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# *Journal of Eco-Friendly Agriculture*



**Doctor's Krishi Evam Bagwani Vikas Sanstha**  
(Doctor's Agricultural and Horticultural Development Society)  
Registered under Society Registration Act 21, 1860  
Lucknow - 226 016, India

# JOURNAL OF ECO-FRIENDLY AGRICULTURE

(A Bi-annual Scientific Research Journal)

Doctor's Krishi Evam Bagawani Vikas Sanstha

(Doctor's Agricultural and Horticultural Development Society)

Registration No. 131380, ISSN 2229-628X

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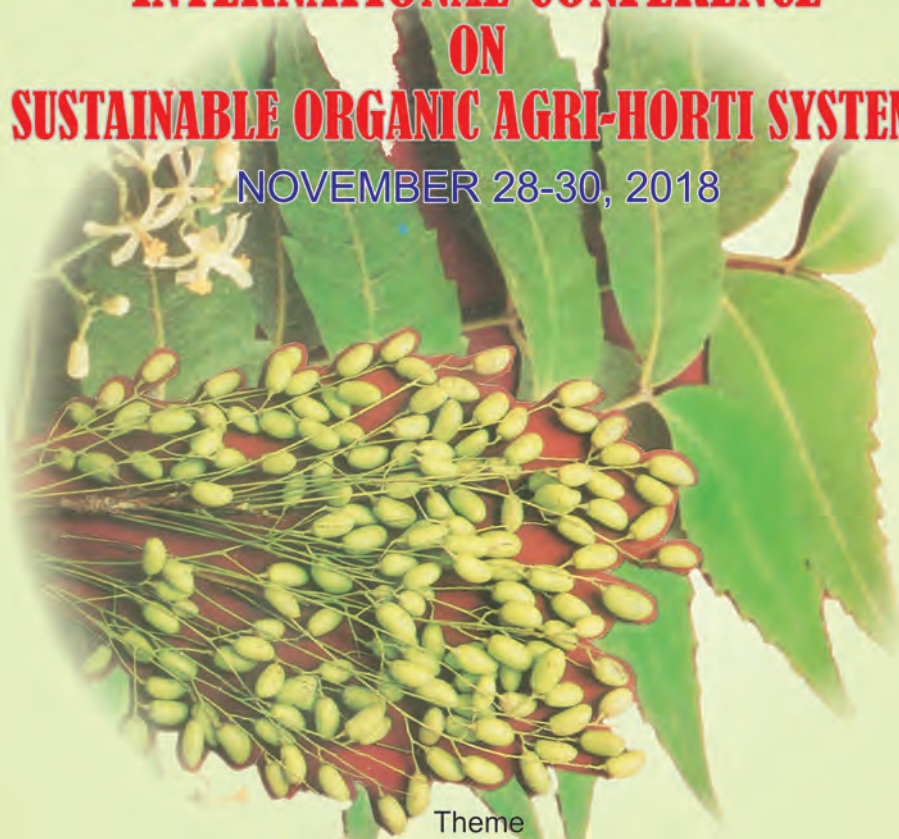
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# INTERNATIONAL CONFERENCE ON SUSTAINABLE ORGANIC AGRI-HORTI SYSTEMS

NOVEMBER 28-30, 2018



## Theme

Plant Origin Pesticides (Including Neem) in Agriculture,  
Integrated Pest and Nutrient Management, Animal Husbandry

## Venue

ICAR- Indian Institute of Sugarcane Research  
Raebareli Road, P.O. Dilkusha  
Lucknow - 226 002 (Uttar Pradesh), India



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## SOUVENIR

A colourful souvenir will be published to commemorate this occasion. The detailed programme and other useful information regarding the topic of the conference will also be published in souvenir.

## ANNOUNCEMENT FOR OUTSTANDING SCIENTIST AWARD IN THE FIELD OF BIO-PESTICIDES AND BIO FERTILIZERS

The Steering and Organizing Committee of the Doctor's Krishi Evam Bagwani Vikas Sanstha has decided to honour outstanding scientists in the field of bio-pesticides and bio-fertilizers (Two Awards) for their contribution in both basic and applied fields. All interested scientist may please send their current Curriculum Vitae, list of publications and a brief statement of the most significant research achievements along with relevant reference for consideration. In addition to above, ten most important publications (Photocopies) may be submitted with the application. Scientist working in Universities/Institute/Companies may please send their application through proper channel. Scientist not working in the above organization should forward their applications through well known scientist of this field. Last date for the submission of application is 15 October, 2018. Those scientist who has already received award for the same research work elsewhere are not eligible to apply.

The applications should be sent to Dr. R.P. Srivastava, Organizing Secretary, A-601, Indira Nagar, Lucknow-226 016 (Uttar Pradesh) India.

## APPLY FOR FELLOWSHIP OF THE SOCIETY

During the conference 'Fellow of Society' will be honoured. On the successful completion of 13 years of the completion of the *Journal of Eco-friendly Agriculture*, the Society has decided to recognize eminent scientists by awarding fellowship of the society (Fellow of Doctor's Agricultural and Horticultural Development Society, FDAHDS). For this, interested scientists may apply to the General Secretary, Doctor's Agricultural and Horticultural Development Society with their bio-data in prescribed format (given in the end of recent two issues of the journal) along with the fee of Rs 5000/- The applications will be evaluated by a competent committee for the award of the fellowship. Only Life Members are eligible to apply by paying an additional amount of Rs. 5000/- for the Life Membership separately.

