommended N through FYM + bio-fertilizer), T_3 (FYM (10 t ha^{-1}) + 75% recommended N through FYM), T_4 (FYM (10 t ha^{-1}) + 75% recommended N through FYM + biofertilizer), T_5 (FYM (10 t ha^{-1}) + 50% recommended N through FYM), T_6 (FYM (10 t ha^{-1}) + 50% recommended N through FYM + biofertilizer), T_7 (recommended FYM (10 t ha^{-1} only), T_8 (recommended NPK (160:80:80 kg ha^{-1}) only, and T_9 (recommended FYM 10 t ha^{-1}) + recommended NPK (160:80:80 kg ha^{-1}). Treatments were replicated thrice in a randomized complete blocks design. Physical and chemical properties of the initial experimental soil are presented in (Table 1). The nutrients were supplied in the form of straight fertilizers like urea (160 kg N ha^{-1}), single super phosphate (80 kg P_2O_5 ha^{-1}) and muriate of potash (80 kg K_2O ha^{-1}). Fifty per cent of nitrogen and full dose of phosphate and potash were applied as basal dose and the remaining fifty per cent of N was applied after 45 days of transplanting in T_8 and T_9 treatments. For bio-fertilizers, Arka Microbial Consortium (AMC) developed by ICAR-IIHR was used in the experiment and it contains N fixing, P and Zn solubilizing and plant growth promoting microbes in a single carrier. After 15 days of transplanting, recommended dose of AMC @5 kg ha^{-1} was applied at 2 cm deep to individual plants and immediately covered with soil. Similar method of application was also followed for ratoon crop after harvest of main crop in $T_{2,}$ $T_{4,}$ and T_6 treatments. Quantities of added fertilizers are given in (Table 2).

Table 1. Physical and chemical proprieties of initial experimental soil

Physical properties	
Bulk density (Mg m^{-3})	1.32
Particle Density (Mg m^{-3})	2.65
Pore space (%)	42
Chemical properties	
pH (1:2.5)	7.75
Electrical conductivity (dSm^{-1})	0.36
Organic carbon (g kg^{-1})	5.0
Available N (kg ha^{-1})	185
Available P (kg ha^{-1})	28
Available K (kg ha^{-1})	200
Exchangeable Ca (cmol (p^+) kg^{-1})	5.25
Exchangeable Mg (cmol (p^+) kg^{-1})	0.84
DTPA Fe (mg kg^{-1})	7.5
DTPA Mn (mg kg^{-1})	5.8
DTPA Cu (mg kg^{-1})	1.33
DTPA Zn (mg kg^{-1})	1.22

Each experimental plot size was 4.8 m long and 4 m wide with spacing of 40 cm between the plants and 60 cm between the rows. There was a space of 0.5 meter between the plots and 0.5 meter between replications. Basil variety Cim-Saumya (CIMAP) was sown in two nursery beds of 6.0 m in length with 1 m in width and 10 cm height. Forty days old (40) healthy and uniformly rooted seedlings of sweet basil were transplanted to the field. Weeding was done manually and drip irrigation was given daily for half an hour in the early stages and subsequently irrigation was given depending on the soil moisture condition. Fresh weight from each plot was converted to per hectare and it was expressed in tones (t). In order to determine the essential oil content (%), a sample of 100 g of basil fresh herb from the each plot were collected and mixed with 500 ml distilled water and then were subjected to hydro-distillation for 3 h using a Clevenger-type apparatus (Darzi *et al.* 2012). The quality of basil oil samples was analyzed by gas

Table 2. Treatment wise applied quantities of FYM, inorganic fertilizer and bio-fertilizers

Treatments	Quantity of inputs			Total nutrient supplied		
	FYM (t ha^{-1})	NPK (kg ha^{-1})	BF* (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1:FYM (10 t ha^{-1}) + 100% Rec. N through FYM	35	0	-	224	39.2	31.5
T_2:FYM (10 t ha^{-1}) + 100% Rec. N through FYM + BF	35	0	5	224	39.2	31.5
T_3:FYM (10 t ha^{-1}) + 75% Rec. N through FYM	28.75	0	-	184	32.2	25.9
T_4:FYM (10 t ha^{-1}) + 75% Rec. N through FYM + BF	28.75	0	5	184	32.2	25.9
T_5:FYM (10 t ha^{-1}) + 50% Rec. N through FYM	22.5	0	-	144	25.2	20.3
T_6:FYM (10 t ha^{-1}) + 50% Rec. N through FYM + BF	22.5	0	5	144	25.2	20.3
T_7:Rec. FYM (10 t ha^{-1}) only	10	0	-	64	11.2	9
T_8:Rec.NPK (160:80:80 kg ha^{-1})	0	Rec	-	160	80	80
T_9:Rec.NPK (160:80:80 kg ha^{-1}) + Rec. FYM (10 t ha^{-1})	10	Rec	-	234	91.2	89

FYM=Farm Yard Manure; Rec.=Recommended and *BF=Bio-fertilizer chromatography (Varian 3800 series) using VH-5 column for GC and VH-5 MS column for GCMS 30 m x 0.2 mm with 0.2 mm film thickness, oven temperature programmed at 60^0C for 5 min then 210^0C hold for 1 min then 240^0C hold it for 1 min and helium gas as a carrier at 1 ml min^{-1}. Injector and detector temperature were 270^0C and 240^0C, respectively. Methyl chavicol and Linalool constituents of the oil were identified based on their retention time by comparing with the peak retentions times of those authentic standards obtained from Sigma, Aldrich, Bengaluru and run under identical conditions, then it were estimated in respect to total components and expressed as percentage.

The data recorded from the experiment were analyzed using SAS 9.3 version of the statistical package (SAS Institute Inc 2011). Analysis of variance (ANOVA) was performed using SAS PROC ANOVA procedure. Means were separated using Fisher's protected least significant difference (LSD) test at a probability level of $p<0.01$.

Results and discussion

Fresh herbage yield

Fresh herbage yield of basil differed significantly due to application of different levels of N through FYM along with and without bio-fertilizers and inorganic fertilizer in the main crop and ratoon during two years of the experiment. It is evident from the Table 3 that the application of NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) *i.e.,* T_9 recorded significantly the highest herbage yield in the main crop (39.96 t ha^{-1}) and ratoon (19.37 t ha^{-1}). The lowest fresh herbage yield per hectare was obtained in T_7 applied with FYM (10 t ha^{-1}) alone (22.92 t ha^{-1}) and in ratoon (10.76 t ha^{-1}). Similar trend was also reflected in total herbage yield of basil. Application of NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) *i.e.,* T_9 recorded significantly the highest total herbage yield (59.3 t ha^{-1}) while, the lowest value (33.7 t ha^{-1}) was recorded in T_7 applied with FYM alone.

Nutrients through chemical fertilizer is expected to be more available that reflect on its uptake by plants leading to enhance the growth and yield. On the other hand, combined application of organic manure along with inorganic fertilizer regulated the supply of nutrients which in turn increased the yield (Merestala 1996). Similar findings were also reported by Mohamad *et al.* (2014) in *Ocimum basilicum*.

Essential oil content

Essential oil content plays a key factor in selecting the "adequate" combination of fertilizers in sweet basil cultivation. Application of different levels of FYM, bio-fertilizers and inorganic fertilizer on essential oil content (%) in the main crop and ratoon showed a significant difference (Table 3). Application of recommended NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) recorded maximum essential oil content (0.48 and 0.45 %) whereas the lowest essential oil content was recorded with recommended dose of FYM alone in T_7 (0.31 and 0.17%) in the main crop and ratoon, respectively. The content of soil nutrient enhanced with application of organic manure, that had positive effect on the growth parameters, herbage and oil yield (Khalid *et al.* 2006).

Oil yield

Oil production is the most important parameter in basil farming. The results of different levels of N through FYM, bio-fertilizers and inorganic fertilizer on oil yield of main crop and ratoon recorded during the two years of the field experiment showed a significant increase in oil production which can be attributed to the increase of nitrogen doses either through organic or inorganic form (Table 3). In the present study, oil yield per hectare increased with the increase of FYM doses, but with application of NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) recorded maximum oil yield in the main crop (199.7 kg ha^{-1}) and in ratoon (107.58 kg ha^{-1}). The lowest oil yield per hectare was obtained in T_7 applied with FYM

Table 3. Effect of different levels of N applied through FYM, inorganic fertilizer and bio-fertilizers on fresh herb yield (t ha^{-1}) of basil (*Ocimum basilicum* L.)

Treatments	Pooled mean					
	Fresh herb yield(t ha^{-1})		Essential oil content(%)		Oil yield(kg ha^{-1})	
	Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T_1	29.62^{D}	14.18	0.42^{C}	0.32^{D}	128.7^{D}	61.10^{D}
T_2	32.78^{C}	15.45^{C}	0.45^{B}	0.41^{C}	152.6^{C}	84.02^{C}
T_3	27.06^{EF}	12.91^{E}	0.35^{D}	0.23^{F}	97.4^{E}	40.90^{EF}
T_4	29.51^{D}	14.19^{D}	0.40^{C}	0.25^{E}	126.2^{D}	48.28^{E}
T_5	25.47^{F}	11.54^{F}	0.35^{D}	0.22^{FG}	90.2^{E}	35.81^{FG}
T_6	27.70^{E}	12.54^{E}	0.34^{D}	0.21^{G}	97.6^{E}	38.91^{EF}
T_7	22.92^{G}	10.76^{G}	0.31^{E}	0.17^{H}	73.8^{F}	26.94^{G}
T_8	36.83^{B}	17.25^{B}	0.46^{AB}	0.43^{B}	177.9^{B}	96.13^{B}
T_9	39.95^{A}	19.37^{A}	0.48^{A}	0.45^{A}	199.7^{A}	107.58^{A}
Mean	30.21	14.25	0.39	0.30	127.1	59.96
CV (%)	3.07	1.67	2.75	3.41	3.81	10.17
LSD (P<0.05)	1.61	0.39	0.018	0.017	8.39	10.55

Legend: FYM=Farm Yard Manure; Rec.=Recommended; BF=Bio-fertilizer

(10 t ha^{-1}) alone in the main crop (73.8 kg ha^{-1}) and in ratoon (26.94 kg ha^{-1}). Highest total oil yield was observed in T_9 applied with NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) and the lowest total oil yield was recorded in T_7 applied with FYM alone. Integrated nutrient management improve the chemical, physical and biological soil proprieties that reflect positively on plant growth and oil yield (Patra *et al*. 2000). These results are similar to the observation of Zeinab (2005), Dadkh (2012) and El-naggar *et al*. (2015).

Oil quality

The most important volatile molecules identified in basil essential oil are methyl chavicol as phenolic compound and linalool as monoterpene (Mondello *et al*. 2002) and Sajjadi (2006). The quality standard of the essential oil in basil is determined by polyphenols concentration (Toor 2006). Comparing the integration peaks, there was a significant difference in methyl chavicol percentage within the treatments. The results in (Table 4) showed that T_9 applied with NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) recorded the highest percentage of methyl chavicol in the main crop of 2015 (52.3%) while, in the main crop of 2016, application of FYM (10 t ha^{-1}) +100% recommended N through FYM + bio fertilizers *i.e.,* T_2 recorded maximum methyl chavicol percentage (63.78%). In ratoon, application of FYM (10 t ha^{-1}) + 100% recommended N through FYM + bio fertilizers recorded the highest methyl chavicol percentage (59.39 and 59.67%) during first and second year, respectively. The lowest percentage of methyl chavicol was recorded with T_7 (40.05 and 46.2%) in main crop and in ratoon (40.22 and 41.49%) of 2015 and 2016, respectively.

Linalool content increased with dosage of nutrients application as shown in (Table 6). Application of NPK (160:80:80 kg ha^{-1}) + FYM (10 t ha^{-1}) *i.e.,* T_9 recorded the highest percentage of Linalool in the main crop (25.29 and 22.88%) and ratoon (26.59 and 25.19%). While, the lowest Linalool percentage was recorded in T_7 of the main crop (19.20 and 15.20%) and ratoon

Table 4. Content of principle ingredient in basil essential oil (%) as influenced by different levels of N applied through FYM, bio-fertilizers and inorganic fertilizer

Treatments	Methyl chavicol (%)				Linalool (%)			
	2015		2016		2015		2016	
	Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon	Main crop	Ratoon
T_1	45.49	43.84	60.07	50.23	20.01	21.46	23.06	20.19
T_2	49.39	59.39	63.78	59.67	22.3	20.07	21.37	23.48
T_3	41.42	45.60	57.57	50.15	20.7	19.08	20.76	19.60
T_4	50.83	59.23	62.92	55.38	21.13	20.14	21.11	22.71
T_5	40.39	42.28	56.08	43.28	19.56	18.43	19.81	17.67
T_6	46.06	52.66	59.67	51.22	20.49	21.16	17.59	20.25
T_7	40.05	40.22	46.20	41.49	19.20	15.20	15.28	16.25
T_8	42.5	54.60	49.52	53.90	23.44	21.47	22.22	24.22
T_9	52.31	45.50	52.62	44.17	25.29	22.88	26.59	25.19

(15.28 and 16.25%) during 2015 and 2016, respectively. Secondary metabolism such as phenolics increases in stress condition, this may justify the highest percentage of methyl chavicol as a result of organic manure application (Sousa *et al.* 2005). Adding biofertilizers resulted in an increase in phenolics content because it promotes roots growth and making the nutrients in available form for plant absorption (Javanmardi *et al*. 2002). Thus microorganisms can fix N_2 and supply it to the plant they synthesis siderophores which play a key role for solublization of minerals such as phosphorus and iron which become readily available for plants.

The outcome of the present investigation revealed that the maximum fresh herbage yield, essential oil content, oil yield and its best quality was obtained with application of recommended FYM (10 t ha^{-1}) + recommended NPK (160:80:80 kg ha^{-1}) for both main as well as in ratoon basil crop. Addition of bio-fertilizers also increased the content of principle ingredient in basil essential oil (methyl chavicol and linalool). Hence, the incorporation of full dose of recommended FYM along with 50% of recommended N through inorganic fertilizer as basal and the remaining fifty per cent as top dressing at 45 days after transplanting may be recommended for basil crop to realize higher herbage and oil yield and better oil quality in sweet basil.

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Annual and monthly rainfall trend in plantation and spice farming Western Ghats districts

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Abstract

Rainfall analysis of important plantation and spices producing districts such as The Nilgiris (Tamil Nadu), Kodagu (Karnataka) Idukki (Kerala) and Wayanad (Kerala) with 100 years data (1901 to 2000) obtained from the India Meteorological Department (IMD), Pune indicated that mean annual rainfall were 1839.7 mm, 2715.7 mm, 2979.4mm and 3381.0 mm with a coefficient of variation (CV) of 16.0%, 17.0%, 25.8% and 19.6%, respectively. The contribution of southwest monsoon(June-September) to the annual rainfall in these districts were 80.3% (Wayanad), 78.9% (Kodagu), 65.2% (Idukki) and 56.3% (The Nilgiris) with corresponding CV of 24.1%, 20.6%, 32.5%, and 24.6%, respectively. The declining trend in mean annual rainfall was noticed for Idukki, Wayanad and The Nilgiris, whereas, for Kodagu, it was stable. The change was significant in Wayanad and The Nilgiris. Similar trend was also observed for the southwest monsoon rainfall. The maximum decline in annual and southwest monsoon rainfall was noticed in The Nilgiris followed by Wayanad. Pre and post monsoon rainfall receipts were comparatively less with high inter-annual variations. The pre-monsoon (March-May) receipt and its coefficient of variation (CV) was 252.4 mm & 20.6% (Kodagu), 360.9 mm & 36.5% (Idukki), 251.7 mm & 36.6% (The Nilgiris) and 274.2 mm & 54.2% (Wayanad) 252.2 mm. The post monsoon (October-December) rain was maximum in Idukki 548.1 mm (CV 27.9%) followed by The Nilgiris 503.4 mm(CV 31.3%), Wayanad, 333.1 mm(CV 37.8%) and Kodagu 310.5 mm (CV 32.7%). In all these districts there was a declining trend in the pre-monsoon rain with maximum decline in The Nilgiris. Similar declining trend was also observed in post-monsoon rain except for The Nilgiris, where the trend has been increasing. Overall, the study gives an indication that there was a spatial and temporal variation in rainfall amounts. The maximum decline in annual rainfall and the southwest monsoon was observed in The Nilgiris and Wayanad. July was the rainiest month in all the districts studied. Significant negative trend was asscoaited with The Nilgiris for January, May, June, July and August months. Whereas, in Kodagu, no significant trend was observed for mean monthly rainfall, except for August. In Idukki, significant negative changes were noticed for January, March, October and December rainfall. Monthly rainfall of January, March, April and July monthly rainfall were showed significant negative trend in Wayanad,. These negative trends across important plantation and spices producing districts of the Western Ghats would affect not only the agricultural economy of this sector but also water resources.

