



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

B Al-mansour, D Kalaivanan¹, M A Suryanarayana², K Umesha & A K Nair³

Department of Plantation, Spices, Medicinal and Aromatic Crops,
College of Horticulture, UHS Campus, Bengaluru, Karnataka.

*E-mail: baraaalmansour@yahoo.com

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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

¹Division of Soil Science & Agricultural Chemistry, ²Division of Floriculture and Medicinal Crops, ³Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru-560 089, Karnataka.

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 & Ordoorkhani 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 *khari* season of 2015 and 2016. The experimental station is located at an altitude of 890 m above mean sea level and 13°58' N latitude and 77°29' E longitudes. The nine treatments of experiment contain T₁ (FYM (10 t ha⁻¹) + 100% recommended N through FYM), T₂ (FYM (10 t ha⁻¹) + 100% recommended N through FYM + bio-fertilizer), T₃ (FYM (10 t ha⁻¹) + 75% recommended N through FYM), T₄ (FYM (10 t ha⁻¹) + 75% recommended N through FYM + biofertilizer), T₅ (FYM (10 t ha⁻¹) + 50% recommended N through FYM), T₆ (FYM (10 t ha⁻¹) + 50% recommended N through FYM + biofertilizer), T₇ (recommended FYM (10 t ha⁻¹ only), T₈ (recommended NPK (160:80:80 kg ha⁻¹) only), and T₉ (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 P₂O₅ ha⁻¹) and muriate of potash (80 kg K₂O 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 T₈ and T₉ 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 T₂, T₄ and T₆ treatments. Quantities of added fertilizers are given in (Table 2).

Table 1. Physical and chemical proprieties of initial experimental soil

| <i>Physical properties</i> | |
|--|------|
| Bulk density (Mg m ⁻³) | 1.32 |
| Particle Density (Mg m ⁻³) | 2.65 |
| Pore space (%) | 42 |
| <i>Chemical properties</i> | |
| 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°C for 5 min then 210°C hold for 1 min then 240°C hold it for 1 min and helium gas as a carrier at 1 ml min⁻¹. Injector and detector temperature were 270°C and 240°C, 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.*, T₉ 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 T₇ 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.*, T₉ recorded significantly the highest total herbage yield (59.3 t ha⁻¹) while, the lowest value (33.7 t ha⁻¹) was recorded in T₇ 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 T₇ (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 T₇ 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 T₉ applied with NPK (160:80:80 kg ha⁻¹) + FYM (10 t ha⁻¹) and the lowest total oil yield was recorded in T₇ 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 T₉ 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.*, T₂ 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 T₇ (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.*, T₉ 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 T₇ 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 N₂ and supply it to the plant they synthesis siderophores which play a key role for solubilization 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

K Kandiannan*, K S Krishnamurthy, C K Thankamani & S J Ankegowda¹

ICAR- Indian Institute of Spices Research, Kozhikode - 673012, Kerala.

*E-mail: kandiannan@gmail.com

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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 associated 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

¹Regional Station, ICAR-Indian Institute of Spices Research, Appangala, Madikeri, Kodagu-571201, Karnataka.

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° 16' N) down to just short of Kanyakumari (about 8°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 < 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 \pm 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