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## INTERNATIONAL CONFERENCE ON SUSTANABLE ORGANIC AGRI-HORTI SYSTEMS

Doctor's Krishi Evam Bagwani Vikas Sanstha

(Doctor's Agricultural and Horticultural Development Society)

A-601, Sector-4. Indira Nagar, Lucknow – 226 016 (U.P.), India

NOVEMBER 28-30, 2018

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## BACKGROUND

Awareness is increasing about the organic farming all over the world. But farmers in many countries are yet to realise about the ill effect of modern agriculture practices. Hence, the alternative methods of farming particularly the organic farming is the need of the hour. Thus, use of natural products in agriculture has assumed greater practical importance with the current thrust on environmental safety and sustainability.

Statistics make it clear that use of insecticides, fungicides, weedicides and chemical fertilizers has increased manifold over the past several years, which continues to having increasing trend even today. At the same time, the losses have increased and several new problems are now visible. The indiscriminate use of these chemicals in crop management is not a solution to sustainable agriculture but has resulted in serious damages to non-target pest, diseases, and animals including human beings, besides killing natural enemies. This even causes development of resistance amongst pests and diseases to pesticides, may cause higher residue hazards, etc. This is resulting & upsetting of balance in nature.

This has prompted scientist's to look for a fresh approach towards crop management, nutrients management and also to safeguard the ecological balance. Thus, there is a need to use eco-friendly bio-pesticides, bio fertilizers, integrated pest management practices and integrated nutrient management technologies for doubling food production using organic techniques.

In recent years awareness has increased about the use of bio-pesticides, bio-agents, bio-fertilizers and other eco-friendly components for protecting environment and health hazards. But more focussed research is required for doubling production with sustainable organic *Agri-Horti Systems*. Thus, technologies need to be refined, which are eco-friendly as well as suitable for increasing production and reducing health hazards.

Keeping the above in view, the **International Conference on Sustainable Organic Agri-Horti Systems** is proposed, where the progress of research work will be discussed in detail and road map will be prepared for further systematic studies/research with emphasis on environmental friendly & sustainable technologies.

## INVITATION

We are immensely happy to extend our cordial invitation to you to participate in the **International Conference on Sustainable Organic Agri-Horti Systems** w.e.f. November 28-30, 2018 to be held at ICAR-Indian Institute of Sugarcane Research, Lucknow.

This conference is being organized by Doctor's Krishi Evam Bagwani Vikas Sanstha, (Doctor's Agricultural and Horticultural Development Society) Camp Office: A-601, Sector-4, Indira Nagar, Lucknow – 226 016 (U.P.), India in collaboration with ICAR- Indian Institute of Sugarcane Research, Lucknow, Department of Agriculture and Horticulture, U.P. Government Lucknow, NBRI Lucknow, NCOF Ghaziabad, Directorate of Plant Protection Faridabad and CISH Lucknow. The conference will be held in the beautiful and cosmopolitan city Lucknow, the capital of Uttar Pradesh.

The organising committee is providing a unique platform and has drawn a comprehensive program for the conference. You will be having the opportunity to interact with researchers, renowned scientists, scholars,

The hotel accommodation cost from Rs. 2500-7500 or onwards. Kindly send two days hotel charges in advance and for this please contact Dr. D. K. Tondon on mobile 94504411266.

The following hotels can be contact directly. If required you may send the money to us and will book for you. These are special rates.

1	<b>Hotel Clark Avadh</b> 8, Mahatma Gandhi Road, Hazratganj, Lucknow-226001, U.P., India	4 Star Hotel, Rent Rs. 6000/- per day for double occupancy room Contact Person- Shri R Bhargava, Mob: +919415015340, 0522-2620131 Email: reservation@clarksavadh.com
2	<b>Hotel Gemini</b> Gemini Continental, Near Hazratganj, Near Chatar Manzil, Lucknow 226001, U.P., India	4 Star Hotel Standard Superior (Double occupancy) - Rs. 4200/- Luxury Room (Double occupancy) - Rs. 5000/- + Tax Contact Person - Mr. Altamash Mob: +91-9918101228 Email: welcome@geminicontinental.com
3	<b>Hotel Gomti</b> 6, Sapru Marg, Near Hazratganj, Lucknow 226001, U.P. India (Govt. Hotel of State Tourism)	Three Star AC deluxe - Rs. 3000/- AC executive - Rs. 2500/- AC ordinary - Rs. 2000/- Air cooled - Rs. 900/- (All double occupancy) Contact Person - Mr. Ajeet Kumar Srivastava Mob: +91-9415233498, +91-522-2611463 Email: hotelgomti@up.tourism.com
4	<b>Hotel Bandhan</b> B-11, Faizabad Road, Indira Nagar, Lucknow-226016, U.P. India	Three Star Double occupancy Rooms are available between Rs. 2000/- to Rs. 3000/- Contact Person - Mr. Sandeep Kanojia Mob: +91-9972200377 Email: sandeepkanojia@oyorooms.com

### EXCURSION EVENTS

Towards the end of conference, research cum recreational tours can be organised if sufficient delegates register for it, on 01-12-2018. Tours will be undertaken to the fields of Indian Institute of Sugarcane Research, Lucknow, fields of Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, Chota Imambara, Bara Imambara, Bhulbulayia, Residency, Sahid Smarak, Ambedkar Park. The lunch will be arranged at Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow. The total excursion cost will be Rs. 1000/- per person. The same can be deposited along with registration fee.