Keywords: annual and monthly rainfall trend, rainfall analysis, plantation and spice crops, western ghats districts

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Introduction

Western Ghats (WG) in India are internationally recognized as a region of immense global importance for the conservation of biological diversity, besides striking geological, cultural and aesthetic values. The WG Mountains are considered older than the Himalayas. A significant characteristic of the WG is the exceptionally high level of biological diversity and endemism. The entire mountain chain is recognized as one of the world's eight 'hottest hotspots' of biological diversity along with Sri Lanka. The forests of the WG include some of the best representatives of non equatorial tropical evergreen forests in the world (http://whc.unesco.org/en/list/1342). The WG constitute a practically unbroken hill chain (with the exception of the Palakkad Gap) or escarpment running roughly in a north-south direction, for about 1500 km parallel to the Arabian sea coast, from the river Tapi (about 21^o 16' N) down to just short of Kanyakumari (about 8^{o}19'N) at the tip of the Indian peninsula. The high ranges of the WG are crucial for the security of water resources of the peninsular India (WGEEP 2011), runs through Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The definition of WG and detailed boundaries are described in the report of the Western Ghats Ecology Expert Panel (WGEEP 2011). The district boundaries do not, by and large, coincide with limits of WG. The majority of districts also include either west coast or western peninsular tract regions along with WG areas. Only four districts *viz*., Kodagu from Karnataka, The Nilgiris from Tamil Nadu, Wayanad and Idukki from Kerala are fully in the Western Ghats region. These districts contribute significantly to the plantation and spice economy of the country and houses main plantation crops like tea, coffee, rubber, and spice crops such as cardamom, black pepper and ginger. As these crops are mostly grown as rainfed, analysis of rainfall and identification of trend is essential for designing proper crop management plans in the light of current climatic change.

Materials and methods

Four exclusive WG districts *viz*., Kodagu from Karnataka, The Nilgiris from Tamil Nadu, Wayanad and Idukki from Kerala were selected for the study. These are high altitude districts have dense forest cover and enjoy higher rainfall. The altitude of Wayanad district is 700 to 1,200 masl lies in the latitude between 11°27' and 15°58' N and the longitude 75°47' and 70° 27' E. Idukki's mean altitude is 1,200 m but many peaks rise above 2000masl and the district lies between 9°15' and 10°2' N and 76°37' to 77°25' E. The Nilgiris altitude varies between 300 m and 2,789 masl situated between 11°08' to 11°37' N and 76°27' to 77°4' E longitude. Kodagu has the lowest elevation range between 900 to 1,750 masl located between 11°56' to 12°56' N latitude and 75°22' to 76°11' E longitude. The rainfall data of these districts for hundred years (1901 to 2000) were purchased from IMD, Pune and used for rainfall analysis.

A non-parametric Mann-Kendall test was used for the detection of rainfall trends (Mann, 1945; Kendall, 1975). Test was performed using free trial version of XLSTAT software. The Mann-Kendall Statistic (S) measures the trends of rainfall series over time. Positive values indicate an increase in constituent concentrations over time, whereas negative values denote a decrease in constituent concentrations over time. The strength of the trend is proportional to the magnitude of the Mann-Kendall Statistic (*i.e*., large magnitudes indicate a strong trend). If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple non-parametric procedure developed by Sen (1968a and b). According to this test, the null hypothesis H0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H1, which assumes that there is a trend at P d"0.05.

Results and discussion

Major plantation and spice crops like tea, coffee; black pepper and cardamom are produced in higher elevation of the WG districts where their relative spread and yield are high compared to lower elevation areas or plains. These crops used to grow under rainfed condition as the rainfall receipt was high and distribution also was good. The yield of these crops now often fluctuates mainly due to higher inter-annual variability in rainfall. Results of study conducted to find out the rainfall trend of potential plantation and spice producing WG districts *viz*., Idukki and Wayanad in Kerala, The Nilgiris in Tamil Nadu and Kodagu (Coorg) in Karnataka are presented and discussed here.

The Nilgiris

Mean annual rainfall was 1839.7mm (Table 1) with a coefficient of variation of 16.0%. Monthly rainfall pattern from May through November has received above 100mm with July being the rainiest month (366.9mm) with its high variability (43.5% C.V.) contributes 19.95% to annual rainfall. The rainfall from the southwest and northeast monsoons as well as summer rainfall were correspondingly 1035.7mm, 503.4mm, 251.7mm that accounts 56.3%, 27.36%, 13.69% of annual rainfall, respectively. Mann-Kendall Statistics (S) and Sen's slope value have shown that there was a negative trend for monthly rainfall except in November and December. The annual rainfall also manifested a negative trend. The value of 'p' presented in the Table 1 hinted that there exists a significant trend for monthly rainfall of January, May, June, July, August as well as annual rainfall. Raju *et al*. (2013) have classified The Nilgiris climate as semi-arid to humid type. Previously, Manorama *et al*.(2007) and Manivannan *et al*. (2016) examined The Nilgiris rainfall data for crop planning but not looked into the trend identification. Manorama *et al*.(2007) analyzed thirty years (1971 to 2000) observed rainfall data and suggested appropriate planting time for root crops like potato, cabbage and carrot during the third week of April and the end of August following crop rotation. Manivannan *et al*. (2016) stated that a major part of The Nilgiris is covered under forest (56%) followed by plantation

Table 1. Rainfall statistics, Mann-Kendall and Sen's slope estimates for The Nilgiris, Tamil Nadu

Variable	Minimum	Maximum	Mean	Std. deviation	Contribution %	Kendall's tau	Mann-kendall Statistics (S)	Variance(S)	p-value (Two-tailed)	Sen's slope
Jan	0.0	217.1	33.7	40.8	1.83	-0.172	-850.00	112666.00	0.011	-0.181
Feb	0.0	124.4	23.5	31.3	1.28	-0.040	-194.00	112404.67	0.565	-0.006
Mar	0.0	246.6	30.0	35.3	1.63	-0.028	-136.00	112737.33	0.688	-0.023
Apr	12.3	211.2	82.7	42.0	4.50	-0.052	-257.00	112740.33	0.446	-0.113
May	38.6	402.4	139.0	75.1	7.56	-0.253	-1251.00	112747.00	0.0002	-0.674
Jun	79.2	525.2	229.8	91.5	12.49	-0.136	-673.00	112749.00	0.045	-0.640
Jul	68.8	1243.3	366.9	159.8	19.95	-0.304	-1504.00	112748.00	< 0.0001	-1.980
Aug	71.6	653.6	258.0	106.4	14.02	-0.146	-721.00	112749.00	0.032	-0.650
Sep	44.2	365.2	181.0	70.4	9.84	-0.081	-403.00	112747.00	0.231	-0.307
Oct	75.7	571.0	248.2	90.2	13.49	-0.061	-304.00	112746.00	0.367	-0.292
Nov	13.2	554.7	180.5	111.2	9.81	0.027	134.00	112750.00	0.692	0.127
Dec	0.0	323.4	74.7	68.7	4.06	0.075	372.00	112739.33	0.269	0.209
Annual	1252.5	2797.8	1839.7	295.2	100.00	-0.383	-1895.00	112749.00	< 0.0001	-5.711

(20%) like tea, coffee and the remaining areas are used for vegetables. They also stressed that many places experience sever water scarcity and moisture stress during summer months due to frequent dry spells even during monsoon periods that adversely affects the productivity of plantations and vegetable crops in this region. They also strongly advocated strengthening water harvesting structures to capture excess rainfall received between 20th and 45th weeks and utilize for farming.

Kodagu

Mean annual rainfall of this district was 2715.7mm (Table 2) with 17.0% C.V. Monthly rainfall pattern signaled that receipt was less during winter and summer months and July is considered the rainiest month (876.6mm) with a coefficient of variation of 34.8%. The rainfall amounts from southwest and northeast monsoons as well as summer rainfall were 2143.1mm, 310.5mm, 252.4 mm that respectively accounts 78.9%, 11.4%, 9.3% of annual rainfall. The rainfall receipt between May and October was more than 100 mm per month. Sufficient soil moisture would be available for crop production during these months. Mann-Kendall Statistics (S) and Sen's slope analysis have indicated that there was a positive trend in annual rainfall. Although few months showed negative trend in monthly rainfall, the 'p' values proved that as such there was no significant trend in monthly rainfall except for August where 'p' value was less than 0.05%. Raju *et al*. (2013) have classified the Kodagu climate as per-humid to humid type. Increasing rainfall trend was also reported by Mallappa *et al*. (2015) for Kodagu district. The district is popular for cardamom and coffee + black pepper cropping system and contributes substantially for national production. Ankegowda *et al*. (2010) have identified the length of growing period for this region between 21st and 43rd week (21st June to 28th November) with more dependable rainfall with lesser C.V. and suggested crop production operations to be carried out during this period for various crops.

Table 2. Rainfall statistics, Mann-Kendall and Sen's slope estimates for Kodagu, Karnataka

Variable	Minimum	Maximum	Mean	Std. deviation	Contribution %	Kendall's tau	Mann-kendall Statistics (S)	Variance(S)	p-value (Two-tailed)	Sen's slope
Jan	0.0	41.0	4.7	7.9	0.17	-0.070	-326.00	108554.00	0.324	0.000
Feb	0.0	72.3	5.0	10.3	0.18	-0.047	-220.00	109261.33	0.508	0.000
Mar	0.0	130.6	18.5	20.8	0.68	-0.078	-386.00	112732.67	0.252	-0.038
Apr	0.8	175.0	81.6	39.6	3.00	0.002	11.00	112740.33	0.976	0.002
May	43.6	470.1	152.3	90.6	5.61	-0.025	-123.00	112747.00	0.716	-0.071
Jun	144.9	959.4	513.9	193.8	18.92	0.118	586.00	112750.00	0.081	1.184
Jul	196.1	2290.5	876.6	305.8	32.28	-0.036	-178.00	112750.00	0.598	-0.518
Aug	196.1	1316.3	530.7	214.4	19.54	0.240	1186.00	112750.00	0.000	2.197
Sep	58.8	518.3	221.9	98.9	8.17	0.102	505.00	112749.00	0.133	0.523
Oct	37.4	411.7	207.5	77.4	7.64	-0.069	-342.00	112750.00	0.310	-0.295
Nov	0.0	327.6	83.6	64.8	3.08	-0.058	-288.00	112750.00	0.393	-0.177
Dec	0.0	225.0	19.4	29.7	0.71	0.023	114.00	112132.00	0.736	0.000
Annual	1728.7	4659.1	2715.7	463.6	100.00	0.119	590.00	112750.00	0.079	2.549

Idukki

Idukki's mean annual rainfall was 2979.4mm (Table 3) with very high percentage of C.V. of (25.8%). Highest rainfall among months was received by July (673.7 mm) with 45.7% C.V. The monthly rainfall between May and October was above 100 mm and contribution to annual rainfall was maximum (22.61%) for July followed by June 18.92% and August (14.77%). The rainfall from southwest and northeast monsoons as well as summer rainfall were 1943.9mm, 548.1mm, 360.9mm that accounted 65.2%, 18.4%, 12.1% of annual rainfall respectively. Mann-Kendall Statistics (S) and Sen's slope results have indicated that there was a negative trend in monthly and annual rainfall except August (Table 3) and the trend was significant for months of January, March, October and December with 'p' less than 0.05%. Raju *et al*. (2013) have classified the Idukki's climate as Per-humid to humid type. Krishnakumar and Rao (2006) have analysed the long term rainfall data (1871–2000) of Kerala and found that the failure of northeast and pre-monsoon rainfall lead to droughts in 65% of the years during summer that has affected the most plantation crops and they attributed this to man-made interventions into the ecological balance particularly during the last 50 years. Krishnakumar & Rao (2008) have argued that the monthly rainfall over Kerala for the period 1871 to 1994 showed an increasing tendency during October and November but a decreasing trend was shown by December. Similar trend was more evident since 1961 onwards. Archana *et al*. (2014) have noticed a decreasing monthly and annual rainfall trend in Kerala which they attribute to anthropogenic green house gas (GHG) emissions due to increased fossil fuel use, land-use change due to urbanisation and deforestation, proliferation in transportation associated atmospheric pollutants. Murugan *et al*. (2000; 2009; 2011) have reported the changes in rainfall trends of this region and discussed possible negative impacts on crops and plants as well as ecosystem hydrology because cardamom, coffee, tea and native forest plants are highly sensitive to precipitation changes.

Table 3. Rainfall statistics, Mann-Kendall and Sen's slope estimates for Idukki, Kerala

Variable	Minimum	Maximum	Mean	Std. deviation	Contribution %	Kendall's tau	Mann-kendall Statistics (S)	Variance(S)	p-value (Two-tailed)	Sen's slope
Jan	0.0	177.2	22.7	32.7	0.76	-0.197	-963.00	112335.67	0.004	-0.130
Feb	0.0	144.5	22.0	25.0	0.74	-0.090	-446.00	112676.67	0.185	-0.061
Mar	0.0	130.4	40.6	29.4	1.36	-0.137	-679.00	112742.33	0.043	-0.189
Apr	17.1	324.2	119.2	51.5	4.00	-0.008	-41.00	112745.00	0.905	-0.010
May	48.6	552.3	201.1	117.4	6.75	-0.047	-235.00	112749.00	0.486	-0.200
Jun	148.2	1621.9	563.8	266.3	18.92	-0.057	-282.00	112750.00	0.403	-0.669
Jul	172.6	1812.8	673.7	307.9	22.61	-0.095	-471.00	112749.00	0.162	-1.458
Aug	116.3	1387.1	440.2	201.6	14.77	0.029	144.00	112748.00	0.670	0.282
Sep	48.4	673.2	266.2	143.2	8.93	-0.029	-144.00	112750.00	0.670	-0.202
Oct	35.4	825.0	306.1	116.0	10.27	-0.141	-698.00	112750.00	0.038	-0.833
Nov	22.5	407.6	183.3	89.6	6.15	-0.084	-416.00	112750.00	0.216	-0.395
Dec	0.0	254.8	58.7	55.7	1.97	-0.135	-667.00	112744.33	0.047	-0.294
Annual	1597.3	5000.3	2979.4	768.6	100.00	-0.050	-246.00	112750.00	0.466	-2.073

Wayanad

Annual rainfall of Wayanad district varied between 2321.2 mm and 6142.0mm with a mean of 3381.0mm (Table 4) having the second lowest C.V. of 19.6% among the districts studied . Mean monthly rainfall of July was the highest (1131.3mm) with 41.4% C.V. that contributed 33.46% to the annual rainfall. The contribution of June and August months rainfall were 21.53% and 18.40% respectively to the annual rainfall. The rainfall from southwest and northeast monsoons and summer rainfall were 2716.6mm, 333.1mm, 274.2mm that shared 80.3%, 9.85%, 8.11% of the annual rainfall, correspondingly. More than 100 mm rainfall has been received during May to October months. Mann-Kendall Statistics (S) and Sen's slope trend have indicated that there was a significant negative trend in monthly rainfall for January, March, April, July. The annual rainfall recorded 'p' values less than critical 0.05%. Raju *et al*. (2013) have classified the Wayanad climate as Per-humid to moist sub-humid type. Rao & Krishnakumar (2005) have indicated that there was no change in the onset of monsoon over Kerala (1st June ± 7 days) over a period of time (1871-2004), and only 28.2 percent of the years only fell under early or late monsoon years. Further, it was also noticed that if the monsoon was early that season would receive deficit rainfall, and no trend was seen when the monsoon was late. They also reported that there was decline of 6.8% in annual rainfall over the period which was more evident in monsoon rainfall since the last sixty years. Similar negative trend for the district was reported by Sushant *et al*. (2015). In another study by Kumar & Srinath (2011) showed that weakening of the early phase of the southwest monsoon precipitation; increasing polarisation of daily rainfall and more frequent heavy rainfall days that hastened maturation of a variety of crops. Gaetaniello *et al*. (2014) have observed that the variability in rainfall was more influential than the air temperature fluctuation in this district. During the study period (1951 to 2008), the monsoon rainfall decreased, while maximum and minimum daily temperature increased and farmers perceived

Table 4. Rainfall statistics, Mann-Kendall and Sen's slope estimates for Wayanad, Kerala

Variable	Minimum	Maximum	Mean	Std. deviation	Contribution %	Kendall's tau	Mann-kendall Statistics (S)	Variance(S)	p-value (Two-tailed)	Sen's slope
Jan	0.0	67.6	6.6	12.9	0.20	-0.165	-676.00	92420.67	0.026	0
Feb	0.0	77.3	8.4	14.2	0.25	-0.061	-260.00	97517.33	0.407	0
Mar	0.0	129.0	20.9	24.0	0.62	-0.149	-712.00	108916.00	0.031	-0.092
Apr	3.7	217.3	88.3	44.1	2.61	-0.185	-898.00	109416.00	0.007	-0.42
May	19.7	658.8	165.0	136.3	4.88	-0.056	-271.00	109417.00	0.414	-0.164
Jun	91.6	1583.3	728.0	294.0	21.53	-0.131	-635.00	109417.00	0.055	-2.102
Jul	222.4	3193.6	1131.3	468.9	33.46	-0.282	-1367.00	109415.00	< 0.0001	-5.869
Aug	134.1	1962.9	622.2	299.5	18.40	0.000	-1.00	109417.00	1.000	-0.002
Sep	27.0	700.5	235.2	146.7	6.96	-0.085	-414.00	109416.00	0.212	-0.578
Oct	34.9	523.8	213.8	101.0	6.32	-0.114	-554.00	109416.00	0.095	-0.67
Nov	0.0	316.0	96.3	76.0	2.85	-0.063	-303.00	109408.33	0.361	-0.171
Dec	0.0	144.4	23.0	31.0	0.68	-0.060	-281.00	107353.67	0.393	0.000
Annual	2321.2	6142.0	3381.0	664.0	100.00	-0.334	-1621.00	109417.00	< 0.0001	-9.417

that drought was the major climatic challenge to existing farming practices. Kandiannan *et al*. (2008) analysed the 26 years (1980–2005) rainfall of high rainfall tract of northern agroclimatic zone of Kerala and observed that coefficient of variations for monthly rainfall from April to November was less than 100% and it is considered more dependable rainfall for crop production in this region. They also reported that the rainfall receipt from December to March was less and crops would suffer for want of moisture and suggested for adequate soil water conservation measures. Krishnakumar *et al*. (2009) showed that there was a significant decreasing trend in southwest monsoon rainfall while increase in post-monsoon season over the State of Kerala.