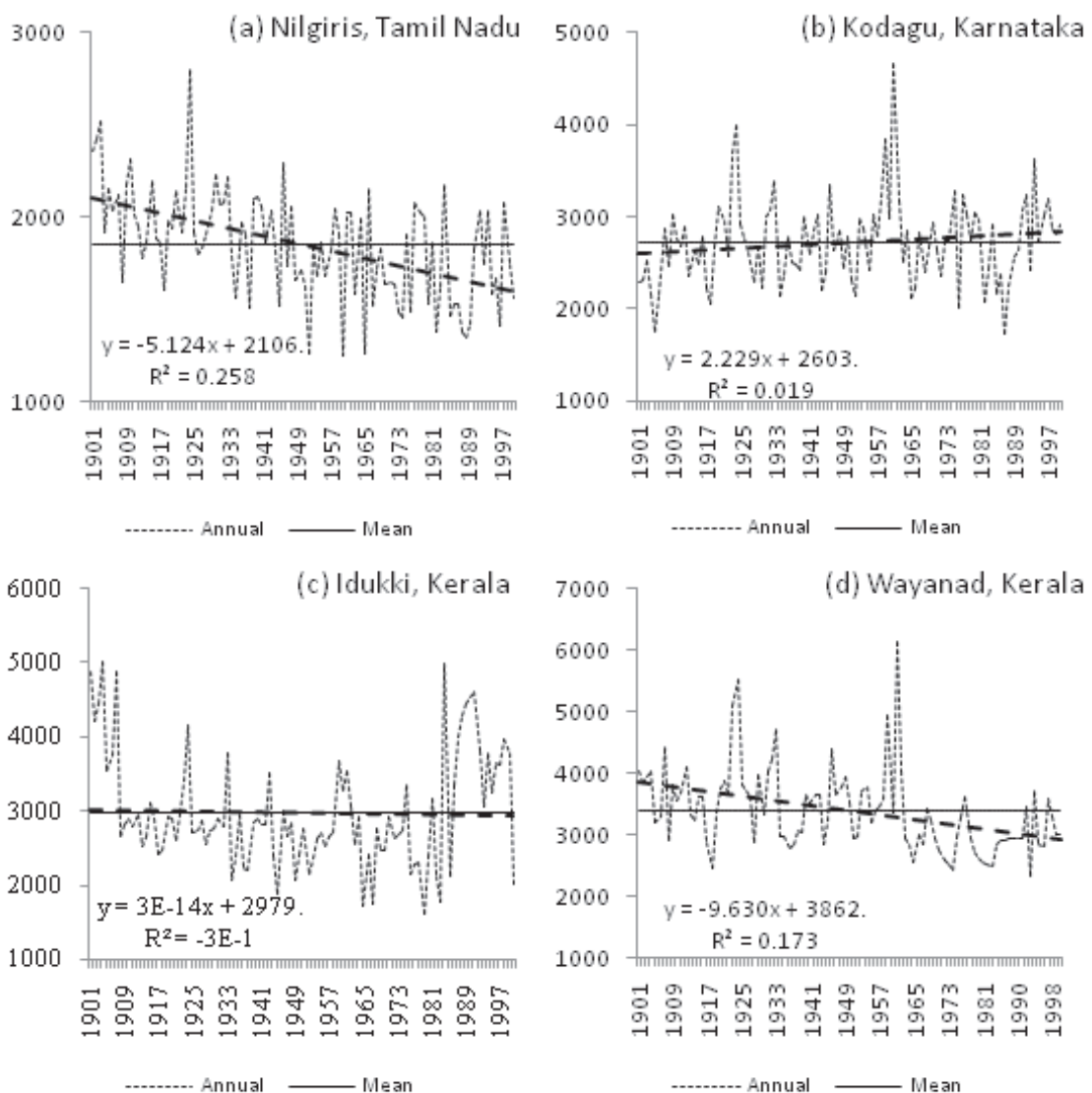


Fig. 1. Annual rainfall trend in exclusive Westen ghats districts (Nilgiris), (b) Kodagu, (c) Idukki, (d) Wayanad

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.)

T S Aswathy*, M K Dhanya, J Jintu, T Sathyan, T T Preethy & M Murugan

Cardamom Research Station, Kerala Agricultural University,
Pampadumpara-685 553, Idukki, Kerala.

*E-mail:aswathyrethna91@gmail.com

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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 their individual 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 strengtheners, 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 that improve 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 pepper rooted 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 | <i>Azospirillum</i> @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 + <i>Azospirillum</i> @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 (5 × 10⁷

cfu), *Azospirillum* (5 × 10⁷ cfu) and PGPR Mix I (Consortium of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *Bacillus sporothermodurans* each with 5 × 10⁷ 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 five plants/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 experiment were 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. But good improvement in vegetative characters was 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 cm²) 60 days after second treatment application compared to all the other treatments. Similar increase of 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 extract performed 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 extract treated 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 |
| <i>Azospirillum</i> - 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 + <i>Azospirillum</i> 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 |
| <i>Azospirillum</i> - 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 + <i>Azospirillum</i> 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

R S Bhai*, K P Subila, S J Eapen, A Reshma, R Pervez¹, A Ishwara Bhat & V Srinivasan

ICAR-Indian Institute of Spices Research, Marikkunnu PO, Kozhikode-673 012, Kerala.