Kindly send your willingness to the Joint Organizing Secretary,  
Dr. Jagdish Chandra, Lucknow, U.P. (M) 9415615666 &  
Dr. AK Misra, Lucknow, U.P., (M) 9838932188

### VENUE OF THE CONFERENCE

ICAR- Indian Institute of Sugarcane Research, Raebareli Road, P.O. Dilkusha, Near Telibagh, Lucknow-226 002, Uttar Pradesh, INDIA. The venue is located at about 5 kilometres from Lucknow Railway station/ Chaudhari Charan Singh International Airport, Lucknow. This is located 1/2 km. before the locality called Telibagh in Cantonment Area.



### PRESENTATION

Presentation of the research work conducted by scientists/development workers will be by keynote lecture, lead lecture and oral presentation or by poster presentation.

### PRIZES

The steering and organising committee will decide to award three prizes for the best poster paper presentations (One each from two sessions). The decision of the judging committee will be final.

organic agri-horti growers, industrialists and developmental organizations discovering different products, screening and evaluation as well as commercialization of these products, which are the important components in sustainable agriculture and horticulture production in our country.

### SCIENTIFIC AND TECHNICAL SESSIONS

Following are the different technical sessions under which researchers can contribute their research findings

Session I	:	Integrated pest management
Session II	:	Integrated nutrient management
Session III	:	Neem and other plant originated bio pesticides
Session IV	:	Breeding for resistance to insect pests, diseases and nematodes
Session V	:	Microbial bio-pesticides alternative to pesticides/herbicides
Session VI	:	Role of bio-dynamics and bio-fertilizers in crop production and protection
Session VII	:	Biological control of plant diseases
Session VIII	:	Commercialization of bio-pesticides, bio-agents and bio-fertilizers
Session IX	:	Role of parasitoids and predators in pest management
Session X	:	Human ecology and home sciences, organic textile and other eco-friendly agriculture
Session XI	:	Role of plant growth regulators for eco-friendly production
Session XII	:	Bio-technological tools for enhancing production
Session XIII	:	Eco-friendly Animal Husbandry

### CALL FOR PAPERS

Scientists/Researchers/academicians working in the area of IPM, IDM, INM, bio-pesticides, bio-agents, bio-fertilizers, human ecology, home science, organic textile and other allied eco-friendly areas are invited to submit, abstracts and full papers for scrutiny by the technical committee by 15<sup>th</sup> October 2018.

### INFORMATION FOR SUBMISSION OF ABSTRACTS

The abstract for oral or poster presentation should not exceed 300 words. The abstract should contain a title, author's name, affiliation, contents, key words and e-mail. Please mention clearly whether it is for oral or poster presentation. The abstract should be sent to e-mail : [organicconference2018@gmail.com](mailto:organicconference2018@gmail.com)

### IMPORTANT DEADLINE TO REMEMBER:

1. Registration	:	15/10/2018
2. Submission of demand draft	:	15/10/2018
3. Submission of abstract	:	15/10/2018
4. Hotel reservation	:	01/11/2018
5. Submission of full paper	:	01/11/2018

### REGISTRATION FEE

	Before 15/10/2018	After 15/10/2018
Research scientists / Development scientists / Officers /	6000	6500
Research associates		
Students (Non Ph D), Retired scientists, Farmers, NGO officials	4000	4500
Company's executive	10000	11000
Foreign delegates	US\$ 250	US\$ 260

### MODE OF PAYMENT

By Demand draft in favour of **DOCTOR'S KRISHI EVAM BAGWANI VIKAS SANSTHA** payable at LUCKNOW and sent it to the following address A-601, Indira Nagar, Lucknow-226016, Uttar Pradesh (India). The Registration and hotel charges may be sent by 15-10-2018.

**The payments can also be made by NEFT/IMPS/SWIFT transfer. The bank details are as per below -**

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2. IFSC Code	:	PUNB0241400
3. SWIFT Code	:	PUNBINBBLHT
4. Bank Name	:	Punjab National Bank
5. Branch	:	HAL Township, Lucknow-226016
6. Address	:	HAL Township, Faizabad Road, Lucknow, Uttar Pradesh-226 016 (India)
7. MICR Code	:	226024011

### IMPORTANT INFORMATION

1. While sending the delegate fee electronically, please enter your name/address/mobile number in the remarks column to enable us to trace your deposits/registration, etc.
2. The delegate registration fee include's conference kit, souvenir, Other important literature and hospitality. Organizers can provide letters of invitation on request
3. Delegate registration fee waiver, travel financial support will not be possible so kindly excuse.
4. Correspondence related to submission of abstract/ papers / key note addresses / material for souvenir should be made on : [organicconference2018@gmail.com](mailto:organicconference2018@gmail.com)
5. General correspondence related to conference should be made on mail [ecofriendlyagriculture@gmail.com](mailto:ecofriendlyagriculture@gmail.com)

### ACCOMMODATION

We will assist all our delegates in booking accommodation in Lucknow. These bookings will be taken on request. We have available in Lucknow government guest houses, hostels and various hotel to all our Guests.