Rainfall analysis of exclusive WG districts indicated that there was a temporal and spatial variation in rainfall receipt among these districts and high mean annual rainfall was

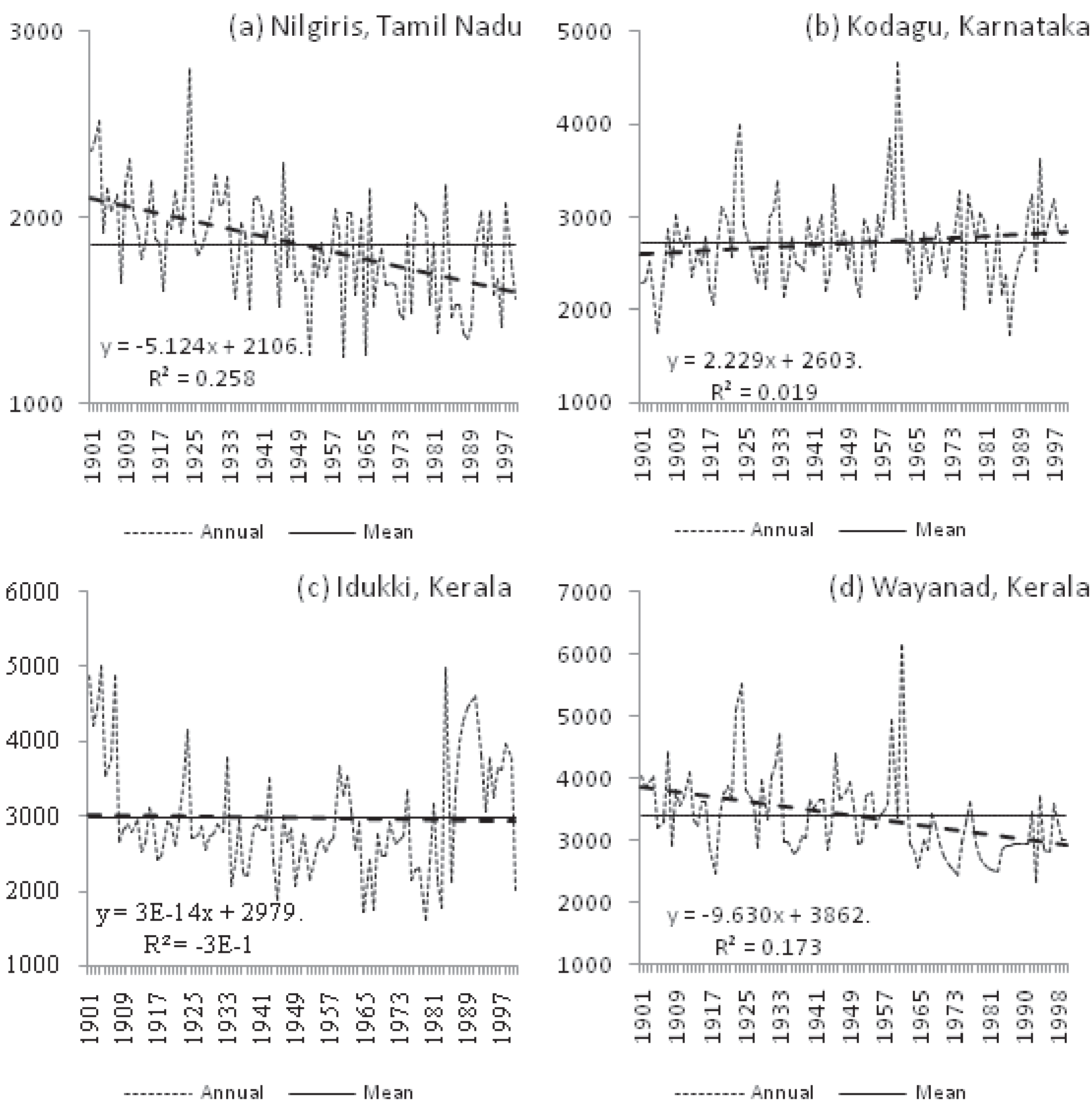

Fig. 1. Annual rainfall trend in exclusive Westen ghats districts (Nilgiris), (b) Kodagu, (c) Idukki, (d) Wayanad

received in Wayanad (3381.0 mm) followed by Idukki (2979.4 mm), Kodagu (2715.7 mm) and Nilgiris (1839.7). Decreasing trend in mean annual rainfall was noticed in Idukki, Wayanad and The Nilgiris, whereas in Kodagu the annual rainfall was stable (Fig. 1). The trend was significant for The Nilgiris and Wayanad. Similar trend was also observed for southwest monsoon rainfall. The decline in annual rainfall and the southwest monsoon was noticed for The Nilgiris and Wayanad. July was the rainiest month in all these districts. The negative trend was significant for January, May, June, July and August for the The Nilgiris, whereas in Kodagu no significant trend for mean monthly rainfall was observed except for August. At Idukki, significant negative changes were noticed for January, March, October and December months rainfall; whereas in Wayanad, January, March, April and July months rainfall showed significant negative trend. These negative trends in these important plantation and spices producing districts of the WG would affect the agricultural economy and hydrological systems.

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Effect of biofertilizers and organic supplements on the growth of black pepper rooted cuttings (*Piper nigrum* L.)

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Abstract

An experiment was conducted at the Cardamom Research Station, Kerala Agricultural University, Pampadumpara (Kerala) with an objective to study the effect of different biofertilizers (Phosphorus solubilizing bacteria, *Azospirillum* and Plant Growth Promoting Rhizobacteria Mix I) and organic supplements (fish extract and humic acid) on the growth of black pepper rooted cuttings. The results of the experiment indicated that application of Phosphorus solubilizing bacteria (5 g) along with *Azospirillum* (5 g), humic acid (0.2%) and fish extract (0.5%) was the best combination for the production of black pepper rooted cuttings with improved vegetative characters (plant height, number of leaves, number of roots, length of roots and leaf area) compared to theirindividual inoculation.This innovative information can be effectively utilized and advocated for the commercial production of black pepper rooted cuttings with lusty growth.

Keywords: black pepper, bio fertilizers, organic supplements, roots and shoot growth, nutrient management

The availability of quality planting material is one of the major issues that black pepper growers face in India. The conventional propagation methods have several limitations due to low success rate, poor rooting, spread of soil borne pathogens and poor survival rate of transplanted rooted cuttings (Rini *et al.* 2016). In order to overcome these problems, a technological intervention is needed to boost both the production and supply of quality planting materials. In the context of promoting organic cultivation, the use of biofertilizers for quality seedlings/cuttings production secures much importance because they are eco-friendly, low cost, capable of improving crop yields and quality sustainably. Biofertilizers improve growth rate of plants and soil health as they act as plant strengthners, phytostimulators, plant health improvers, and have the potential to fix nitrogen (Babalola 2014). The fertility of the soil is also restored by biofertilizers so that plants were better protected from getting any diseases (Amna 2010). Fish emulsions are used as a source of nitrogen during the early or vegetative stage of development to boost plant growth and also this has been documented to promote seedling growth in many crops (Murray & Anderson 2004). Humic substances are organic materials thatimprove soil structure, fertility and nutrient uptake (Trevisan *et al*. 2010). Hence, the present study was designed and conducted at the Cardamom Research Station, Pampadumpara, Kerala Agricultural University during 2017 to evaluate the efficacy of promising bio-fertilizers and select organic supplements on the production of quality black pepperrooted cuttings.

The most popular local black pepper variety '*Karimunda'*was chosen in the evaluation. This study comprised eight treatments including untreated control, sole and combined application of following bioagents and organic supplements.

	Treatments with dose
T_1	Phosphorus solubilizing bacteria(PSB) @10 g plant^{-1}
T_2	*Azospirillum* @10 g plant^{-1}
T_3	Plant Growth Promoting Rhizobacteria (PGPR Mix I) @10 g plant^{-1}
T_4	0.2% Humic acid @100 ml plant^{-1}
T_5	0.5% Fish extract @100 ml plant^{-1}
T_6	PSB @5 g plant^{-1} + *Azospirillum* @5 g plant^{-1} + 0.2% Humic acid @100 ml plant^{-1} + 0.5% Fish extract @100 ml plant^{-1}
T_7	PGPR Mix I @5 g plant^{-1} + 0.2% Humic acid @100 ml plant^{-1} + 0.5% Fish extract @100 ml plant^{-1}
T_8	Untreated control

Local *Karimunda* cuttings were planted in polythene bags size of 20 × 15 cm filled with potting mixture composed of garden soil, sand, and farm yard manure in 1:1:1 proportion. The potting mixture had an initial nutrient status of organic carbon (1.98%), N (0.704 mg/100 g) available P (4.01 mg/100 g) and K (43 mg/100 g) with a pH of 5.3. The treatments were superimposed and evaluated *in vivo* under greenhouse condition. Commercial formulations of phosphorus solubilizers ($5x10^7$ cfu), *Azospirillum* ($5x10^7$ cfu) and *PGPR* Mix I (Consortium of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *Bacillus sporothermodurans* each with 5×10^7 cfu) were obtained from the Department of Agricultural Microbiology, College of Agriculture, Vellayani. The humic acid containing 12% potassium humate was used in this study. Fish extract was prepared as per the standard procedure. Equal quantity of fish and jaggery was taken, sliced, mixed and kept in closed container with periodical stirring up to 30 days, after that the solution was strained through a muslin cloth and stored.

The experiment was conducted using Completely Randomized Design (CRD) with four replications. Five plants were kept in each replication.In addition to this fiveplants/ treatment were also maintained for destructive sampling to study the root characters. Talc based formulation of PSB, *Azospirillum*, PGPR Mix I, humic acid and fish extract individually and in combination were applied to the root zone of one month old black pepper cuttings grown in polythene bags. The treatments were given twice at fortnightly interval (when the plants were 30 and 45 days old).

Observations on the height, number of leaves, leaf area and root characters were recorded 60 days after second treatment application. The experimental soil (potting media) was analyzed for physicochemical properties like pH, organic carbon and available N, P and K content. The leaf chlorophyll content was estimated as per the protocol of Sadasivam & Manickam (1992). The data collected from the experimentwere processed statistically with appropriate statistical tool for the interpretation of the results.

There was no significant difference with respect to morphological characters before treatment application. Butgood improvement invegetative characterswas noted after the application of biofertilizers and organic supplements.Black pepper rooted cuttings responded well to combined inoculation of biofertilizers and organic supplements compared to individual inoculation and control (Table 1). Application of PSB along with *Azospirillum*, humic acid and fish extract (T_6) resulted increased plant height (98.66 cm), numbers of leaves (12.16), number of roots (13.50), root length (28 cm) and highest leaf area (63.18 cm^2) 60 days after second treatment application compared to all the other treatments. Similar increaseof growth was recorded in black pepper for combined inoculation of biofertilizers such as *Azospirillum*, Phosphobacteria and VAM (Kandiannan *et al*. 2000; Bopaiah & Khader 1989). In addition to this, fish emulsions have been reported to increase the nitrogen accessibility (Weinert *et al.* 2014). According to Chen & Aviad (1990) the application of humic substances increase root length and produce more secondary roots. As a result, the plants were capable of absorbing more available nutrients from the soil which in turn resulted better establishment and subsequent growth and development. Thus, the combined inoculation of PSB and *Azospirillum* along with humic acid and fish extractperformed best through improving the morphological characters of the cuttings compared to their individual application.

Total chlorophyll content was maximum in plants treated with PSB along with *Azospirillum,* humic acid and fish extract (0.64 mg/100 g) followed by the combined application of PGPR Mix I along with *Azospirillum*, humic acid and fish extract (0.60 mg/100 g). The least quantity of chlorophyll was observed in control plants (0.42 mg/100 g). This can be attributed to the increased uptake of nutrients leading to enhanced chlorophyll content. Pereira *et al.* (2015) reported that maize plants when inoculated with *Azospirillum* under different dosages of nitrogen enhanced the chlorophyll content. Our best treatment also includes *Azospirillum* as one component. This contributes to the increased chlorophyll content of the treated plants.

Nutrient status of the potting mixture 60 days after second treatment application (Table 2) showed that, readily available nutrient content of potting mixture was improved through the application of biofertilizers and organic supplements compared to control. Among the treatments, PSB along with *Azospirillum* humic acid and fish extracttreated soil showed higher levels of organic carbon (3.17%), available phosphorus (17.83 mg/100 g) and potassium (84.66 mg/100 g) whereas, available nitrogen was highest for combined application of PGPR Mix I along with *Azospirillum*, humic acid and fish extract (1.05 mg/100 g). Increased availability of nutrients in the potting mixture was attributed through combined application of biofertilizers and organics. Bio inoculants have had influence in increasing the organic carbon content of turmeric (Sumathi *et al*. 2011). Biofertilizers like *Azospirillum* and PSB were highly beneficial to plants through augmentation of nitrogen and phosphorus content in soil, thus making these two essential nutrients available to the plant and also produce phytohormones like auxins (Singh *et al*. 2011; Rocheli *et al*. 2015). In our experiment also treatments consisting of PSB along with *Azospirillum*, humic acid and fish extract (T_6) resulted in high available organic carbon, P & K compared to control which is responsible for increased growth parameters observed. The increase in P availability could be attributed to the application of PSB which produces organic acids that act as a chelating agent and thereby, releases P into the soil solution and making it more available resulted in improved root growth. These findings are in agreement with the findings of Naik & Hari babu (2007) and Sharma *et al.* (2009) in guava.

It is evident that, the combined application of PSB (5 g) along with *Azospirillum* (5 g), 0.2% humic acid (100 mL $plant^{-1}$) and 0.5% fish extract (100 mL $plant^{-1}$) followed by PGPR Mix I (5 g) along with 0.2% humic acid (100 mL $plant^{-1}$) and 0.5% fish extract (100 mL $plant^{-1}$) produced healthy black pepper rooted cuttings with good morphological characters than those of sole application of any of these biofertilizers and organics. Therefore, this technology could be effectively advocated to produce black pepper root cuttings with lusty growth in nurseries.