*E-mail: rsbhai@rediffmail.com

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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 by 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 carbosulfan (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 chlamydosporia*, 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+ Carbosulfan 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 10⁹ mL⁻¹) each to 100 kg potting mixture. *Streptomyces* spp. grown as broth culture in Nutrient broth and 100 mL (cfu 10¹⁰ mL⁻¹) mixed with 1 kg vermicompost and grown for 5 days (cfu10⁸ 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 + Carbosulfan 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 + Carbosulfan (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. chlamydozporia*. 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. + Carbosulfan 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. chlamydozporia* 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 - <i>T. harzianum</i> + <i>P. chlamydozporia</i> | 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 + Carbosulfan | 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 | | | | | |

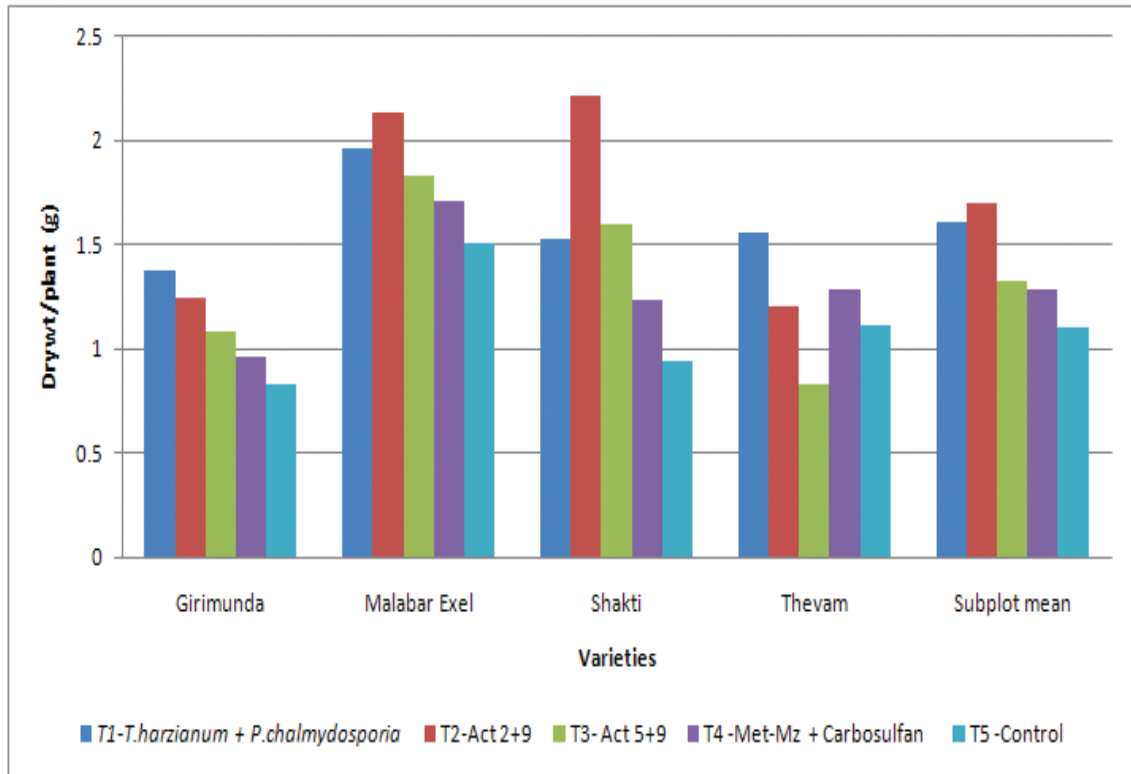


Fig. 1. Dry wt (g)/plant

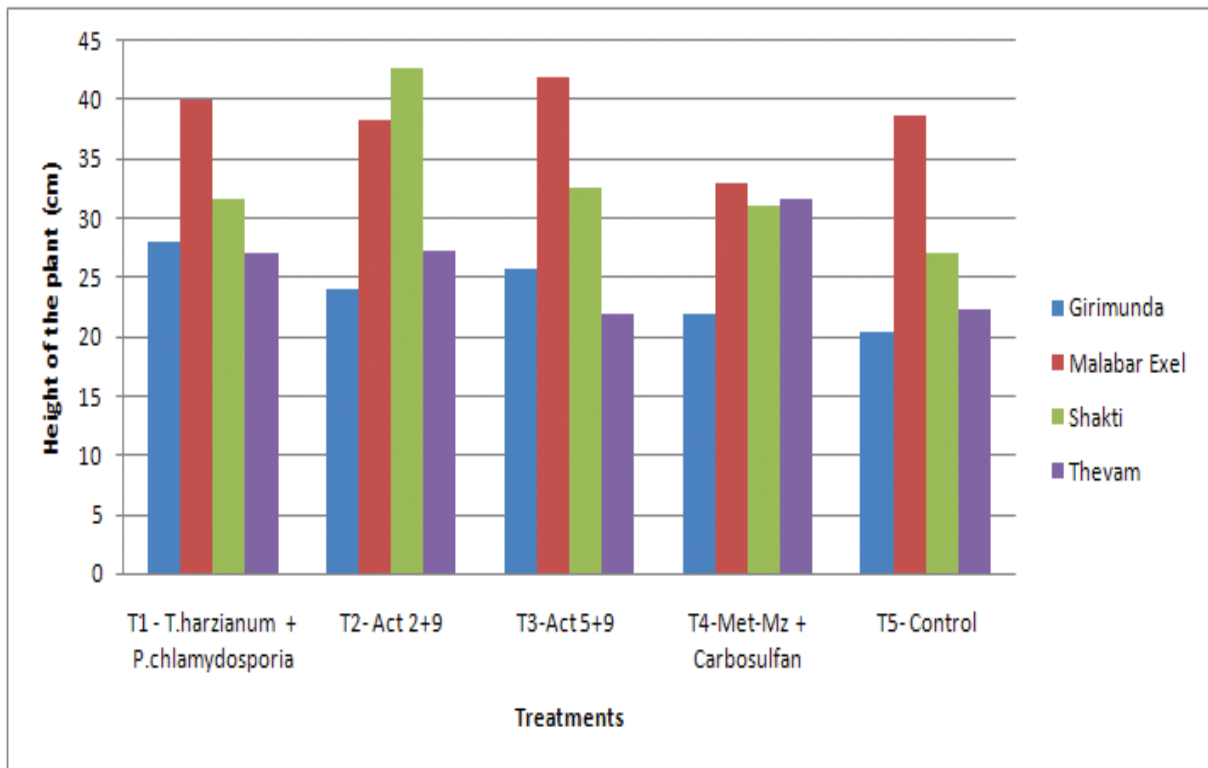


Fig. 2. Height of the plants

Table 2. Influence of treatments on number of roots

| Treatments | IISR Girimunda | IISR Malabar Excel | IISR Shakthi | IISR Thevam | Sub plot mean |
|--|-------------------|--------------------------|-----------------|----------------|------------------|
| T1- <i>T. harzianum</i> + <i>P. chlamydosporia</i> | 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- <i>T. harzianum</i> + <i>P. chlamydosporia</i> | 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- <i>T. harzianum</i> + <i>P. chlamydosporia</i> | 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 | IISR | IISR | IISR | Sub plot mean |
|---|-----------|---------------|---------|--------|---------------|
| | Girimunda | Malabar Excel | Shakthi | Thevam | |
| T ₁ - <i>T. harzianum</i> + <i>P. chlamydosporia</i> | 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 - <i>T. ha</i> + <i>P. chal</i> | 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.)

S Aarathi*, J Rema, B Sasikumar, K V Saji & M Anandaraj

ICAR-Indian Institute of Spices Research, Kozhikode-673 012, Kerala.

*E-mail: aarthichandru@gmail.com

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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 glyceracetocarmine (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.