# Nutrient diagnostics and fertilizer prescription in Citrus: A perspective analysis

A.K. Srivastava<sup>1</sup> and P.S. Shirgure<sup>2</sup>

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## Abstract

Productivity of a crop depends essentially on the two premier facts, nutrient balance and the biological activity. The biggest constraint in making soil analysis more purposeful is the non-redressal of spatial variation in soil fertility. Conjoint use of geoinformatics (Geographical Information System, Global Positioning System, Remote Sensing) and site specific nutrient management strategy have offered an easier method of combating such pivotal factor driving into reduced fertilizer use efficiency. Sensor-based technology (called proximal sensing of nutrients on real time basis) has further added a new dimension in providing the nutrient supply as per canopy size (Normalised difference vegetation index) using programmable multi-channel fertigation. Rhizosphere properties vis-à-vis microbial and nutrient dynamics has dictated soil fertility management options in recent past, especially in many of the perennial fruit crops badly suffering through recurrent replant failures. Identification, isolation and characterization of rhizosphere specific microbes and later their up-scaling in consortium mode has given some definite edge, especially, with mycorrhiza-based microbial consortium, in overcoming the multiple soil fertility constraints on one hand and successfully addressing the replant issues on the other hand. Development of microbial consortium (microbial reactor) exploiting the native and natural microbial synergisms (with twin role as growth promoter and antagonistic to soil borne pathogens) is one of the popular methods of managing multiple soil fertility constraints occurring within the rhizosphere. Such rhizosphere specific consortia (often called as crop-microbiome) could further engineer rhizosphere's nutrient demand and supply through loading with organic manures in a much value added form using a widely accepted concept like integrated nutrient management (INM).

**Keywords:** Fruits; Microbial consortium; Integrated nutrient management; Rhizosphere properties; fertigation; Geographical information system.

Citrus is considered highly nutrient responsive crop (Fageria et al., 2008; Srivastava, 2009). Balanced fertilization is considered one of the effective ways of not only cutting the cost of production, but doubling the farmers income as well (Srivastava 2010a; Srivastava and Malhotra 2014). In this regard, 4R Nutrient steward concept is considered by for the best strategy towards balanced fertilization (Srivastava and Singh, 2003b; 2005; Srivastava et al., 2010).

Considering 60 per cent of the world's arable lands having mineral deficiencies or elemental toxicity problems, citrus, by the virtue of its perenniality have emerged as world's leading fruit crop (Malhotra and Srivastava, 2015). Nutrient management-based production system of citrus like any other fruit crop is inherently complex to understand due to large variation in nutrient-use-efficiency (Chanda, 2014; Bhatnagar et al., 2016). Citrus is considered evergreen in nature, blessed with nutrient conservation mechanism, to facilitate an increased carbon return per unit of invested nutrient due to comparatively longer duration of photosynthesis eventually leading to higher nutrient-use-efficiency (Bindi et al., 1997, Centritto et al., 1999 a; 1999 b; Scholberg and Morgan, 2012). Perennial fruit trees (Ehleringer and Cerling, 1995) play an important role in

carbon cycle of terrestrial ecosystems and sequestering atmospheric CO<sub>2</sub> (Carbon sequestration in biomass of citrus trees ranges from 23.9 tons CO<sub>2</sub> ha<sup>-1</sup> for young trees to 109 tons CO<sub>2</sub> ha<sup>-1</sup> for mature trees) (Idso and Kimball, 2001; Conroy, 1992; Keutgen and Chen, 2001). 4R nutrient management concept, exploiting criteria of right choice of fertilizers at right dose at right stage of right crop has been the most pivotal driving force towards improved nutrient-use-efficiency (Germana, 1994; Kreditsu and Srivastava, 2014; Johns et al., 2009). However, citrus by the virtue of their perennial nature of woody framework (Nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages from the point of view of nutrient requirement and preferential requirement of some nutrients by specific fruit crop, collectively make them nutritionally more efficient than the annual crops (Fischer et al; 2012; Goh, 2004).

## Diagnosis of nutrient constraints

The gap in productivity level of Asia from research farm to farmers field is the major cause of concern (Peng et al., 2000; Srivastava, 2010a; 2010b; 2011; 2013a; 2013b), and the absence of adequate information on soil fertility and plant nutrition is frequently ascribed (Lareen et al; 2016). The

subject is further complicated by merely any reference values available with regard to diagnosis of nutrient constraints in different commercial citrus cultivars. The diagnostics available for other commercial cultivars have not provided the desired results when evaluated under varied citrus agro climates. Resultantly, the orchards continue to produce sub-optimally due to increasing gap between the amounts of nutrients added to that of annual demand with orchard age. Such emerging scenario simply goes un-noticed to the citrus growers, which is more worrying (Srivastava, 2013c; 2013d).

Many attempts on similar lines were earlier made to identify nutritional problems of citrus orchards in countries like China including other parts of India employing a variety of diagnostic methods, amounting to many discrepancies in the interpretation of results (Srivastava and Singh, 2001c; 2002; 2003a; 2003b). The nutrient constraint diagnosis hence, seldom addresses the problems that originally exist in field and, therefore, not sufficed to inflict the desired response of fertilization (Srivastava and Singh 2004a, 2004b; 2004c). Such differences in outcome of diagnosis can be overcome by developing a suitable nutrient diagnostics very specific to a cultivar, soil type, and climate (Srivastava and Singh, 2006; 2007). These studies have confirmed that large amounts of fertilizers are not always essential for maximum yields (Srivastava and Ngullie, 2009). Many methods have been used to develop and diagnose nutritional problems, but none of them is considered serving the purpose in entirety. Once a suitable nutrient diagnostics are developed, their application in mapping the distribution of different kinds of nutrient deficiencies becomes next important issue at individual orchard level or at location level (Srivastava et al., 2007; 2015). Application of geospatial tools in precision mapping of nutrient constraints is envisaged (Das et al., 2015; Srivastava et al., 2014). Any attempt of this kind, promise to ensure the sustainability in citrus production strongly level of low orchard productivity. The poor response of fertilization is largely attributed to non-redressal of nutritional problems originally existing in field in the absence of cultivar specific nutrient diagnostics (Srivastava and Singh, 2008a). The premier citrus cultivars of India, namely Nagpur mandarin (*Citrus reticulata* Blanco), 'Mosambi' sweet orange (*Citrus sinensis* Osbeck), Malta sweet orange (*Citrus sinensis* Osbeck), (*Citrus sinensis* Osbeck), Khasi mandarin (*Citrus reticulata* Blanco), Acid lime (*Citrus aurantifolia* Swingle), Kinnow mandarin (*Citrus deliciosa* Lour. x *Citrus nobilis* Tanaka) were extensively surveyed. DRIS indices were developed based on leaf analysis data in relation to fruit yield and accordingly nutrient constraints were identified (Srivastava and Singh, 2001a; 2001b; 2005; 2007; 2008b; 2009b; Srivastava et al., 2007).