Table 1. Effect of biofertilizers and organic supplements on growth of black pepper rooted cuttings after second treatment application

Treatments	60 DAT				
	Plant height (cm)	Number of leaves	Number of roots	Length of roots	Leaf area (cm)
Phosphorus solubilizing bacteria (PSB)- 10 g plant^{-1}	76.50	10.33	12.83	21.00	48.45
Azospirillum- 10 g plant^{-1}	75.50	9.00	9.16	15.86	43.29
PGPR Mix I- 10 g plant^{-1}	73.83	10.00	9.83	17.16	46.02
Humic acid @2%	67.33	8.50	9.20	15.46	45.60
Fish amino acid @0.5%	70.66	8.83	6.26	11.83	36.98
Phosphorus solubilizing bacteria (PSB) 5 g plant^{-1} + *Azospirillum* 5 g plant^{-1} + Humic acid @2% + Fish amino acid @0.5%	98.66	12.16	13.50	28.00	63.18
PGPR Mix I 5 g plant^{-1} + Humic acid @2% + Fish amino acid @0.5%	79.50	10.66	10.16	36.00	48.91
Control	49.33	6.50	5.13	6.33	23.52
CD (P<0.05)	18.779	2.418	0.491	1.805	0.243
CV	14.352	14.409	3.027	5.425	0.320

Table 3. Effect of biofertilizers and organic supplements on nutrient status of potting mixture 60 days after second treatment application

Treatments	pH	Organic carbon %	Available N (mg/100 g)	Available P (mg/100 g)	Available K (mg/100 g)
Phosphorus solubilizing bacteria (PSB)- 10 g plant^{-1}	6.7	2.64	0.906	11.41	73.16
Azospirillum- 10 g plant^{-1}	6.5	2.63	0.900	13.63	74.83
PGPR Mix I- 10 g plant^{-1}	7.1	2.65	0.913	14.29	75.83
Humic acid @2%	6.3	2.63	0.903	11.35	68.83
Fish amino acid @0.5%	6.8	2.64	0.903	7.02	66.83
Phosphorus solubilizing bacteria (PSB) 5 g plant^{-1} + *Azospirillum* 5 g plant^{-1} + Humic acid @2% + Fish amino acid @0.5%	7.38	3.17	0.970	17.83	84.66
PGPR Mix I 5 g plant^{-1} + Humic acid @2% + Fish amino acid @0.5%	7.25	2.92	1.053	14.75	80.33
Control	5.5	2.01	0.706	3.56	46.00
CD (P<0.05)	0.444	0.061	0.024	0.206	5.356
CV	3.915	1.411	1.550	0.275	4.336

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Effect of biocontrol agents on production of rooted back pepper cutting by serpentine method

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Abstract

Availability of disease free quality planting material is a major limiting factor in black pepper cultivation. In order to meet the increasing demand and also to create awareness on good agricultural practices for healthy disease free planting material production to farmers, a nursery experiment was started with improved varieties of black pepper by adopting a non-chemical bio-intensive management strategy. Here solarization of potting mixture was the main concern followed my amending the solarized potting mixture with potential bioagents. The experiment was designed in a two factor CRD with four improved varieties and five treatments. Each treatment contains a combination of two bioagents with antifungal and nematicidal properties respectively. The common recommended fungicide Metalaxyl-Mancozeb (0.125%) and nematicide carbsosulfan (0.1%) was used as control. The treatments were incorporated individually into solarized potting mixture and planted with improved varieties used *viz*., IISR Girimunda, IISR Malabar Excel, IISR Shakti and IISR Thevam, The plants in each treatment were kept for multiplication by serpentine method with proper irrigation and phytosanitation. The results of plant growth and establishment in different treatments, showed that fortification of solarized potting mixture with *Trichoderma harzianum* + *Pochonia chlamydosporia* combination or combination of *Streptomyces* strains (Act 2+9) are significantly superior (35.46% and 21% respectively) for the production of healthy rooted planting material. IISR Malabar Excel and IISR Thevam produced the maximum number of plants from a single node cutting in treatment with *T. harzianum* + *P. chlamydosporia* (T1) (59 nos. and 51 nos. respectively) followed by IISR Malabar Excel with Act 2+9 and Act 5+9 (45 nos. each). So an average of 6-7 plants/month/cutting was produced in the potential treatment while it was only 3-4 plants in control. The advantage of the method is that, after solarization and fortification with respective bioagents, there is no need for further application of any fungicides, insecticides or any other nutrient spray as usually done. Thus the method of soil solarization followed by fortification of either with *T. harzianum*+ *P. chlamydosporia* or combination of *Streptomyces* strains *viz., Ketasatospora setae* (Act 2) and *S. tauricus* (Act9) is found suitable for the production of healthy quality planting material of high yielding varieties to meet the increasing demand of planting material with a C:B ratio of 1:2.

The demand for healthy planting material of high yielding black pepper varieties is on the increase and the country needs large quantity of quality planting material to meet the increasing demand. The present study was aimed to establish a model nursery to produce disease free healthy planting material of improved varieties of black pepper by creating awareness among farmers with good agricultural practices and by adopting non-chemical bio-intensive management strategies.

The experiment was conducted in collaboration with a farmer at Omasserry in Thamarassery Panchayat (Kozhikode district). Initially a nursery shed was constructed (24 m × 20 m) and roofed with white polythene sheet of 100 microns. Single node rooted plants of four released varieties of black pepper *viz*., IISR Girimunda, IISR Malabar Excel, IISR Shakti and IISR Thevam (indexed for viruses and raised under insect proof conditions at ICAR-Indian Institute of Spices Research, Chelavoor) was used as the source material.

Nursery mixture was prepared by mixing soil, sand and FYM in 1:2:1 and sterilized by solarization. Briefly, the nursery mixture prepared was made into small beds of size 3x1m in a place where there is direct exposure to sunlight. The bed was watered thoroughly and covered with polythene sheet of 100microns and sealed air tight and kept for solarization on 5th November till 25th December 2015.

Biocontrol agents such as *Trichoderma harzianum*, *Pochonia chlamydospori*a, and 3 promising *Streptomyces* sp. *viz*., *Streptomyces tauricus* (strain Act 9). *Streptomyces* sp. (strain Act 5) and *Ketosatospora setae* (strain Act 2) (Bhai *et al.* 2016) in different combinations were used as growth promoters as well as bioagents for incorporating into the nursery mixture.

The experiment was designed in a two factor CRD with four improved varieties of IISR and five treatments. The five treatments were T1- *T. harzianum* + *P. chlamydosporia*, T2- *Streptomyces* strains 2+9, T3- *Streptomyces strains* 5+9, T4- Metalaxyl-Mz+ Carbsosulfan and T5-control without any amendments. The individual treatments were incorporated with the solarized nursery mixture separately and filled in polythene bags (15 cm × 10 cm) @250 g bag^{-1}. *T. harzianum* and *P. chlamydosporia* were made in liquid form with water and added @100 mL (cfu 10^9 mL^{-1}) each to 100 kg potting mixture. *Streptomyces* spp. grown as broth culture in Nutrient broth and 100 mL (cfu 10^{10} mL^{-1}) mixed with 1 kg vermicompost and grown for 5 days (cfu10^8 mL^{-1})) and applied @1 kg 100 kg^{-1} potting mixture. The treatment imposed poly bags were arranged inside the nursery and planted with single node virus free (indexed) rooted cuttings as mentioned above and were allowed to grow by serpentine method.

When the number of rooted nodes in the serpentine reached around 10, the rooted middle cuttings were cut and separated leaving three plants at the tip and nucleus plant at the end and were kept for establishment to a 3-4 leaf stage in the same nursery. Five plants each were taken from each treatment and observed for biometric growth parameters. The biometric observations were recorded on height of the plant, fresh and dry weight of the plant, number of roots, root length and root biomass. The soil was analysed for the presence of targeted pathogens like *Phytophthora capsici* and nematodes (*Radopholus similis* and *Meloidogyne incognita*), pH and dehydrogenase activity (DHA).

The data were analyzed by using PROC ANOVA procedure of SAS 9.3. Least square means statements were used for mean separation.

After nine months of growth by serpentine method, the variety IISR Malabar Excel and IISR Thevam produced the maximum number of plants in T1 (*T. harzianum* + *P. chlamydosporia* (59 nos. and 51 nos. respectively) followed by T2 (Act 2+9) in case of Malabar Excel (45nos) and T3 (Act 5+9) (45 nos) in case of Thevam, from a single node cutting. An average of 6-7 plants/month/cutting was produced from these varieties with the treatment T1, while it was only 4 plants/month/ cutting in control. In case of IISR Girimunda, the performance was almost the same with all the three bioagent combinations when compared to Metalaxyl-Mz + Carbsosulfan and control. However, IISR Shakti showed comparatively lesser performance with bioagent combinations. The results of the study clearly showed the response of varieties to bioagents. In all cases, the number of plants produced with Metalaxyl-Mz + Carbsosulfan (T4) was comparatively lesser when compared to control (Table 1). The root system was also healthy in all treatments except for control where the root was not profusely grown. No disease of any kind was observed in any of the plants. Though there is no difference between varieties in fresh weight of the plant, the dry weight (Fig. 1) is significantly superior in treatment with *Streptomyces* strains (Act 2+9) and is at par with *T. harzianum* and *P. chlamydosporia*. Not much difference was observed in the number of leaves between treatments but, there is difference in the height of the plants (Fig. 2) where bioconsortia showed increased height when compared to Metalaxyl-Mz. + Carbsosulfan and control. Difference was observed in number of roots, root length, and root fresh and dry biomass (Tables 2 to 5). Since the nursery mixture was solarised and irrigation was limited to once in two days, there was no incidence of soil borne infections caused by *Phytophthora capsici*, *Sclerotium rolfsii* or nematodes (the common diseases otherwise observed in nurseries), in any of the treatments including control (Table 6). The pH of the soil in untreated plants ranged from 4.55-5.66. It is interesting to note that the pH of the soil is raised to neutral in treatments with *T. harzianum* + *P. chlamydosporia* where it ranged from 6.86-7.63. In the case of *Streptomyces* combinations the pH ranged from 4.85 to 6.85 (Table 6) and the dehydrogenase activity which reflects the total oxidative activity of soil microflora, (Liang *et al.* 2014) was unaffected by the incorporation of bioagents like *Trichoderma*, *Pochonia* or *Streptomyces* sp. (Table 6). So without the addition of external nutrients, the micro flora enriched solarized mixture supported the growth of plants as well as prevented the incidence of infection caused by nematodes, *Phytophthora* or any other soil borne pathogens of black pepper. This may be due to the increased microbial activity either through the production of IAA or other growth promoting traits including siderophore production which is observed in the case *Streptomyces* strains (Suseela Bhai *et al*. 2016).

Thankamani *et al*. (2005) reported the effect of *Pseudomonas fluorescens* (IISR-6) and *T. harzianum* (P-26) on the growth of black pepper rooted cuttings in the nursery. However, no

Table 1. No. of cuttings produced in nine months from a single plants

Treatments	IISR Girimunda	IISR Malabar Excel	IISR Shakthi	IISR Thevam	Sub plot mean	Increase over control (%)
T_1-*T. harzianum* + *P. chlamydosporia*	36.00	59.60	23.00	51.00	42.40	35.46
T_2-Act 2+9	36.00	45.60	32.00	38.00	37.90	21.08
T_3-Act 5+9	34.00	34.00	32.60	45.80	36.60	15.00
T_4-Metalaxyl-Mancozeb + Carbsosulfan	25.40	26.40	34.00	32.60	29.60	-5.43
T_5-Control	23.60	29.40	41.60	30.60	31.30	-
Main plot mean	31.00	39.00	32.64	39.60		
LSD (P<0.05)						
VT	0.87					
T	0.95					
V × T	1.90					

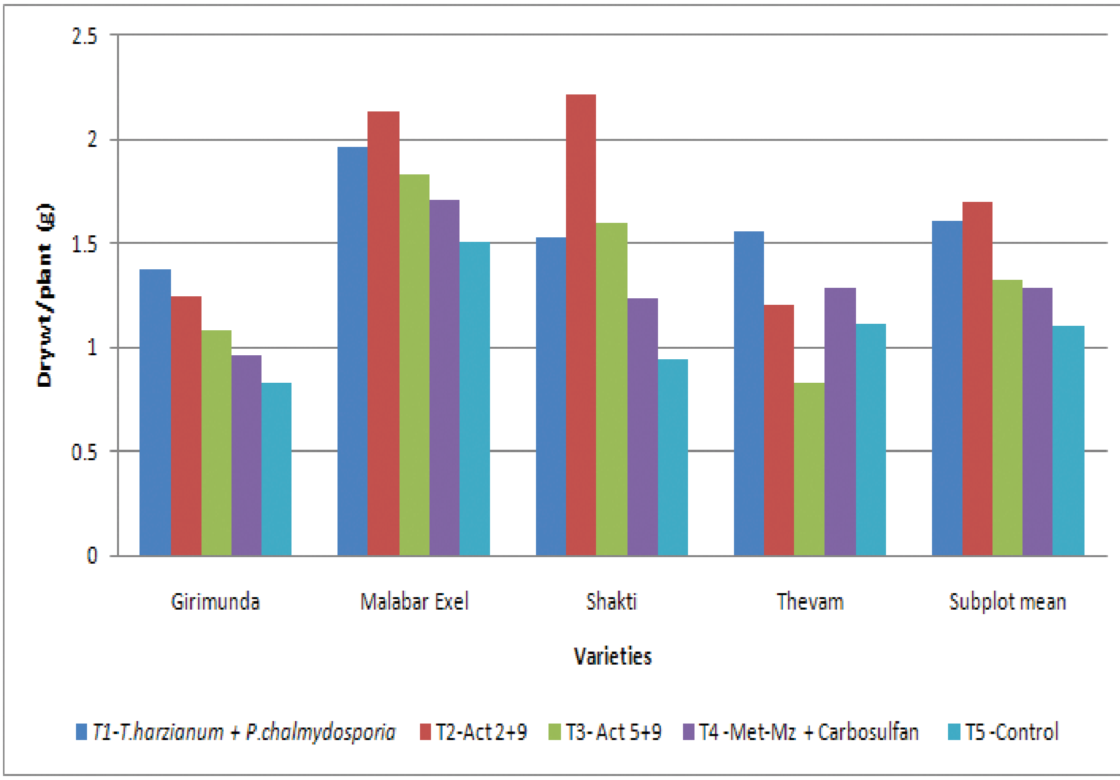

Fig. 1. Dry wt (g)/plant

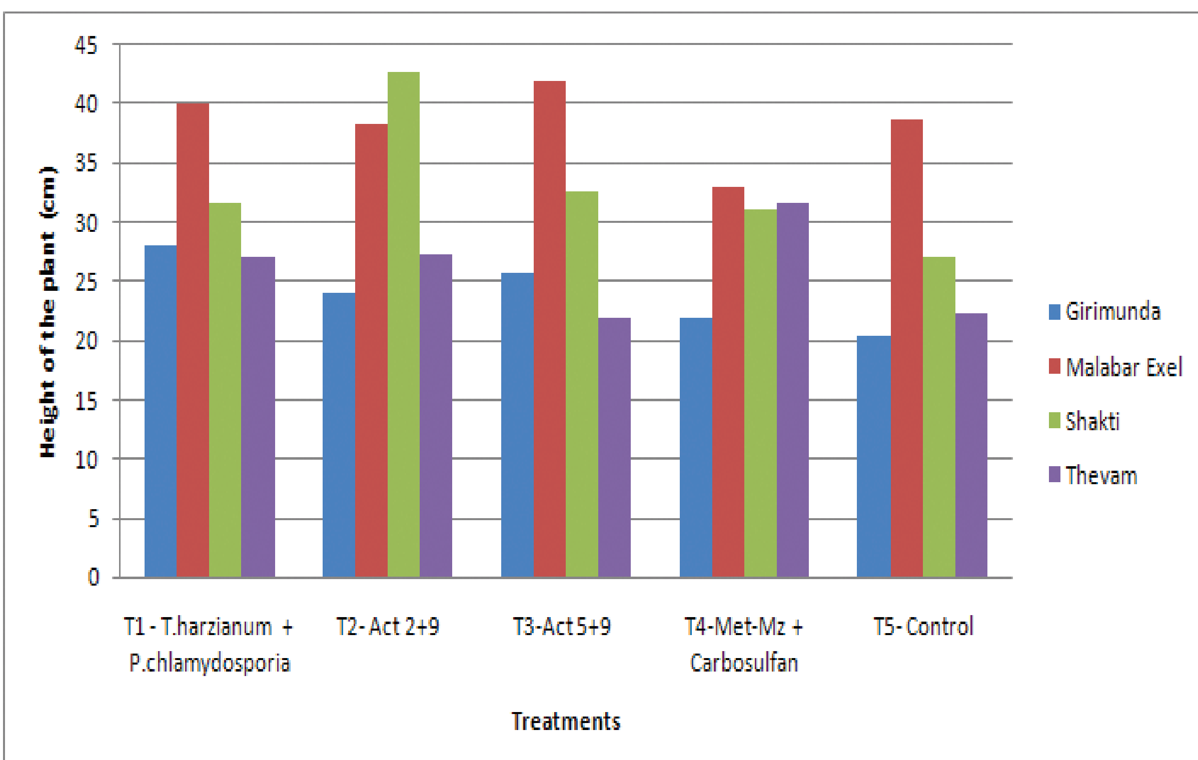

Fig. 2. Height of the plants

Table 2. Influence of treatments on number of roots

Treatments	IISR Girimunda	IISR Malabar Excel	IISR Shakthi	IISR Thevam	Sub plot mean
T1-*T. harzianum* + *P. chlamydosporia*	7.67	8.67	4.00	12.67	8.25
T2-Act 2+9	6.00	11.33	8.33	10.00	8.92
T3-Act 5+9	6.67	8.00	9.33	8.33	8.08
T4-Metalaxyl-Mancozeb + Carbsosulfan	6.33	7.33	5.00	8.00	6.67
T5-Control	8.67	6.33	5.33	7.33	6.92
Main plot mean	7.07	8.33	6.4	9.27	
LSD ($P<0.05$)					
V	2.02				
T	NS				
V × T	NS				

Table 3. Influence of treatments on root dry biomass (g)