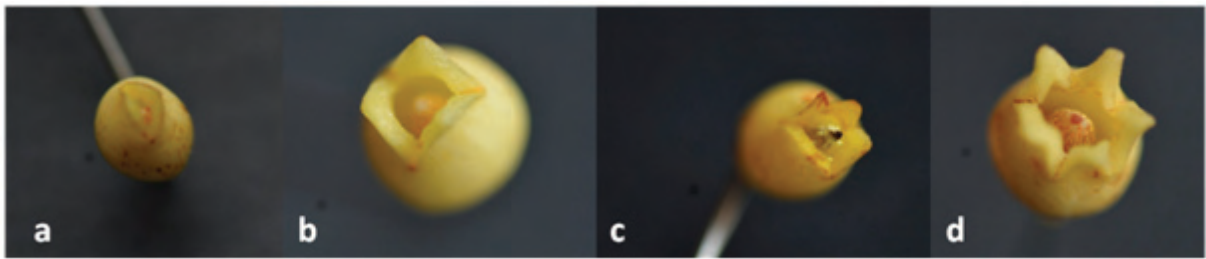


Fig. 1. Variation in flower opening in monoecious tree flowers [a) Dimerous, b) Trimerous, c) Tetramerous and d) Pentamerous]



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

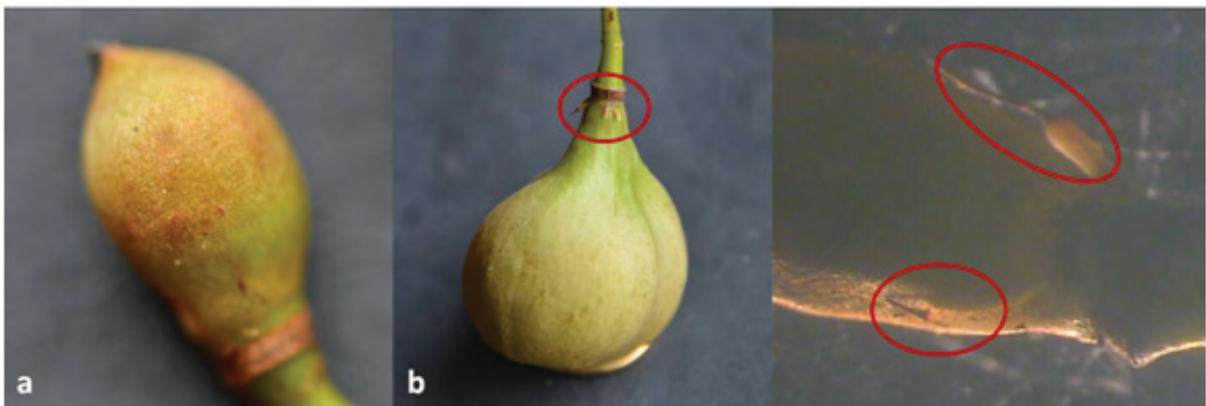


Fig. 3. Developed fruits from monoecious trees [a) from pistillate flowers, b) from hermaphrodite flowers (remnants of the stamen) and c) Microscopic view (20x)]

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

| Tree No | Average number of flowers | | | | Staminate | | Pistillate | | Hermaphrodite | |
|-------------|---------------------------|--------------|---------------|----------------|------------------------|-------------------------|----------------------|----------------|----------------------|--|
| | Staminate | Pistillate | Hermaphrodite | 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

A A Waman* & P Bohra

Division of Horticulture and Forestry,
ICAR-Central Inland Agricultural Research Institute, Port Blair-744 101, Andaman & Nicobar.
*E-mail: ajit.hort595@gmail.com

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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 3rd to October 11th) 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.* T₁: layering on July 3, T₂: layering on July 23, T₃: layering on August 12, T₄: layering on September 1, T₅: layering on September 21 and T₆: 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 vulgare* Mill.)

S L Sawargaonkar*, A K Singh & S Sahu

College of Agriculture & Research Station, Indira Gandhi Krishi Vishwavidyalaya,
Raigarh-496 001, Chhattisgarh.