**Leaf Analysis- Based diagnostics:** The leaf nutrients norms were developed employing two diverse diagnostic methods (Field Response Studies and Survey/Modelling and Diagnosis) using different citrus cultivars (Table 1). The difference in diagnostic methods apart from the agroclimate and nutrient uptake behavior of cultivar are the major contributory factors towards variation in reference values being recommended in relation to yield (Srivastava and Singh, 2003b; 2005; 2007; 2008b).

**Nagpur mandarin (*Citrus reticulata* Blanco):** Optimum leaf nutrient standards for 'Nagpur' mandarin: 2.24-2.40% N, 0.07-0.110% P, 1.18-1.56% K, 1.32-1.55% Ca, 0.48-0.67% Mg, 110-132 ppm Fe, 29-43 ppm Mn, 8-14 ppm Cu and 19-30 ppm Zn.

**Khasi mandarin (*Citrus reticulata* Blanco):** Optimum leaf nutrient standards for 'Khasi' mandarin: 2.23-2.49% N, 0.10-0.11% P, 1.86-2.12% K, 2.12-2.32% Ca, 0.28-0.38% Mg, and 148-180 ppm Fe, 72-85 ppm Mn, 10-19 ppm Cu and 24-39 ppm Zn.

**Kinnow mandarin (*Citrus reticulata* Blanco):** Optimum leaf nutrient standards for 'Kinnow' mandarin: 2.28-2.53% N, 0.10-0.13% P, 1.28-1.63% K, 2.12-3.12% Ca, 0.32-0.53% Mg, ppm Fe, 41.7-76.3 ppm Mn, 6.1-10.3 ppm Cu, 21.3-28.5 Zn.

**Mosambi sweet orange (*Citrus sinensis* Osbeck):** Optimum leaf nutrient standards for 'Mosambi' sweet orange: 1.98-2.57% N, 0.091-0.17% P, 1.33-1.72% K, 1.73-2.98% Ca, 0.32-0.69% Mg, 69.5-137.1 ppm Fe, 42.2-87.0 ppm Mn, 6.6-15.8 ppm Cu, 11.6-28.7 ppm Zn, 12.8-23.1 ppm B, and 0.39-1.1 ppm Mo.

**Sathgudi sweet orange (*Citrus sinensis* Osbeck):** Optimum leaf nutrient standards for 'Sathgudi' sweet orange: 2.01-2.42% N, 0.09-0.12% P, 1.12-1.82% K, 1.93-2.73% Ca, 0.36-0.53% Mg, 53.5-82.1 ppm Fe, 48.7-79.3 ppm Mn, 3.7-8.9 ppm Cu, 16.5-23.2 ppm Zn, 12.8-23.1 ppm B, and 0.39-1.1 ppm Mo.

**Malta sweet orange (*Citrus sinensis* Osbeck):** Optimum leaf nutrient standards for 'Malta' sweet orange: 2.14-2.31% N, 0.10-0.14% P, 1.10-1.56% K, 2.89-3.41% Ca, 0.39-0.52% Mg, 42.6-81.4 ppm Fe, 28.1-54.3 ppm Mn, 4.2-8.9 ppm Cu, 28.1-54.3 ppm Zn.

**Acid lime (*Citrus aurantifolia* Swingle):** Optimum leaf nutrient standards for Acid lime: 1.80-2.12% N, 0.09-0.13% P, 0.79-1.43% K, 2.04-3.12% Ca, 0.28-0.46% Mg, 38.4-98.3 ppm Fe, 28.1-58.4 ppm Mn, 6.1-9.9 ppm Cu, 16.9-21.4 ppm Zn.

**Soil Fertility Norms:** The soil test method rests on the assumptions that roots would extract nutrients from the soil

in a manner comparable to chemical soil extractants, and that there is a simple direct relation between the extractable concentration of nutrients in the soil and uptake by plants (Srivastava et al., 2009). This is based on the concept that an ideal soil is one where the cations are present in ideal proportions (Srivastava and Singh, 2009a). One serious defect of this approach, is that it has to be significantly modified in relation to soil type, in particular as between calcareous and non-calcareous soils (Srivastava et al., 2008). Besides adjusting the recommendations in relation to targetted yield. Otherwise, soil nutrient depletion has grave implications in terms of : i. more acute nutrient deficiencies, ii. two wide spread nutrient deficiencies, iii. fall in fertilizer use efficiencies and in returns from fertilization, iv. weakening the foundation of sustainable high yield and v. very high remedial cost involved in building up the depleted soils (Srivastava and Kholi, 1997). Differential soil fertility norms (Srivastava and Singh, 2001a; 2001b; 2001c; 2002) were obtained in relation to commercial citrus cultivars are briefly summarised below (Table 1).