Treatments	IISR Girimunda	IISR Malabar Excel	IISR Shakthi	IISR Thevam	Sub plot mean
T1-*T. harzianum* + *P. chlamydosporia*	0.99	0.62	0.52	0.97	0.78
T2-Act 2+9	0.93	0.98	0.57	0.54	0.76
T3-Act 5+9	0.51	0.50	0.3	0.40	0.54
T4- Metalaxyl-Mancozeb + Carbsosulfan	0.47	0.54	0.37	0.51	0.47
T5-Control	0.44	0.41	0.41	0.56	0.46
Main plot mean	0.67	0.61	0.52	0.6	
LSD ($P<0.05$)					
V	0.05				
T	0.14				
V × T	0.29				

Table 4. Influence of treatments on root length (cm)

Treatments	IISR Girimunda	IISR Malabar Excel	IISR Shakthi	IISR Thevam	Sub plot mean
T1-*T. harzianum* + *P. chlamydosporia*	31.67	36.33	19.00	22.33	27.33
T2-Act 2+9	29.00	32.67	21.00	24.33	26.75
T3-Act 5+9	26.67	26.67	24.67	26.00	26.00
T4- Metalaxyl-Mancozeb + Carbsosulfan	21.67	29.67	18.00	28.00	24.33
T5-Control	18.00	26.33	28.33	24.00	24.17
Main plot mean	25.4	30.33	22.20	24.93	
LSD ($P<0.05$)					
V	5.29				
T	NS				
V × T	NS				

Table 5. Influence of treatments on root fresh biomass (g)

Treatments	IISR Girimunda	IISR Malabar Excel	IISR Shakthi	IISR Thevam	Sub plot mean
T_1-*T. harzianum* + *P. chlamydosporia*	5.37	5.83	3.53	6.70	5.36
T_2-Act 2+9	4.37	7.07	3.83	4.23	4.88
T_3-Act 5+9	2.87	4.37	5.63	3.37	4.06
T_4- Metalaxyl-Mancozeb + Carbsosulfan	2.47	4.07	2.93	4.00	3.37
T_5-Control	2.97	3.47	3.30	3.97	3.43
Main plot mean	3.61	4.96	3.85	4.45	
LSD (P<0.05)					
V	0.54				
T	1.32				
V × T	NS				

Table 6. Effect of treatments on pH and Dehydrogenase activity

Treatments	IISR Girimunda		IISR Malabar Excel		IISR Shakthi		IISR Thevam	
	pH	DHA	pH	DHA	pH	DHA	pH	DHA
T_1- *T. ha* + *P. chal*	7.38	1.21	6.86	2.72	7.30	1.98	7.63	2.05
T_2- Act 2+9	5.56	3.57	4.85	2.74	5.43	2.19	6.72	2.22
T_3- Act 5+9	5.05	3.17	6.68	3.13	5.17	1.14	5.10	1.68
T_4- Met-Mz + Carbosulfan	6.46	2.52	5.44	1.98	4.81	0.99	6.33	1.10
T_5- Control	5.64	0.94	4.55	0.96	5.66	0.53	4.86	0.61
CD (P<0.05)	0.10	0.09	0.09	0.02	0.12	0.17	0.09	0.22

such reports are available for the combined use of *T. harzianum* and *P. chlamydosporia* for the production of rooted plants of black pepper, except for the individual use of *T. harzianum* against foot rot and *P. chlamydosporia* against slow decline diseases. The present study recommend soil solarisation along with the use of *Trichoderma* + *Pochonia* combination or combination of *Streptomyces* strains Act 2+9 for the production of healthy rooted planting material. The effect of solarized potting mixture on growth of black pepper rooted cuttings was reported earlier (Thankamani *et al*. 2007). Since both *Phytophthora* and nematodes are serious threats of black pepper, the treatment combinations are made in such a way that the combination contain one antagonist against *Phytophthora* and another antagonist against nematode. Similar work was reports for the use of consortia in planting material production. Consortia of *P. fluorescens* + *T. harzianum* + *Paecilomyces lilacinus* were used for the production of tomato seedlings for combating nematode infection (Mukhtar 2013) and *P. fluorescens* + *T. harzianum* for the production of nematode free papaya seedlings (Rae 2007). The promotive effects of *Pseudomonas* and *Trichoderma* were quite significant in growth promotion in tomato during nursery and crop growth stages (Kumar *et al.* 2007). Similarly, Mukhtar (2013) reported the biocontrol potential of *Pasteuria penetrans*, *P. chlamydosporia*, *P. lilacinus* and *T. harzianum* against *Meloidogyne incognita* in okra.

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Diversity in floral characters of monoecious nutmeg (*Myristica fragrans* Houtt.)

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Abstract

Floral diversity in monoecious type nutmeg reveals three types of flowers namely; pistillate, staminate and hermaphrodite flowers. The structure of hermaphrodite flowers in nutmeg is reported for the first time. The flowers are borne on the leaf axil, flowering habit of the three types of flowers are seen in cymes as well as solitary in the same tree. The gynoecium consists of single ovary with bifid stigma in the pistillate flowers and the androecium of staminate flowers has adnate 7-13 anthers. Intra flower variability is evident in case of hermaphrodite flowers. In hermaphrodite flower the androecium ranges with 1-4 anthers, in the form of fused filament or free filament or both; some anthers are fused with the gynoecium. Besides remnants of the stamen in the developed fruits of hermaphrodite flowers, staminodes are also observed in the flowers. Colour of all the three types of flowers are light creamy yellow, with thick gamosepalous perianth which bursts as bilobed, trilobed, tetralobed and pentalobed lobes during anthesis. Analysis of variance of trees for flower types and floral attributes like flower type, number of anthers, length of anthers, length of filaments and length of ovary are found to be highly significant. High coefficient of variation is recorded for hermaphrodite (183.84%) and pistillate (171.71%) flowers. The pollen viability of the hermaphrodite flowers are found less as compared to the staminate flowers. The percentage of pollen viability is 79.74 and 90.77 in hermaphrodite and male flower respectively. In the population studied, the occurrence of hermaphrodite flower in monoecious tree ranged from 0 - 10%.

Keywords: hermaphrodite flowers, intra floral variability, monoecious, *Myristica fragrans* Houtt., pollen viability

Nutmeg (*Myristica fragrans* Houtt.) (Myristicaceae) is an important tree spice, yielding two spices, namely, the nutmeg (dried seed) and the mace (dried aril surrounding the seed). Nutmeg is hitherto considered to be predominantly dioecious in nature (Flach 1966). However, of late this concept is undergoing a paradigm shift, as monoecious trees are being reported often across the country (Krishnamoorthy *et al.* 1996; Krishnamoorthy *et al.* 2012; Rema *et al.* 2014). Though some literature is available on the reproductive biology of dioecious nutmeg (Armstrong & Drummond 1986), there is no report available for monoecious nutmeg trees.

Here we attempt to study the floral diversity of monoecious nutmeg.

The study on sex differentiation and variability in monoecious nutmeg was carried out at ICAR-Indian Institute of Spices Research (IISR), Kozhikode during June to September 2015. Total of 53 trees of 18 year old were selected randomly from the germplasm maintained at ICAR IISR and were studied for sex of tree from December 2014 onwards. The sex of flowers were recorded in all the trees at monthly interval. Out of the 53 trees of the selected population 6 trees are found to be monoecious. These 6 monoecious trees are used in the present study.

Details of 6 monoecious trees conserved at ICAR-IISR, Chelavoor:

Plant number	Source	Nature of plant
C- 1	ICAR-IISR, Experimental Farm, Peruvannamuzhi	Seedling
C- 9	ICAR-IISR, Experimental Farm, Peruvannamuzhi	Seedling
C- 21	ICAR-IISR, Experimental Farm, Peruvannamuzhi	Seedling
C- 43	ICAR-IISR, Experimental Farm, Peruvannamuzhi	Seedling
C -45	ICAR-IISR, Experimental Farm, Peruvannamuzhi	Seedling
C -54	Farmers field Ankola	Seedling

Within the 6 monoecious trees observations on inter and intra floral variability in monoecious for anther length, number of anthers, filament length, ovary length and flower opening type were recorded. Total of 100 flowers / month were collected from each tree and observations were recorded for variability during peak flowering season June – September, 2015.

Pollen viability test was done using Acetocarmine staining method. Pollen viability estimated using glyceroacetocarmine (Marks 1954). The pollen viability percentage determined as the ratio of the number of viable pollen to the total pollen number.

ANOVA for the floral attributes were done using SAS 9.3 software.

Based on the observations made on the phenological measurements inter and intra flower variability in monoecious nutmeg flowers are prominent. Three types of flowers are recorded in monoecious trees namely, pistillate, staminate and hermaphrodite flowers. The structure of hermaphrodite in nutmeg is reported for the first time. The flowers are borne on the leaf axil, flowering habit of the three types of flowers are seen in cymes as well as solitary in the same tree. All the types of flowers were light creamy yellow colour in monoecious tree, with thick gamosepalous perianth which bursts as trilobed or bilobed (less frequent) lobes during anthesis as reported earlier (Armstrong & Drummond 1986). However, addition to this tetralobed and pentalobed are observed rarely in monoecious trees (Fig. 1). Tetralobed lobes are reported in *M. fatua*, this type of lobe opening helps in more access for insects (pollinators) to enter the flower (Sharma & Armstrong 2013). The androecium of staminate flowers consisted of adnate 7-13 anthers, with average of 9.30 anthers and 4.09 and 3.18 mm of anther length and filament length respectively, androecium with 8-10 anthers were reported earlier by Armstrong & Drummond (1986) in staminate flowers. The gynoecium consists of single ovary with a mean length of 5.28 mm with bifid stigma in the pistillate flowers (Tables 1 & 2). Intra flower variability is evident in case of hermaphrodite flowers. In hermaphrodite flower the androecium ranges with 1-4 anthers, in the form of fused filament or free filament or both; some anthers are fused with the gynoecium (Fig. 2); the length of the anther varies from 3-6 mm. Besides remnants of the stamen in the developed fruits of hermaphrodite flowers, staminodes are also observed in the flowers (Fig.

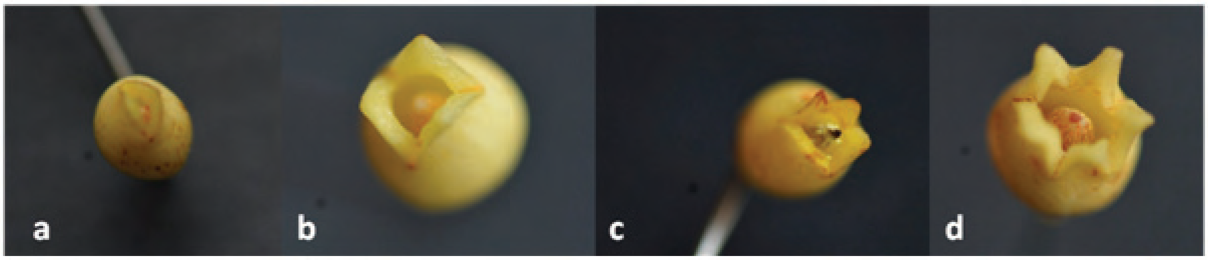

Fig. 1. Variation in flower opening in monoecious tree flowers [a) Dimerous, b) Trimerous, c) Tetramerous and d) Pentamerous]

Fig. 2. Intra flower variability in number and length of anthers of hermaphrodite flowers

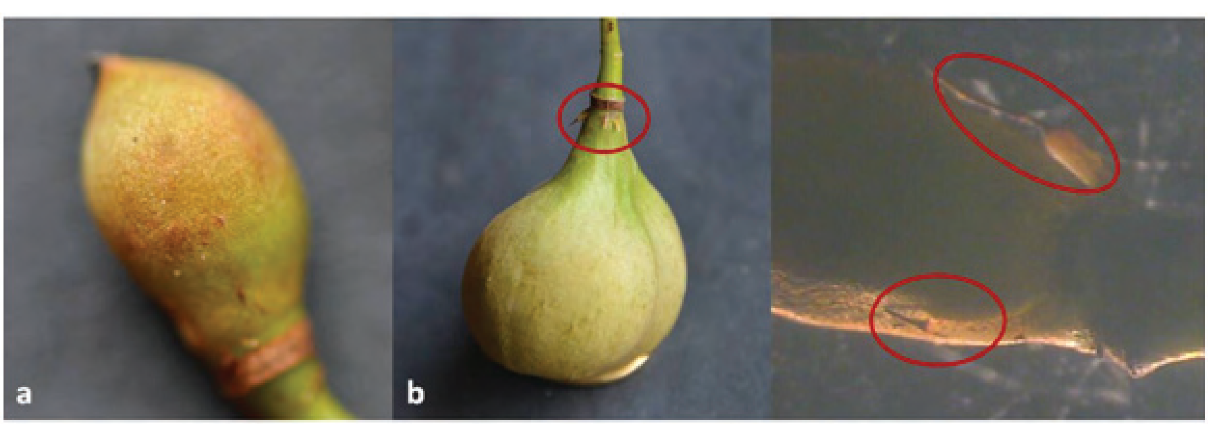

Fig. 3. Developed fruits from monoecious trees [a) from pistillate flowers, b) from hermaphrodite flowers (remnants of the stamen) and c) Microscopic view (20x)]

Table 1. Analysis of variance for flower types and floral attributes

Tree No	Average number of flowers			Staminate			Pistillate	Hermaphrodite	
	Staminate	Pistillate	Herma-phrodite	No. of anthers	Length of anthers (mm)	Length of filament (mm)	Length of ovary (mm)	No. of anthers	Length of ovary (mm)
C-1	100.00	0 (0.71)	0 (0.71)	8.88	4.10	2.94	0 (0.71)	0 (0.71)	0 (0.71)
C-9	92.66	5.66 (2.17)	1.66 (1.28)	9.42	5.50	3.82	6.00 (2.45)	2.25 (1.38)	5.20 (2.27)
C-21	83.00	11.00 (2.87)	7.33 (2.43)	8.86	3.10	2.98	5.59 (2.36)	2.23 (1.46)	5.23 (2.28)
C-43	100.00	0 (0.71)	0(0.71)	8.98	4.06	3.48	0 (0.71)	0 (0.71)	0 (0.71)
C-45	100.00	0 (0.71)	0(0.71)	10.92	3.92	3.18	0 (0.71)	0 (0.71)	0 (0.71)
C-54	50.66	41.00 (6.38)	8.33 (2.58)	8.76	3.88	2.70	5.80 (2.41)	2.20 (1.44)	5.40 (2.32)
Mean	87.72	19.22 (2.26)	5.77 (1.40)	9.30	4.09	3.18	5.79 (2.30)	2.22	5.28 (2.21)
CD (P<0.05)	12.97**	NS	NS	0.30**	0.17**	0.15**	0.10**	NS	0.23**
CV (%)	8.31			8.20	10.40	12.09	4.04		4.94

Values in the parenthesis are transformed

3). Analysis of variance of trees for flower types and floral attributes like flower type, number of anthers, length of anthers, length of filaments and length of ovary are found to be highly significant (Table 1). High coefficient of variation is recorded for hermaphrodite (183.84%) and pistillate (171.71%) flowers (Table 2). The pollen viability of the hermaphrodite flowers are found less as compared to the staminate flowers. The percentage of pollen viability is 79.74 and 94.77 in hermaphrodite and male flower respectively (Table 3). In the population studied, the average segregation of staminate, pistillate and hermaphrodite flower in the collected samples is 87.72, 19.22 and 5.77, respectively with approximate ratio of 17: 4:1. The occurrence of hermaphrodite flower in monoecious tree ranged from 0-9%. In 90% of the flowers studied the stamen length is found shorter than the stigma thereby excluding the chance of selfing. Moreover the pollen viability is also found less in these flowers. Variability in flowering phenology among individuals has direct impact on their fitness (Mauricio *et al.* 2013). However, the influence of environment factors on sex expression and floral variability need to be studied in detail in nutmeg.

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Table 2. Mean, range and CV% for floral traits in monoecious nutmeg

Category	Characters	Mean	Range	CV%
Sex of flowers	Staminate	88.37	50-100	21.33
	Pistillate	9.11	0-50	171.71
	Hermaphrodite	2.74	0-15	183.84
Staminate	No. of anther	9.30	7-13	11.49
	Length of anther (mm)	4.09	3-6	20.25
	Length of filament (mm)	3.18	2-4	16.74
Pistillate	Length of ovary (mm)	5.42	5-6	8.28
Hermaphrodite	No. of anther	2.22	1-4	43.58
	Length of ovary (mm)	5.31	4-6	9.54

Table 3. Pollen viability in staminate and hermaphrodite flowers of monoecious nutmeg

Flower type	Number of pollens observed	Viable pollen	Sterile pollen	% of viability
Staminate flower	152.66	145.00	7.67	94.77
Hermaphrodite flower	124.33	104.33	20.00	79.74

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Air layering in cinnamon (*Cinnamomum verum* L.) under wet humid tropical conditions

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Abstract

Cinnamon is a cross pollinated species and seed propagation has resulted in development of considerable variability in growth, yield and quality among the populations. Air layering has been considered as one of the efficient methods of multiplication in cinnamon. However, the success of layering varies greatly depending on the local environmental conditions. In the present investigation, air layering was performed at 20 days interval during rainy season (July 3^{rd} to October 11^{th}) of two consecutive years in Bay islands. Result revealed that first week of July was the most suitable time for air layering in cinnamon as it supported better rooting percentage (87.5%).