*E-mail: shrikant.sawargaonkar@gmail.com

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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 × 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 vulgare* mill., stability, superiority

Fennel (*Foeniculum vulgare* 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, cardiotoxic, 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 (S²di) 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, $b_i = 1$ and $S^2d_i = 0$). 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 ($b_i = 1$) and non-significant deviation for regression ($S^2d_i = 0$). 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, $S^2d_i = 0$ but the value of $b_i \neq 1$, indicating their adaptation to high input conditions. For umbels plant⁻¹ genotype RF 205 and FNL 67 had $b_i = 1$ and $S^2d_i = 0$, 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 | Umbelets 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 (S²di =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 (S²di=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) | 2012-13 | | Disease reaction |
|---------|-------------|------------------------------|---------------|-------------|------------------|
| | | | % superiority | | |
| | | | RF 101(NC) | Local check | |
| 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 meteorological parameters recorded with Indian meteorological 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 humidity 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. Meteorological parameters during crop growth period from 2012-13 to 2014-15

| Year | Temperature | | Humidity | | Rain fall (MM) |
|---------|------------------------|-------|----------|-------|----------------|
| | (°C) | | (%) | | |
| | 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 annuum* L.) in arid condition

R L Bhardwaj¹, M M Sundria, S R Kumhar & N Kumar

Agricultural Research Station, Agriculture University, Jodhpur-342 304, Rajasthan.

*E-mail: rajubhardwaj3@gmail.com

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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 (T₈ 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 (T₁ treatment).

Keywords: *Capsicum annuum*, 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

¹Agricultural Research Station, Mandor, Jodhpur-342 304, Rajasthan.

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.*, T₁ = Check basin method, T₂ = furrow irrigation method, T₃ = Raise bed with trench method, T₄ = Flat bed with drip irrigation, T₅ = Flat bed + plastic mulch + drip irrigation, T₆ = Raise bed with drip irrigation, T₇ = Raise bed + organic mulch + drip irrigation, T₈ = Raise bed + plastic mulch + drip irrigation, T₉ = 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 x 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 quintal 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 T₈ treatment, which was significantly superior to other treatment but at par with T₆, and T₇ treatments. The maximum survival per cent of seedling in T₈ 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 T₁ 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 T₈ treatment whereas longest root system (10.50 cm) was observed in T₃ treatment. The minimum stem girth (1.68 cm) and the number of roots plant⁻¹ (53.57) were observed in T₁ treatment whereas shortest root system (7.97 cm) was observed in T₉ 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 |
|----------------|---------------------|--------|-------------------|------------|--|----------------------------|---------------------|----------------------------------|
| | 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 T₉ treatment whereas the maximum days (51.39) was required in T₅ 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 T₈ treatment, whereas lowest yield (153.45 q ha⁻¹) was recorded under T₁ 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 T₈ treatment followed by Rs 296192.61 ha⁻¹ with B: C ratio of 3.11 in T₅ treatment and lowest net profit of Rs 119007.80 ha⁻¹ with a B: C ratio of 1.63 in T₁ 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 T₅, T₇ and T₈ 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 T₅ treatment which closely followed by T₈ 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 (T₅ & T₈ 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 (T₂), drip irrigation system alone (T₄), drip irrigation system with LLDPE mulch (T₅ & T₈), drip irrigation with organic mulch (T₇) and sprinkler system (T₉) over conventional surface irrigation by check basin method (T₁) 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 Infestation |
|----------------|------------|-----------|-------------------------|--|--------------------------------------|---------------|---------------|------------------|
| 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 curling (5.5%) and highest quality score of fruit (9.11) was observed in T₈ treatment which was closely followed by T₇ and T₅ treatments where as maximum incidence of fruit rot (20.02%) and leaf curling (15.84%) was reported in check basin method of irrigation (T₁ treatment) whereas minimum quality score (6.50) was observed in T₉ 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 T₈ treatment whereas highest incidence of white flies (17.43 plant⁻¹) and weed infestation (30.03 weed m⁻²) was observed in T₁ 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

D G Patel, H B Patel*, P T Patel, H Patel & A U Amin

Seed Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University,
Jagudan-382 710, Mahesana, Gujarat.

*E-mail: hirenpbg@yahoo.co.in

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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 (S²di) 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 (S²di) 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 (P<0.05) | C.V. % |
|-----------------------------|----------|------------------------------|------|---------|------|---------|----------------|--------|
| | | JI-09-21 | GI-3 | | | | | |
| 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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