**Nagpur mandarin (*Citrus reticulata* Blanco):** Optimum soil fertility limit was observed as : Alkaline  $\text{KMnO}_4$ -N 118.4-1321.2  $\text{mg kg}^{-1}$ , Olsen-P 9.2-10.3  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 178.4-232.5  $\text{mg kg}^{-1}$ , DTPA-Fe 12.4-16.2  $\text{mg kg}^{-1}$ , DTPA-Mn 8.6-12.2  $\text{mg kg}^{-1}$ , DTPA-Cu 2.1-2.3  $\text{mg kg}^{-1}$  and DTPA-Zn 0.98-1.1  $\text{mg kg}^{-1}$  in relation to fruit yield of 39.7-54.1  $\text{kg tree}^{-1}$ .

**Khasi mandarin (*Citrus reticulata* Blanco):** Optimum soil fertility limit was observed as : Alkaline  $\text{KMnO}_4$ -N 220.8-240.6  $\text{mg kg}^{-1}$ , Bray-P 6.2-7.8  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 252.2-300.8  $\text{mg kg}^{-1}$ , DTPA-Fe 82.2-114.6  $\text{mg kg}^{-1}$ , DTPA-Mn 21.4-32.8  $\text{mg kg}^{-1}$ , DTPA-Cu 0.82-1.62  $\text{mg kg}^{-1}$ , and DTPA-Zn 2.18-4.22  $\text{mg kg}^{-1}$  for an optimum fruit yield of 25.0-32.0  $\text{kg tree}^{-1}$ .

**Kinnow mandarin (*Citrus reticulata* Blanco):** Optimum soil fertility limit was observed as : Alkaline  $\text{KMnO}_4$ -N 118.2-128.4  $\text{mg kg}^{-1}$ , Olsen-P 9.4-16.3  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 158.3-208.2  $\text{mg kg}^{-1}$ , DTPA-Fe 3.1-9.3  $\text{mg kg}^{-1}$ , DTPA-Mn 4.8-7.3  $\text{mg kg}^{-1}$ , DTPA-Cu 0.58-1.25  $\text{mg kg}^{-1}$ , DTPA-Zn 0.64-0.98  $\text{mg kg}^{-1}$  for the fruit yield of 61.8-140.3  $\text{kg tree}^{-1}$ .

**Mosambi sweet orange (*Citrus sinensis* Osbeck):** Optimum soil fertility limit was observed as: Alkaline  $\text{KMnO}_4$ -N 130.1-142.2  $\text{mg kg}^{-1}$ , Olsen-P 9.8-11.4  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 182.4-210.3  $\text{mg kg}^{-1}$ , DTPA-Fe 13.2-18.6  $\text{mg kg}^{-1}$ , DTPA-Mn 14.6-22.6  $\text{mg kg}^{-1}$ , DTPA-Cu 2.16-2.42  $\text{mg kg}^{-1}$ , DTPA-Zn 0.98-1.21  $\text{mg kg}^{-1}$ , hot water soluble-B 0.28-0.48  $\text{mg kg}^{-1}$ , and  $(\text{NH}_4)_2\text{C}_2\text{O}_4$ -Mo 0.08-0.10  $\text{mg kg}^{-1}$  for the fruit yield of 79.4-93.9  $\text{kg tree}^{-1}$ .

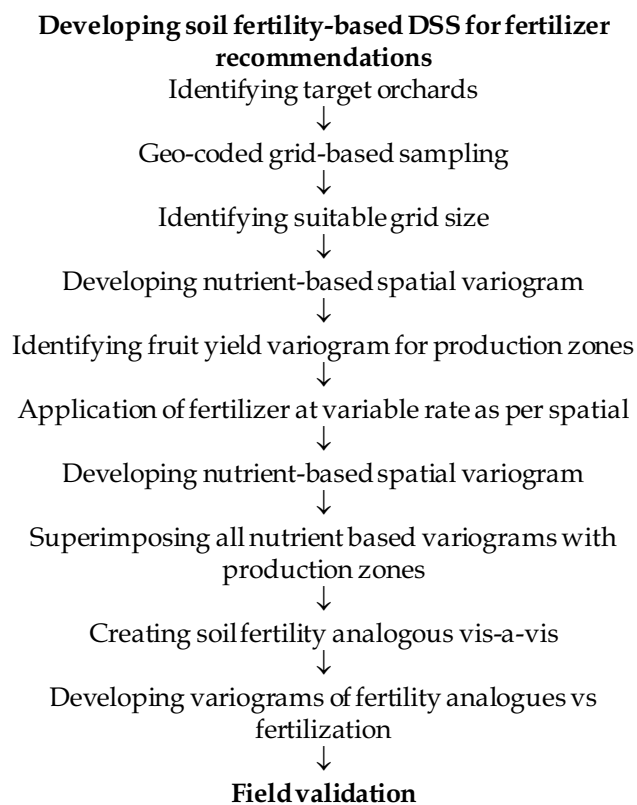
**Sathgudi sweet orange (*Citrus sinensis* Osbeck):** Optimum soil fertility limit was observed as: Alkaline  $\text{KMnO}_4$ -N 120.1-152.2  $\text{mg kg}^{-1}$ , Olsen-P 10.1-12.3  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 162.3-

206.4, DTPA-Fe 11.2-16.4  $\text{mg kg}^{-1}$ , DTPA-Mn 10.1-18.3  $\text{mg kg}^{-1}$ , DTPA-Cu 2.2-3.6  $\text{mg kg}^{-1}$ , DTPA-Zn 0.54-1.10  $\text{mg kg}^{-1}$ .