Keywords: Propagation; Season; Spice crop; Tropical islands

Cinnamon (*Cinnamomum verum* L.) or *dalchini* is one of the ancient tree spices grown in India. Though both bark as well as leaves are known to possess aromatic components mainly cinnamaldehyde and eugenol, the bark of this species is valued as a spice. It has been used in the form of dried bark, bark powder, oil and oleoresins. Cultivation of this spice in India is mainly confined to States of Andaman and Nicobar Islands, Kerala, Karnataka, North Eastern India and parts of Tamil Nadu and Maharashtra. Combined estimate of cinnamon and *tejpat* suggests that in India, it's being grown on 2,770 ha area with about 5,050 t production (Indian Horticulture Database 2014). However, the production is not enough to meet the domestic demand and hence, cinnamon is being imported from other countries of the world (Indian Spices 2016). Increasing the productivity through development and adoption of improved technologies is a key factor in reducing the dependence on import.

Soil and climatic conditions of the Andaman and Nicobar Islands are well suited for the cultivation of cinnamon (Parthasarathy *et al*. 2009) and presently it is cultivated in about 150 ha yielding 40 t annually. Quality of cinnamon is assumed to be the finest in the islands compared with other parts of the country (Singh & Sankaran 2012). Large availability of interspaces in the coconut and arecanut plantations in the Andaman and Nicobar

Islands could be successfully utilized for its cultivation (Waman *et al.* 2016). However, existing plantations in the islands are of seedling origin. One can easily notice variations in cinnamon seedlings for leaf size, shape and colour of new flush, apart from the distinct chemotypes (Krishnamoorthy *et al.* 1988). Ergo, considerable variability is noticed in the yields and quality of the final produce and hence, vegetative propagation is of interest (Rema *et al.* 1997). The present report concerned an effort to identify the most appropriate time for carrying out air layering under island condition.

The present investigation was carried out in the Division of Horticulture and Forestry of ICAR- Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands during 2015 and 2016. The islands exhibit typical tropical climate with average temperature of 18-31°C and annual rainfall of 3,100 mm distributed over May to December. Further, the relative humidity ranges between 60-90% in a year, while the average lies near to 70-80%.

For layering, healthy shoots of 25-30 cm length and 1.0-1.5 cm thickness were selected. Leaves and small branches near the ringing area on selected shoots were removed and two circular cuts were given to the shoots for removing a ring of bark of about an inch width. Commercial formulation of rooting hormone (Lipsa, Kolkata) was used for root induction and ringed portion was covered with soil: farmyard manure (1:1) before wrapping with polythene (20 cm × 20 cm). Experiment consisted of six treatments *i.e.* T_1: layering on July 3, T_2: layering on July 23, T_3: layering on August 12, T_4: layering on September 1, T_5: layering on September 21 and T_6: layering on October 11. Experiment was laid out in completely randomized design with 20 layers in each treatment. Various parameters were recorded at the time of separation (90 days after layering) and data was subjected to analysis of variance using Web Agri Statistical Package 2.0 (WASP 2.0, ICAR-RC for Goa, Ela, India).

Air layering was performed for six times during rainy season under island condition. Generally, rooting process is facilitated by the rains (Ranaware *et al.* 1995) and hence, the dry periods in the islands were avoided during the experimentation. Pooled analysis of two years data revealed that percentage root induction varied between 35.0% and 87.5% amongst the treatments studied (Table 1). Maximum rooting percentage was obtained in layers done on 3rd July (87.5%) followed by those done on 23rd July, while it was the lowest in layering performed on 21st September. Though rooting response varied considerably during different seasons, the mean number of primary roots per layer did not vary significantly (Table 1).

Table 1. Air layering in cinnamon under Andaman condition as affected by time of layering (pooled data of two years)

Treatment	Rooting percentage	Number of primary roots layer^{-1}	Mean length of primary root (cm)	Mean thickness of primary root (mm)
July 3	87.5	5.8 a	5.52 b	2.74 a
July 23	57.5	4.2 a	7.37 a	2.33 a
August 12	47.5	4.2 a	5.18bc	2.04 a
September 1	50.0	3.7 a	8.53 a	2.17 a
September 21	35.0	5.3 a	3.60 c	2.15 a
October 11	43.2	3.8 a	4.00bc	2.20 a

*Means followed by same alphabet in a column do not differ significantly at 5% level of significance using least significant difference

Length of longest root varied significantly amongst the studied treatments (Table 1). Maximum length of primary root was observed in propagules obtained from cinnamon layered on 1st September (8.5 cm), which remained on par with layers of 23rd July. Similar to rooting percentage, length of root was found to be the lowest (3.6 cm) in layers of 21st September batch. Thickness of root ranged from 2.04 to 2.74 mm; however, the differences were non-significant amongst the treatments studied.

Similar to present communication, significant variations for rooting response and growth parameters have been reported from different agro-ecological regions of the country *viz*., West Bengal (Banerjee *et al*. 1982), Karnataka (Hegde *et al*. 1989) and Maharashtra (Ranaware *et al*. 1995). These reports have suggested the positive effects of rainy period on layering success; however, the raining season and pattern vary significantly in different regions and hence, location specific studies are required. As no reports are available for island conditions, present study was conducted. The prevalence of optimum microclimate during the part of the year would possibly have helped in maximizing the rooting success. Rema *et al.* (1997) reviewed different propagation methods in spice crops in which they supported the possible role of endogenous auxins, sugars and other biochemical constituents in variable rooting success during different seasons.

It could be concluded that first week of July is the most suitable time for carrying out air layering under Andaman and Nicobar Islands condition. This technique being easier, farmers can easily multiply superior types in large number. In addition, inputs required for the purpose are easily available at cheaper cost and hence, it could be a boon for on farm production of quality planting material in the Andaman Islands.

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Stability analysis for seed yield and yield attributing traits in fennel (*Foeniculum vulguare* Mill.)

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Abstract

Study was carried to evaluate phenotypic stability of 13 genotypes of fennel for seed yield and yield attributing traits. Out of 13 genotypes, three were checks (RF 205, RF 201 and local fennel) grown in Randomized Block Design (RBD) with three replications in each year. The significant genotypic differences were observed for all the characters suggesting differential responses of genotypes to the environmental changes. The results showed that among 13 genotypes RF 205 and Local fennel were found stable for seed yield plant^{-1}, FNL 69 for days to flower, FNL 70 and RF 101 for primary branches plant^{-1}, FNL 74 for umbels umbellet^{-1} and FNL 71 for umbels plant^{-1}. The results revealed that some reliable predictions about G x E interaction as well as its unpredictable components contributed significantly in determining the stability of genotypes. The wider stability recorded by RF 205, RF 201 and local fennel during all the three years which will be useful for development of high yielding varieties of fennel.

Keywords: fennel, *Foeniculum vulguare* mill., stability, superiority

Fennel (*Foeniculum vulguare* mill.) is a highly cross pollinated and very important seed spice crop exhibiting 82.2% to 91.4% natural out crossing (Ramanujam *et al*. 1964). The hybridization of diverse genotypes followed by selection in segregating crop will be helpful in identifying heterozygous and heterogenous progeny. Insects plays an important role in maintaining heterogeneity in fennel crop. The existing varieties were developed using mass selection. Fennel seeds are having medicinal importance as carminative, cardiotonic, stimulant, vermicide and lactagogue (Lal 2014). The research efforts were for enhancing the productivity through developing high yielding inbreds and pure line varieties. India is the largest producer, consumer and exporter of spices and spice products. The total production of spices during 2013-14 was 5.9 MT from an area of 3.16 million ha (Annual Report 2014-15). Fennel had very little share to total production of spices. This yield gap can be minimized by growing suitable cultivars with appropriate packages of practices. For this development of high yielding and insect and pest resistant with good quality stable variety is essential. The newly variety must perform consistent performance across the environments and over the years for high yield and other yield attributing and quality traits. Phenotypically stable genotypes are of great importance because environmental conditions vary from season to season. Wider adaptation to a particular environment and consistent performance of recommended genotypes is one of the main objectives in breeding programme. A differential response of fennel genotypes when grown under different environments in the *Rabi* season has been reported by few scientists (Lal 2014; Drazic *et al.* 2014). Hence information on availability of stable high yielding varieties of Fennel is lacking. Keeping this in view, the present investigation was undertaken to determine the genotype x environment (year) interaction on stability parameters and to identify the stable and responsive genotypes for yield and yield contributing characters of fennel for Chhattisgarh.

The experimental materials consisted of 13 genotypes obtained from All India Coordinated Research Project (AICRP) on spices, Indian Institute of Spices Research (IISR), Kozhikode, Kerala, evaluated for stability of seed yield and yield attributing traits for the three years during 2012-13 to 2014-15 at the experimental farm of College of Agriculture and Research Station (CARS), Raigarh (21.9°N, 83.4°E, 215 m), Indira Gandhi Krishi Vishwavidyalaya (IGKV), Chhattisgarh. Out of 13 genotypes RF 205, RF 201 and local fennel were standard checks grown in Randomized Block Design (RBD) with three replications. Twenty plants in each row in plot size of 4 × 2.5 m, were maintained after thinning. The inter- and intra-row spacing was kept at 45 cm and 20 cm, respectively. The recommended package of cultural practices was followed to raise a good crop. In each plot, five competitive plants were identified randomly for recording data on days to 50% flowering, plant height (cm), primary branches plant^{-1}, umbels plant^{-1}, umblets umbel^{-1} and seed yield plot^{-1} (kg). The data recorded during three years were subjected to stability analysis according to the model proposed by Eberhart & Russel (1966) and three stability parameters mean (m), regression coefficient (bi) and the deviation from linearity (S^2di) were estimated.

Table 1. Year wise analysis of variance (mean sum of squares) for phenotypic stability of yield in Fennel

Source	df	Mean sum of square (MSS)											
		Seed yield (Kg ha-1)			Days to 50% flowering			Plant height (cm)			Primary braches plant^{-1}		
		2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Total	65	26925.2	24747.9	18769.3	18.6	15.9	23.0	84.3	44.7	263.4	2.9	2.2	2.3
Replications	2	2046.8	16550.5	2.3	5.0	5.0	3.3	3.8	6.1	0.9	6.6	6.1	9.3
Genotypes	21	82252.4*	66166.2*	55737.6*	58*	49.5*	70.7*	266.3*	140.3*	830.3*	8.1*	5.9*	4.0*
Error	42	1334.8	4721.9	1849.0	0.0	0.0	0.8	0.0	0.1	1.8	0.1	0.1	0.8

Source	df	Mean sum of square (MSS)					
		Umbles plant^{-1}			Umblets umbel^{-1}		
		2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Total	65	20.6	25.2	34.6	9.9	8.4	77.0
Replications	2	3.8	4.0	1.2	3.4	3.4	125.9
Genotypes	21	64.5*	79.2*	107.2*	30.9*	25.0*	99.6
Error	42	0.0	0.0	1.1	0.0	0.0	61.6

The genotypic differences were found to be highly significant for all the traits in each environment (year). The mean genotypic values from different year were subjected to pooled analysis. The mean sum of squares (MSS) due to genotypes (G) and environments (E) were significant for all the traits except for primary branches plant^{-1} when tested against MSS due to genotype x environments. It revealed the non significant differential response of the varieties to the changing environments. The results were in close conformity to the findings of Lal (2008), Verma & Solanki (2015). The MSS due to G × E when tested against pooled error, were found highly significant for all the characters. Thus stability analysis was carried out for all the traits. The variance due to G × E were divided in to G × E (Linear) and due to pooled deviation (Non-linear). The G × E (Linear) mean squares were found significant for all the traits except primary branches plant^{-1} indicating the presence of predictable components where as significance of pooled deviation for seed yield plot^{-1}, days to 50% flowering, plant height (cm), primary branches plant^{-1} and umbels plant^{-1} showed the presence of non-predictable components. These observations indicated that some reliable predictions about G × E interaction as well as its unpredictable components can be made for these traits. Hence, both components contributed significantly in determining the stability of genotypes (Lal 2008; Verma & Solanki 2015). Among 13 genotypes RF 205 and Local fennel were found stable for seed yield plant^{-1}, FNL 69 for days to flower, FNL 70 and RF 101 for primary branches plant^{-1}, FNL 74 for umbels umbel^{-1} and FNL 71 for umbels plant^{-1} (Table 2).

For days to flower, umbelets /umbel and umbels plant^{-1} FNL 69 had recorded wider stability (above average mean, bi = 1 and S^2di = 0). The genotype FNL 70 was stable for plant height, primary branches plant^{-1}, umbelets umbel^{-1} and umbels plant^{-1} but had low seed yield, indicating its adaptation to stress environments (Lal 2008) while genotype FNL 71 recorded stability for plant height and umbels plant^{-1}. For umbels umbel^{-1} FNL 72 had high stability across the environments of Raigarh. The genotypes FNL 69, FNL 70 and FNL 71 were among the top entries which had their mean umbels plant^{-1} greater than the average of all the genotypes with regression coefficient (bi =1) and non-significant deviation for regression (S^2di =0). This indicated their high stability over the different environments of years (Lal 2008). The genotype FNL 68 and RF 101 had above average mean for umbels plant^{-1}, S^2di = 0 but the value of bi #1, indicating their adaptation to high input conditions. For umbels plant^{-1} genotype RF 205 and FNL 67 had bi = 1 and S^2di = 0, but their mean was low, indicating their adaptation to stress environments (Table 3).

Table 2. Analysis of variance (mean squares) for phenotypic stability of yield and yield contributing characters in Fennel

Source	df	Mean square					
		Seed yield (kg ha^{-1})	Days to 50% flow	Plant height	Prim. Branch	Umbels $^{-1}$ plant	Umblets umbel^{-1}
Total	38	48198.2	71.8	194.5	2.0	34.0	48.5**
Genotypes	12	49045.9*	25.4*	273.9**	3.2	35.4**	21.4**
ENV	2	507452.1*	1008.4**	1221.2**	1.7	145.1**	21.4**
Environment (Gen × Env)	26	47806.9*	25.**	157.8**	1.4	33.4**	61.1**
Environment Linear	1	1014905.6*	17**	2442.0**	3.4	290.3**	1218.5**
Gen. × Env Linear	12	17107.5*	25.1**	122.7**	0.3	44.7**	30.3**
Pooled Deviation	13	1752.6*	8.2*	14.5**	2.3**	3.2**	0.1
Pooled error	13	878.4	8.2	0.2	0.1	0.1	6.8

Table 3. Stability parameters for yield and yield attributing traits in fenugreek

S.N.	Genotypes	Seed yield (kg ha^{-1})			Days to flower			Plant height (cm)		
		MEAN	bi	MSD	MEAN	B	MSD	MEAN	B	MSD
1	FNL 67	470.8	0.9	-784.2	93.4	1.5	11.6**	153.1	1.2**	0.5
2	FNL 68	374.9	0.9	-357.9	90.2	0.9	17.7**	169.4	1.0	1.3**
3	FNL 69	425.2	1.0	1623.5	86.6	1.3**	-0.1	164.8	0.7	68.9**
4	FNL 70	420.5	0.7	-796.2	87.5	1.1	5.2**	169.1	0.8	0.1
5	FNL 71	574.3	1.0	2262.9	84.3	0.8	10.3**	161.9	0.7	0.6**
6	FNL 72	652.1	0.3	1070.8	87.8	0.1	1.1**	160.8	1.4	23.3**
7	FNL 73	514.6	1.5	6542.8**	89.9	0.8	24.3**	173.3	2.4**	13.5**
8	FNL 74	587.6	1.6**	1211.1	91.0	1.6*	6.4**	162.3	2.6**	12.2**
9	FNL 75	503.4	1.8**	1845.3	94.4	0.7	8.1**	160.9	0.4	-0.2
10	FNL 76	462.8	1.4	-668.1	92.0	1.1	0.8**	154.9	0.1	4.5**
11	RF 101	673.4	0.3	655.5	89.1	1.1	15.4**	152.0	0.9	1.8**
12	RF 205	808.4	0.7	-795.9	92.2	0.6	0.9**	137.1	-0.3	58.6**
13	Local check	696.3	0.9	-444.8	87.4	1.3	4.3**	152.6	1.1	0.7**
S.N.	Genotypes	Prim branches			Umblets $umbel^{-1}$			Umblets $plant^{-1}$		
		MEAN	B	MSD	MEAN	B	MSD	MEAN	B	MSD
1	FNL 67	8.2	0.6	1.2**	24.0	1.8**	-6.8	15.7	0.4	0.8**
2	FNL 68	8.6	1.8	0.0	24.5	2.1**	-6.3	23.9	3.1**	1.6**
3	FNL 69	9.2	1.5	1.6**	24.4	0.8	-5.9	25.2	0.7	-0.1
4	FNL 70	8.0	0.3	0.8**	27.2	0.4	-6.8	24.9	1.1**	-0.1
5	FNL 71	6.9	-0.6	6.9**	19.5	0.3	-6.6	29.1	-0.6	0.0
6	FNL 72	7.1	0.8	0.7**	28.4	1.1	-5.8	22.7	-1.6	2.6**
7	FNL 73	7.6	1.8	0.0	28.4	1.4**	-6.7	23.1	0.2	0.2
8	FNL 74	10.2	2.0	6.3**	26.9	0.4	-6.8	20.3	-0.2	23.7
9	FNL 75	7.1	2.6	1.8**	28.1	1.4*	-5.0	19.1	2.4	7.9
10	FNL 76	7.0	1.9	3.2**	26.2	1.0	-6.8	18.3	1.9**	0.7**
11	RF 101	8.0	0.6	0.5**	28.3	1.5**	-6.6	23.1	2.9**	2.9**
12	RF 205	7.0	0.1	0.2**	23.0	0.4	-6.8	20.8	0.7	0.1
13	Local check	6.8	-0.4	5.7	27.7	0.5	-6.5	22.0	1.9**	0.0