**Malta sweet orange (*Citrus sinensis* Osbeck):** Optimum soil fertility limit was observed as : Alkaline  $\text{KMnO}_4$ -N 110.5-124.6  $\text{mg kg}^{-1}$ , Olsen-P 9.2-14.6  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 131.6-181.2, DTPA-Fe 9.8-14.2  $\text{mg kg}^{-1}$ , DTPA-Mn 6.9-9.2  $\text{mg kg}^{-1}$ , DTPA-Cu 0.82-1.10  $\text{mg kg}^{-1}$ , DTPA-Zn 0.81-0.96  $\text{mg kg}^{-1}$  for fruit yield of 23.1-38.9  $\text{kg tree}^{-1}$ .

**Acid lime (*Citrus aurantifolia* Swingle):** Optimum soil fertility limit was observed as : Alkaline  $\text{KMnO}_4$ -N 106.3-118.2  $\text{mg kg}^{-1}$ , Olsen-P 9.2-14.6  $\text{mg kg}^{-1}$ ,  $\text{NH}_4\text{OAc}$ -K 102.4-146.6, DTPA-Fe 4.6-12.3  $\text{mg kg}^{-1}$ , DTPA-Mn 3.2-10.1  $\text{mg kg}^{-1}$ , DTPA-Cu 0.80-1.40  $\text{mg kg}^{-1}$ , DTPA-Zn 0.78-0.89  $\text{mg kg}^{-1}$  for fruit yield of 22.0-41.2  $\text{kg tree}^{-1}$ .

**Decision support for soil test-based fertilizers recommendations:** Any attempt to rationalise the fertilizer use and improve fertilizer efficacy in citrus orchard will surely be associated with consequent enhancement in production provided all other factors are optimum (Zaman and Schmann, 2006; Srivastava, 2013b). Limited attempts in the past have been made in perennial crop like citrus, which needs to be managed through precision based technologies (Srivastava et al., 2014). The development of decision support



tool based on soil fertility variation is one such viable option to address the nutrient mining and fluctuating yield levels. The utility of precision tool like GIS technology in mapping the fertility status of soil has undoubtedly provided the desired accuracy and effectiveness in fertilizer recommendations. The rhizosphere (0-20 cm) oriented soil samples through four grid sizes (10 x 10 m, 20 x 20 m, 40 x 40 m and 60 x 60 m) were collected using GPS-based tracking system at orchard finally earmarked at Umsaitining Ribhoi district of Meghalaya and Ladgaon (Katol), Nagpur district of Maharashtra. The spatial variograms of these parameters were developed based on data generated through soil tests under different grid sizes were developed using geographical information system (GIS) and interpreted for working out the optimum grid size for soil fertility evaluation in Khasi mandarin (Srivastava and Singh, 2006; 2015). The spatial variogram suggested the optimum grid size for precise soil testing is 40 m x 40 m under hilly terrain of northeast India and Central India of Maharashtra, cultivating Khasi mandarin and Nagpur mandarin, respectively. Based on soil test values for different nutrients, doses of fertilizers and targeted fruit yield, a tripartite prediction models were developed viz., Fertilizer Nitrogen = 13.09 (Targeted Fruit Yield) – 2.37 (Soil test value for Nitrogen); Fertilizer Phosphorous = 4.08 (Targeted Fruit Yield) – 26.83 (Soil test value for Phosphorous); Fertilizer Potassium = 1.69 (Targeted Fruit Yield) – 0.39 (Soil test value for Potassium) for Nagpur mandarin. Similarly, prediction equations for Khasi mandarin were developed as decision support viz., Fertilizer Nitrogen = 13.09 (Targeted Fruit Yield) – 2.37 (Soil test value for Nitrogen); Fertilizer Phosphorous = 4.08 (Targeted Fruit Yield) – 26.83 (Soil test value for Phosphorous); Fertilizer Potassium = 1.69 (Targeted Fruit Yield) – 0.39 (Soil test value for Potassium). These decision supports were duly validated in field and now in process of facilitating advisory service using 4R guidelines in citrus.

We are currently working in the process of developing 4R-Nutrient Expert for Citrus with the use of above information. Developing a nutrient diagnostic tool having capacity to diagnose a nutrient constraint as it occurs in field, has always been a challenge. In this regard, we have developed a Ready Reckoner for soil test-based fertilizer recommendation in citrus, the first ever solitary attempt made so far in India (Table 2)

**1.1.4 Soil suitability criteria:** Ideally, there are three basic requirements for successful cultivation of any horticultural crop, namely, climate relatively free from frost, good quality of irrigation water and a reasonably deep uniform fertile soil with good internal drainage (Srivastava and Kholi 1997; Srivastava and Singh, 2008a). Consequences of poor soil type

can often be tailored through efficient use of irrigation, drainage and soil amendments. More often than not, such modifications of the soil (Fig. 1) and its environment are made to assist crop growth and survival in addition to increased nutrient uptake efficiency, a secondary consideration (Srivastava et al., 2007). Different citrus cultivars over the years, have displayed some extraordinary success on great variety of soils. And resultantly, development of distinct commercial belts (Production epicenters) of mango, grapes, citrus, pomegranate, banana, litchi, apple, seed spices/spices, coconut, tea/coffee, pineapple, potato, onion have emerged as major success stories of Indian Horticulture. Their huge success along these commercial belts needs to be analysed from the perspective of role of nature and properties of different soils in order to ensure their continued sustenance. Soil suitability criteria developed for Nagpur mandarin and sweet orange (Table 3) would go a long way in establishing the future citrus industry free of soil related constraints.