Table 4. Two way table showing stable and unstable genotypes for seed yield verses component characters

Genotype no	Stable genotypes	Stability parameters (bi/S2di) of yield components				
		Days to flower	Plant height	Primary bran plant^{-1}	Umbels plant^{-1}	Umblets umbel^{-1}
12	RF 205 (C)	S/S	S/*	S/S	S/S	S/S
13	Local fennel (C)	S/*	S/S	S/*	S/S	S/S

Where, S=stable genotypes; S/*, */S and */*=unstable genotype; bi=regression coefficient; S2di=deviation from regression line; *: bi #1, S2di #0

Based on stability parameters genotypes RF 205 and Local fennel were classified as stable for seed yield plant^{-1}, which had their mean seed yield greater than the average of all the genotypes with unit regression coefficient (bi =1) and non-significant deviation from regression (S^2di =0). This indicated their high stability over all the environments during 2012-13 to 2014-15. Lal (2008) and Verma & Solanki (2015) reported above average stability of Fennel genotypes for seed yield. The genotypes RF 101, FNL 72 and FNL 71 had above average mean, seed yield, regression coefficient of bi =1 but non-significant deviation from regression line (S^2di=0). Hence, indicating its specific adaptability under good agronomic management practices.

Table 5. Superiority of fennel genotypes for yield over checks during 2012-13 to 2014-15

E.N.	E.name	Yield (kg ha^{-1})	% superiority	Disease reaction	
			RF 101(NC)	Local check	
		2012-13			
6	FNL 67	578.1	NO	2.75	MR
11	RF 101 (c)	599.7	NO		MR
12	RF205 (c)	690.2	NO		MR
13	FNL (LC)	562.6	NO		MR
		2013-14			
6	FNL 67		NO	6.36	MR
11	RF 101 (c)	686.9	NO		MR
12	RF205 (c)	777.1	NO		MR
13	FNL (LC)	630.3	NO		MR
		2014-15			
1	FNL 74	918.4	25.2	2.5	MR
4	FNL 75	914.9	24.7	2.1	MR
20	FNL 73	872.0	18.9	-2.7	MR
3	FNL 71	807.3	10.0	-9.9	MR
4	FNL 76	770.4	5.0	-14.0	
	RF 205	957.9	30.6	6.9	
	Local check	896.2	22.2	0.0	
	RF 101	733.6	0.0		

Where, No=No superiority; NC=National check

For the present study the meterological parameters recorded with Indian meterological standard week of 31 for first week of sowing, 37 for vegetative stage, 43 for flowering stage and 49 for physiological maturity stage respectively for 2012-13 to 2014-15 (Table 6). It was observed that during sowing period average optimum temperature of 27.6°C + 21.2°C were present over all the three years. At the same time average maximum humidity of 88.2% with minimum of 66.9% were recorded during first week of sowing. During vegetative stage of fennel crop mean maximum temperature of 24.9°C and minimum temperature of 15.2°C with humidity range of 87.2% to 60.7% recorded. At flowering time consistent maximum minimum temperature of 24.9°C-15.2°C respectively registered with average humidiy of 89.2% to 38.4% present. At physiological maturity mean maximum-minimum temperature of 32.0°C -15.0°C were registered while maximum humidity of 81.8% and minimum temperature of 37.3% were recorded. It was observed that at all the three years no rainfall during throughout the crop period.

The genotype FNL 67 had recorded 2.75 and 6.36 percent superiority for seed yield over local check during 2012-13 and 2013-14 respectively.

Table 6. Meterological parameters during crop growth period from 2012-13 to 2014-15

Year	Temperature (°C)		Humidity (%)		Rain fall (MM)
	Max	Min	Max	Min	
			Seed germination week		
2012-13	27.85	18.57	90.71	61.14	Nil
2013-14	27.86	23.86	86	71.28	Nil
2014-15	27	21.28	88	68.14	Nil
Average	27.6	21.2	88.2	66.9	
			Vegetative stage		
2012-13	25.14	16.28	90.71	64.14	Nil
2013-14	24.29	13	80.28	53.71	Nil
2014-15	25.14	16.25	90.71	64.14	Nil
Average	24.9	15.2	87.2	60.7	
			Flowering stage		
2012-13	25.42	11.42	88.71	29	Nil
2013-14	25.71	15.42	89.57	57.28	Nil
2014-15	25.42	11.42	88.71	29	Nil
Average	25.5	12.8	89.0	38.4	
			Physiological maturity		
2012-13	32.71	14.71	83	32.71	Nil
2013-14	26.14	13.43	81.57	55.14	Nil
2014-15	37.14	16.71	80.71	24	Nil
Average	32.0	15.0	81.8	37.3	

During 2014-15 five genotypes FNL 74, FNL 75, FNL 73, FNL 71, and FNL 76 recorded high heterosis for seed yield over RF 205 and RF 101, whereas FNL 74 & FNL 75 registered positive heterosis over local check.

It was observed that national check (RF 205) showed wider stability for seed yield, days to flower, primary branches plant^{-1}, umbels plant^{-1} and umbelets umbel^{-1} while local fennel had wider stability for seed yield (kg ha^{-1}), plant height, umbels plant^{-1} and umbelets umbel^{-1}. While none of the test entries showed superior stable performance over the national and local checks during all the three years. This appears to be evidence for much greater genotype × environment interaction for the entries to be evaluated than for the pure lines. This is somewhat unexpected in view of the greater homeostasis in unfavorable environments usually found in heterozygous genotypes. This needs further study.

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Effect of irrigation methods and mulching on growth and yield parameters of chilli (*Capsicum annum* L.) in arid condition

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Abstract

The research work was carried out to study the impact of various irrigation methods and mulching on plant growth, production and profitability of chilli *cv.* R.Ch. 1 at Agricultural Research Station, Mandor, Jodhpur during July, 2016 to February, 2017. The results of surface irrigation were compared with drip irrigation system under no mulch and in conjunction with plastic mulch. The results revealed that the crop was irrigated by drip irrigation on raise bed with 100 micron Linear Low Density Poly Ethylene plastic mulch (T_8 treatment) exhibited significantly higher seedling survival at 15 and 30 days after transplanting (95.16% and 91.70%), highest plant height (47.10 cm at 45 DAT and 54.60 cm at harvest), highest number of branches (14.93) plant^{-1}, maximum stem girth (2.32 cm) number of roots plant^{-1} (138.5), highest fruit set (38.47%), length of fresh fruit (12.56 cm), diameter of fruit (3.52 cm) and fresh weight of fruit^{-1} (8.42g) was observed. The maximum number of fruits plant^{-1}(125), highest yield plant^{-1} (1052.5g), yield ha^{-1} (337.63q) and premier fruit quality score (9.11) with maximum net return (Rs.326407.28) and benefit: cost ratio (3.41) was also reported in same treatment. Comparatively minimum time (15 hours) required for one hectare irrigation was also reported in drip irrigation on raise bed with plastic mulch. This led to lower population of white fly plant^{-1} (4.53), minimum weed infestation (1.53 weed m^{-2}), leaf curl (5.50%) and fruit rot (5.0%) incidence than other treatment combinations. The minimum growth, yield and profitability were reported in check basin method of irrigation without mulch (T_1 treatment).

Keywords: *Capsicum annum*, Day After Transplanting, leaf curl, surface irrigation, survival

Chilli (*Capsicum annuum* L.) is an important commercial vegetable cum spice crop of India belongs to the family Solanaceae. The production of chilli crop is affected adversely by moisture deficit. Productivity of the crop can be increased by adopting improved package of practices, particularly *in-situ* moisture conservation by mulching as well as high-tech irrigation especially drip irrigation with appropriate irrigation scheduling. Use of soil cover and mulching is also known to be beneficial chiefly through their influence on soil moisture conservation, solarization and control of weeds. Beneficial response of plants

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to mulch includes early production, more yield and reduced insect and disease problems (Pattanaik *et al.* 2003). Linear Low Density Poly Ethylene (LLDPE) plastic films have been proved as better mulch because of their puncture resistance quality, thinness and lower cost (Panda 2004). Numerous experiments have reported the benefits of LLDPE mulch in several crops, but research is limited on response of chilli production in western Rajasthan by this method. Keeping this in background, the present study was undertaken to study the effect of different irrigation methods and mulching on chilli crop and compare the result with the conventional method of growing the crop under surface irrigation without mulch.

A field experiment was conducted at Agricultural Research Station, Mandor, Jodhpur (Rajasthan), India during *kharif* seasons of year 2016-17. The soil of experimental plot was of sandy loam texture with average pH range 8.5, having organic carbon 0.55%, available N 180 kg ha^{-1}, P 27.5 kg ha^{-1} and K 250.0 kg ha^{-1} during experimentation. The experiment was conducted in a completely randomized design having nine treatments comprising by different irrigation methods and mulching *viz.*, T_1 = Check basin method, T_2 = furrow irrigation method, T_3 = Raise bed with trench method, T_4 = Flat bed with drip irrigation, T_5 = Flat bed + plastic mulch + drip irrigation, T_6 = Raise bed with drip irrigation, T_7 = Raise bed + organic mulch + drip irrigation, T_8 = Raise bed + plastic mulch + drip irrigation, T_9 = Sprinkler irrigation method. In well prepared field, transplanting of Chilli seedlings variety RCh 1 of 35-40 days old were planted in pair row method with a spacing of 45cm x 45 cm/90 cm (33,333 plant ha^{-1}) during last week of June. In check basin and sprinkler system of irrigation the bed size is 2 x 2 meter and in all other methods is 1 × 4 meters. The cultural practices of the crop were followed as per the recommendations. The organic material and LLDPE silver colour film of 100-micron thickness was used for mulching around the plant. The lateral lines of 12 mm diameter LLDPE pipes were laid along with crop rows. The laterals were provided with inlet drippers of 8 litre hr^{-1} discharge capacity. All the observations were taken from five randomly selected plant of each replication throughout the investigation period at appropriate time by adopting standard method for growth, development, fruiting behavior and yield.

Seedling survival per cent (after transplanting in main field at 15 DAT and 30 DAT) was recorded by following formula;

Survival percent = [Total survival transplanted plants / Total transplanted plants] × 100

Plant height (at 45 DAT and at harvesting) was measured from soil surface upto the highest shoot tip by straightening all branches. Stem girth was measured 1 cm from the base of the stem using vernier calliper. Observation of number of branches, days taken to first flower initiation, duration of fruiting period and number of fruit plant^{-1} was recorded by standard counting method. Number of roots, root length was measured by destructive method of uprooting the plants and taking measurement by standard method. Length of fresh fruits measured by scale and fruit diameter using vernier calliper and expressed in centimeter. Fruit set per cent was recorded by following formula;

Fruit set per cent = [Total number of fruit set plant^{-1} / Total number of flowers plant^{-1}] × 100

Fruit weight was determined by weighing method at the time of harvesting and expressed in gram fruit^{-1}. The total fruit yield plant^{-1} and hectare^{-1} was calculated by weighing total marketable fruits and has been expressed in gram and quiantal respectively. Further, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost of cultivation. Benefit-Cost ratio and net profit were carried out to determine the economic feasibility of the crop using surface and drip irrigation as suggested by Tiwari *et al.* (1998a).

The seasonal system cost of drip irrigation system included depreciation, prevailing bank interest rate, and repair and maintenance cost of the system. The fixed cost of drip irrigation system was determined to be Rs 112,000 ha^{-1}. The useful life of drip system was considered to be 10 years. The system cost was evaluated by distributing the fixed cost of system over life period of drip irrigation set. For calculating depreciation, the life of the drip irrigation set and 10% junk value was considered. The interest was calculated on the average of investment of the drip irrigation set taking into consideration the value of the set in the first and last year @10% per annum. Cost of repairs and maintenance of set is @2% of initial cost of the drip irrigation set per year. The cost of cultivation includes expenses incurred in land preparation, interculture operation, fertilizer, crop protection measures, irrigation water and harvesting with labour charges. Therefore, total seasonal cost was worked as: depreciation, interest, repairs and maintenance cost of set + cost of cultivation + cost of mulch. The income from produce was calculated using prevailing average market price of capsicum @ Rs 1250 q^{-1}. Disease incidence (leaf curl and fruit rot) and quality of fruits was measured by visual inspection (Five member team of crop experts and plant pathologist). White fly population $plant^{-1}$ and weed infestation $meter^{-2}$ was calculate by simple counting method. The time required for irrigation was calculated as per actual required time of irrigation of specified area by different methods of irrigation. To test the significance of variance of data obtained from crop growth, yield and economics of variance technique for completely randomized design was done by standard procedure prescribed by Panse & Sukhatme (1985). Significance of difference among the treatments effect was tested by 'F' test and critical difference (CD) was calculated, wherever the results were significant.

The results revealed that, the irrigation methods and mulching are significantly influenced growth attributes at all the growth stages (Table 1). The maximum seedling survival per cent at 15 DAT (95.10%) and 30 DAT (91.70%) was recorded in T_8 treatment, which was significantly superior to other treatment but at par with $T_{6,}$ and T_7 treatments. The maximum survival per cent of seedling in T_8 treatment might be due to more favourable moisture condition for seedling transplanting and re-establishment of roots than others. The height of plant under treatment T8 (47.10 cm at 45 DAT) and treatment T6 (62.60 cm at harvest) was found highest among all other treatments and is 67.19% and 13.40% higher than the T_1 treatment. About to number of branch $plant^{-1}$, maximum value was recorded in treatment T8 (14.93) followed by treatment T7 (12.53) and the lowest value was in treatment T1 (7.17). Maximum stem girth at harvest (2.36 cm) and highest number of roots $plant^{-1}$ (138.50) were observed in T_8 treatment whereas longest root system (10.50 cm) was observed in T_3 treatment. The minimum stem girth (1.68 cm) and the number of roots $plant^{-1}$ (53.57) were observed in T_1 treatment whereas shortest root system (7.97 cm) was observed in T_9 treatment. The higher available moisture status in soil favourably influences the uptake of nutrients which maintains the cell turgidity, cell elongation, photosynthesis and respiration at optimum level, leading to favourable growth and development of plant in terms of plant height, number of branches $plant^{-1}$, stem girth and number of root $plant^{-1}$ in the present study. The highest increase in vegetative growth in drip irrigation with mulching might be due to the availability of soil moisture as well as favourable temperature at optimum level for plant growth development (Pattanaik *et al*. 2003; Paul *et. al*. 2013). The lowest value of vegetative growth in T1 might be because of unfavourable moisture regime (moisture stress or excess moisture) in the soil through surface irrigation and competition of weeds for nutrients (Pattanaik *et al*. 2003; Agrawal & Agrawal 2005). The increased growth attributes might have supplied water and nutrients in adequate proportion, which resulted in triggering the production of plant growth hormone, *viz*., indole acetic acid (IAA) and

Table 1. Effect of different irrigation methods and mulching on vegetative parameter of chilli

Treatments	Seedling survival %		Plant height (cm)		Average number of branches plant^{-1}	Stem girth at harvest (cm)	Length of root (cm)	No. of roots plant^{-1} plant^{-1}
	15 DAT	30 DAT	45 DAT	At harvest				
T_1	78.17	73.93	28.17	55.20	7.17	1.68	9.50	53.57
T_2	82.37	79.23	29.07	57.30	8.07	1.86	10.00	69.77
T_3	86.97	83.83	32.07	61.70	8.27	1.88	10.50	78.37
T_4	88.40	84.73	34.03	61.55	9.48	2.26	8.53	102.50
T_5	90.10	86.33	38.53	61.70	10.28	2.33	8.03	108.70
T_6	92.50	89.33	40.43	62.60	9.98	2.32	9.03	119.00
T_7	93.40	90.90	41.97	53.20	12.53	2.30	8.97	135.70
T_8	95.10	91.70	47.10	54.60	14.93	2.36	8.47	138.50
T_9	85.20	80.10	34.90	56.70	9.73	2.00	7.97	110.10
S.Em. +	1.646	1.539	2.173	1.859	0.442	0.088	0.228	1.300
CD ($P<0.05$)	4.871	4.556	6.432	5.504	1.327	0.260	0.675	3.848

higher number of leaves and roots throughout the cropping period (Sankar *et al.* 2008).

The drip irrigation in combination with mulch significantly increased the yield of chilli as compared to drip irrigation without mulch (Table 2) and surface irrigation methods. The minimum days (42.38) required for first flower initiation was reported in T_9 treatment whereas the maximum days (51.39) was required in T_5 treatment. Among various treatments, highest fruit set (38.47%), length of fresh fruit (12.56 cm), diameter of fruit (3.52 cm), duration of fruiting (71.38 days), fresh weight of fruit^{-1} (8.42 g), maximum number of fruits plant^{-1} (125), highest yield plant^{-1} (1052.5 g) and yield ha^{-1} (337.63 q) was recorded under T_8 treatment, whereas lowest yield (153.45 q ha^{-1}) was recorded under T_1 treatment. This might be due to water stress during the critical growth period and fruit development stage coupled with aeration problem in first few days immediately after irrigation. Another reason to get low yield by surface irrigation without mulch might be due to less availability of nutrients for crop growth due to leaching and high weed competition between the crops (Pattanaik *et al*. 2003). In drip irrigation system on raise bed with plastic mulch the water is applied at a low rate for a longer period at frequent intervals near the plant root zone through lower pressure delivery system, which increases the availability of nutrients near the root zone with a reduction in leaching losses and minimum weed competition. More nutrient availability, especially near the root zone might have increased the translocation of photosynthetes to storage organ of chilli resulting in an increased weight of fruits. This result corroborated the findings of Singh (2007), Sankar *et al*. (2008), Paul *et al*. (2013) and Kumar *et al.* (2016).

Irrigation methods and mulching also significantly influenced the gross return, net return and benefit cost ratio in chill (Table 3). Maximum net profit of Rs. 326407.28 ha^{-1} with B: C ratio of 3.41 was recorded in T_8 treatment followed by Rs 296192.61 ha^{-1} with B: C ratio of 3.11 in T_5 treatment and lowest net profit of Rs 119007.80 ha^{-1} with a B: C ratio of 1.63 in T_1 treatment (Table 3). It is observed that, the drip

Table 2. Effect of different irrigation methods and mulching on yield and yield attributes of chilli

Treatments	First flower initiation (DAT)	Fruit set %	Length of fresh fruit (cm)	Diameter of fresh fruit (cm)	Duration of fruiting (days)	Weight of single fresh fruit (gm)	No. of fruits plant^{-1}	Yield plant^{-1} (gm)	Yield ha^{-1} (q)
T_1	45.70	17.23	10.75	2.87	52.70	7.63	60.33	460.34	153.45
T_2	47.70	17.01	11.30	2.75	54.00	7.79	65.33	508.95	169.65
T_3	47.40	21.31	11.35	2.78	56.10	7.82	68.33	534.37	178.12
T_4	49.19	27.00	12.01	3.01	62.39	7.97	74.17	591.11	197.03
T_5	51.39	31.81	12.19	3.14	68.59	8.23	114.17	939.59	313.19
T_6	49.99	30.89	12.39	3.22	60.39	8.26	89.17	736.52	245.50
T_7	46.58	36.74	12.30	3.28	66.38	8.36	95.00	794.20	251.53
T_8	48.38	38.47	12.56	3.52	71.38	8.42	125.00	1052.50	337.63
T_9	42.38	16.27	11.57	3.10	47.58	7.90	75.00	592.50	184.30
S.Em. +	1.247	1.570	0.201	0.059	1.247	0.133	1.302	9.913	8.257
CD (P<0.05)	3.693	4.649	0.595	0.176	3.693	0.395	3.854	29.337	24.437

irrigation with mulched treatments T_5, T_7 and T_8 gave better net return with higher B: C ratio ha^{-1} than their corresponding treatments without mulching in conventional irrigation method. The highest net return (US$ 7098 ha^{-1}), incremental net return (US$ 1556 ha^{-1}), and incremental benefit-cost ratio (7.03) were found for 50% water application with straw mulch (Biswas *et al*. 2015). The results are in conformity with the findings of Singh (2007), Sankar *et al*. (2008) and Kumar *et al*. (2016). Apart from reducing water consumption, drip irrigation with mulching also helps in reducing cost of cultivation and improving productivity of crops as compared to the same crops cultivated under flood method of irrigation (Paul *et al*. 2013).

Irrigation time significantly pretentious by different irrigation methods. The minimum time required in irrigation (14.50 hours) in T_5 treatment which closely followed by T_8 treatment. Drip irrigation method with or without mulching required less irrigation time than without mulching in conventional irrigation method. There was significant effect of LLDPE mulch over drip irrigation system alone. Drip irrigation with LLDPE mulching (T_5 & T_8 treatment) saving irrigation time (21.40 hour ha^{-1} and 21.35 hour ha^{-1}) upto 60 per cent by reducing water losses and increased irrigation efficiency. The increase in water saving per cent in trench method (T_2), drip irrigation system alone (T_4), drip irrigation system with LLDPE mulch (T_5 & T_8), drip irrigation with organic mulch (T_7) and sprinkler system (T_9) over conventional surface irrigation by check basin method (T_1) was 38.8%, 46.6%, 60.0%, 54.4% and 41.9% respectively. The highest water use efficiency of 592 kg ha^{-1} mm^{-1} was obtained with 50 per cent water application under polyethylene mulch (Biswas *et al*. 2015). Drip irrigation with mulching helps to achieve yield gains of upto 100 per cent, water savings of upto 40-80 per cent, and associated fertilizer, pesticide, and labour savings over conventional irrigation systems in capsicum crop (Paul *et al*. 2013). Similar trend has been reported in water use efficiency for okra crop by Tiwari *et al*. (1998a) and for tomato crop by Singh (2007).

Table 3. Effect of different irrigation methods and mulching on economics, fruit quality, water saving (%), insect-pest and weed infestation of chilli

Treat-ments	Net Return	B:C ratio	Quality score of fruits	Water saving (%) time (h) for ha^{-1} irrigation	No. of white fly $plant^{-1}$	Fruit Rot (%)	Leaf curl (%)	Weed Infest-ation
T_1	119007.80	1.63	7.24	36.30 (0.0%)	17.43	20.02	15.84	30.03
T_2	135858.99	1.78	7.46	22.20 (38.8%)	13.73	18.02	12.34	17.43
T_3	144550.55	1.85	8.04	22.45 (38.2%)	12.43	14.02	10.84	15.53
T_4	170392.68	2.24	8.00	19.40 (46.6%)	11.60	10.82	9.50	12.40
T_5	296192.61	3.11	8.50	14.50 (60.0%)	7.90	7.82	7.30	2.10
T_6	225678.88	2.78	8.20	18.15 (50.0%)	10.40	8.82	8.60	10.10
T_7	230913.36	2.77	8.50	16.55 (54.4%)	9.53	6.00	8.10	5.73
T_8	326407.28	3.41	9.11	14.55 (60.0%)	4.53	5.00	5.50	1.53
T_9	152772.53	1.97	6.50	21.10 (41.9%)	15.43	19.00	13.40	32.18
S.Em. +	0.001	0.005	0.162	1.247	0.346	0.568	0.227	0.394
CD ($P<0.05$)	0.003	0.017	0.480	3.693	1.026	1.68	0.672	1.166

Occurrence of chilli leaf curling and fruit rot was detected throughout the investigation period. The best performance, with a marked reduction in leaf curling and fruit rot and improve fruit quality was observed in drip irrigation with LLDPE mulching (Table 3). The minimum incidence of fruit rot (5.0%), leaf curing (5.5%) and highest quality score of fruit (9.11) was observed in T_8 treatment which was closely followed by T_7 and T_5 treatments where as maximum incidence of fruit rot (20.02%) and leaf curling (15.84%) was reported in check basin method of irrigation (T_1 treatment) whereas minimum quality score (6.50) was observed in T_9 treatment. Presence of white fly and weed was observed throughout the investigation period. The minimum population of white flies (4.53 $plant^{-1}$) and weed infestation (1.53 weed m^{-2}) was observed in T_8 treatment whereas highest incidence of white flies (17.43 $plant^{-1}$) and weed infestation (30.03 weed m^{-2}) was observed in T_1 treatment. This is due to the fact that in drip irrigation with mulching significantly reduced additional moisture level in field environment which in turn increase quality of fruits and reduce disease infestation, white fly population as well as it also trim down weed seed germination, growth and development. The increase in quality of fruits was due to the effective utilization of applied nutrients, water and significantly reduced weed growth; disease incidence and increased rate of photosynthesis, sink capacity and accumulated more amounts of dry matter and finally increased quality of fruits and yield. Conventional surface irrigation methods without mulching provide favorable environmental condition for increase insect population and development of disease as well as germinate and develop high density weed plants. The beneficial effect of drip irrigation and black LLDPE mulch in capsicum, tomato and okra was also reported earlier by Horo *et al.* (2003); Singh (2007); Vankar & Shinde (2007), Bhardwaj & Sarolia (2012), Paul *et al*. (2013).

The combination of raised bed + drip irrigation system with LLDPE mulching is observed to be economical and cost effective as compared with conventional surface irrigation without mulching. Thus, the use of drip irrigation system either alone or in combination with mulching, could increase the chilli yield quality of fruits and profitability. It also reduces white fly population, disease incidence (root rot and leaf curling) and minimise with crop weed competition. Drip irrigation with mulching increase water use efficiency by significant reduction in irrigation time ha^{-1}. It is concluded that the drip irrigation method with LLDPE mulching is suitable for chilli production in arid and semi arid condition of western Rajasthan.

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Evaluation of stable and non shattering isabgol cultivar - Gujarat isabgol 4

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Abstract

Isabgol growing area was surveyed during 2009-10 and selected genotypes were evaluated in preliminary evaluation trial (PET) during 2010-13 and in large scale varietal trial (LSVT) during 2013-15. It was found that JI-09-21 recorded better growth and yield characters and yield over check Gujarat Isabgol 3. The JI-09-21 did not shatter much even after water dripping and recommended for cultivation as Gujarat Isabgol 4.

Keywords: gujarat isabgol 4, isabgol, new variety, non shattering type

Isabgol (*Plantago ovata* Forsk) is a short duration, more remunerative and medicinally important crop of arid and semiarid regions. In India, it is largely grown in Gujarat, Rajasthan, Madhya Pradesh and Haryana. The area under Isabgol in India during 2014-15 is 1.09 lakh hectares. The production recorded 72 thousand MT with productivity of 660 kg ha^{-1}. In Gujarat, area mostly falls in Banaskantha, Kachchh and Patan districts with acreage of nine thousand hectare with production and productivity 5000 MT and 556 kg ha^{-1}, respectively during 2015-16 (Anonymous 2016a). During the last decade, area and production of isabgol has decreased to the tune of 343% and 281%, respectively, mainly due to problems of seed shattering. At the time of maturity, unseasonal rain or heavy dew leads to failure of the crop which is the fact for reduction of area under Isabgol (Anonymous 2016b). The objective of the study was to evolve non-shattering isabgol cultivars.

Isabgol growing area of Kachchh in Gujarat was surveyed during 2009-10 and subsequently genotypes were evaluated. First three years (2010-11 to 2012-13) 13 genotypes (JI-09-03, 07, 10, 13, 15, 16, 20, 21, 22, 23, 24, 25 and 26) with check (Gujarat Isabgol -03) were evaluated in preliminary evaluation – trial (PET). During 2013-14 and 2014-15, nine genotypes (JI-08-02, JI-09-07, 13, 16, 20, 21, 22, 24 and 25) along with check (Gujarat Isabgol -03) was tested. The trials were carried out at three different locations *viz*., Jagudan, Kholwada and Deesa in a randomized block design with three replications.

The stability analysis of variance and stability parameters *viz*., linear regression coefficient (bi) and deviation from regression (S^2di) of genotype means over environment were computed as suggested by Eberhart & Russell (1966).

Shattering per cent was computed as suggested by Singh *et al.* (2005) and Chandra (1967). Five plants in each replication were selected at maturity stage. Entire spike were dipped in water and then observed for seed shattering from selected plants. The percentage of seed shattering calculated by using a following formula.

Shattering per cent = [(Expected seed yield - Seed wt. after threshing) / (Expected seed yield)] × 100

Expected seed yield= H.I. x Sun Dry wt. (kg)/ 100

Considering eight trials at three locations for five years, JI-09-21 was recorded higher (928 kg ha^{-1}) seed yield against 830 kg ha^{-1} of Gujarat Isabgol 3 (GI 3), which was 11.78% higher than GI-3 (Table 1). The new variety named as Gujarat Isabgol 4 was having more tillers $plant^{-1}$ (6.0), more spikes $plant^{-1}$ (22.7), seeds $spike^{-1}$ (80.7), higher test weight (1.58 gm) and high swelling factor (11.4 cc g^{-1}) than that of check variety GI-3, due to these yield contributing traits GI-4 is having high seed yield potential (Table 3). The similar kind of results also obtained by Prajapati *et al.* (2011).

Gujarat Isabgol 4 recorded high mean with regression coefficient (bi) near unity and deviation from regression (S^2di) around zero for seed yield, indicating GI-4 has average responsiveness and are highly stable over environments (Table 2).

The new culture has compact spike and did not separate easily even after dipping in water. Only 7.25% seeds shattered after dipping in water.

Table 1. The comparative yield performance (kg ha^{-1}) of JI-09-21 (GI 4) over different locations

Year	Trial	Yield (kg ha^{-1})		IOC (%)	Rank	S.Em. ±	CD	C.V. %
		JI-09-21	GI-3				(P<0.05)	
Jagudan								
2010-11	PET	1014	894	13.42	1/14	56	167	10.80
2011-12	PET	1078	948	13.71	1/14	49	150	10.39
2012-13	PET	907	863	5.10	2/14	51	155	9.47
2013-14	LSVT-II	946	874	8.24	1/10	52	155	11.55
2014-15	LSVT-II	949	812	16.87	1/10	50	148	11.12
	Mean (5)	979	878	11.46	-	-	-	-
Kholwada								
2013-14	LSVT-II	878	769	14.17	1/10	52	154	13.78
2014-15	LSVT-II	852 *	759	12.25	1/10	31	91	9.56
	Mean (2)	865	764	13.22	-	-	-	-
Deesa								
2014-15	LSVT-II	799	722	10.66	3/10	73	215	14.79
Overall Mean (8 trials)….		928	830	11.78	-	-	-	-
Superiority over check….		8/8	-	-	-	-	-	-

Table 2. Stability Analysis for seed yield in Isabgol

Variety	Yi (mean seed yield)(kg $plot^{-1}$)	bi(reg. coeff.)	S^2_{di}(mean Sq. dev.)
JI -09-21(GI 4)	0.82	0.94	0.00
GI-3 (Ch)	0.42	0.80	0.00
Mean	0.39	-	

Table 3. Comparative yield and quality attributes of JI -09-21 (GI 4)

Character	Mean	
	JI -09-21 (GI 4)	GI 3
Days to flowering	63	64
Days to maturity	102	104
Plant height (cm)	31.0	31.3
No. of tillers plant^{-1}	6.0	5.0
No. of spikes plant^{-1}	22.7	20.2
Spike length (cm)	4.7	4.5
No. of seeds spike^{-1}	80.7	76.4
1000 grain weight (g)	1.579	1.542
Swelling factor (cc g^{-1})	11.4	9.1

Table 4. Effect of water dipping on shattering of isabgol seed

Variety	Without Dipping		H.I %	Dipping in Water (Average of four sample)			
	Dry wt. (kg)	Seed wt. (kg)		Dry wt. (initial) (kg)	Sun dry wt. (kg)	Seed wt. after threshing (kg)	Shattering of seeds (%)
GI 4 (JI-09-21)	1.027	0.175	17.03	0.894	0.731	0.115	7.25
GI 3	0.959	0.158	16.47	1.038	0.811	0.037	70.07

GI-4 recorded 89.67% less shattering than that of check variety, which revealed that Gujarat Isabgol 4 was non shattering in habit as compared to Gujarat Isabgol 3 which is prone to high seed shattering. The post dipped seed weight of GI 4,-was 0.115 kg threshed seeds, which was 96% higher than that of the post dipped seed yield of GI-3 (0.037 kg threshed seeds) (Table 4). Hence, Gujarat Isabgol 4 recommended for cultivation.

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