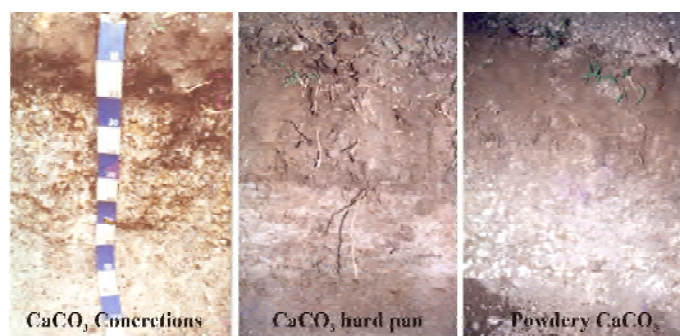


Fig 1. Different forms of soil physical constraints identified in citrus

### Deficiency symptoms

Like any other perennial fruit crop, citrus is a heavy forager of nutrients and, therefore, highly responsive to applied fertilizers. Nutrient mining emerging due to widening gap between the amounts of nutrients applied and to those removed, amount to occurrence of large scale nutrient deficiencies (Srivastava 2013d). A variety of nutrient constraints diagnostic methods are used in citrus orchards. Those comprise of leaf analysis, soil analysis, juice analysis, sap analysis, biochemical analysis, and morphological symptoms-linked deficiency symptoms (Srivastava and Malhotra, 2014). Of them, use of morphological symptoms acts as a field manual for citrus growers who can easily identify the nutritional problems in their orchards and adapt the corrective measures accordingly. The nutrient deficiency symptoms appear on different plant parts, most frequently on leaves, fruits and roots, in addition to types of leaves



Fig 2. Morphological expression of nutrient deficiencies in citrus: Is it post mortem diagnosis...?

depending upon nature and properties of different nutrient elements (Srivastava et al., 2008). The symptoms on fruits are noticed for very immobile nutrients like B and Ca. Development of visible symptoms is accountable to metabolic disorders which cause changes in micro-morphology of plants before these symptoms are identifiable. The way in which the symptoms develop and manifest on younger or older leaves or the fruits, gives a reliable indication about the cause of nutritional disorders (Srivastava et al., 2007). Both deficiency and excess of nutrients can lead to reduction in crop yield coupled with inferior fruit quality (Srivastava and Singh, 2008a). Mild visible leaf symptoms of some of the essential element deficiencies (Fig. 2) can be tolerated without a reduction in yield in some citrus varieties, but not in others. For example, sweet orange trees can withstand the mild foliage symptoms of Zn-deficiency without a loss in yield, while the lemon trees suffer the heavy yield loss (Srivastava

and Singh, 2009a).

**Management of nutrient constraints:** Our initial efforts were to : standardise optimum fertilizer requirement as recommended doses of fertilizers (RDF) through multi-location experiments, scheduling nutrient application across crop phenophases, scheduling fertigation by partitioning both nutrient and water requirement across critical growth stages, backed up by development of cultivar specific nutrient diagnostics, to be in a position to practice advanced methods of nutrient management (Srivastava, 2013b). Attempts were later made to address these issues with combined use of concepts like Site Specific Nutrient Management (SSNM) and soil fertility spatial variogram-based fertilizer recommendations as decision support tool. Success of SSNM depends on correctness of measurement and understanding on variability in available supply of nutrients, which can be summarized in three steps viz., i. assessing variation ii. managing variation, and iii. evaluation but there is hardly any comprehensive coverage addressing the perennial crops. Spatial maps are fundamental to SSNM addressing variation either soil fertility or leaf nutrient composition because they represent either the spatial state of a growing condition. With new advances in technology, grid sampling for developing precision variogram is increasing.

The first step in the process is to divide large fields into small zones using a grid. Next, a representative location within the grid is identified for precision soil sampling (Srivastava and Singh, 2015). Grid sampling is integrated into global positioning system (GPS) based soil sampling and nutrient-mapping that in turn uses a geographic information systems (GIS) to employ variable rate technology (VRT) for fertilizer applications. Optimum grid size soil mapping using specific nutrient-based spatial variograms as a interpretation tool popularly known as DRIS developed for Khasi mandarin of northeast India and Nagpur mandarin of central India aided in measuring the magnitude of changes

in pool of soil available nutrients before and after fertilization (Srivastava et al., 2010).

Nutrient management-based production system of citrus like any other fruit crop is inherently complex to understand due to large variation in nutrient-use-efficiency (Scholberg and Morgan, 2012). Citrus is considered evergreen in nature, blessed with nutrient conservation mechanism, to facilitate an increased carbon return per unit of invested nutrient due to comparatively longer duration of photosynthesis eventually leading to higher nutrient-use-efficiency. 4R-nutrient management concept, exploiting criteria of right choice of fertilizers at right dose at right stage of right crop has been the most pivotal driving force towards improved nutrient-use-efficiency. However, citrus by the virtue of their perennial nature of woody framework (Nutrients locked therein), extended physiological stages of growth, differential root distribution pattern (root volume distribution), growth stages from the point of view of nutrient requirement and preferential requirement of some nutrients by specific fruit crop, collectively make them nutritionally

more efficient than the annual crops. This is the reason, it is considered as such a wholesome concept (Srivastava and Malhotra, 2017).

Any attempt to rationalise the fertilizer use and improve fertilizer efficacy using such Nutrient Stewardship Concept in citrus orchard will surely be associated with consequent enhancement in quality production, provided all other factors are optimum (Tiwari, 2002). Limited attempts in the past have been made in perennial crop like citrus, which needs to be managed through precision-based technologies. Such an attempt exploiting the basic principles of 4R-Nutrient Stewardship will ensure the sustainability in production by raising productivity per unit of nutrient, but long term soil health will be the core agenda of such programme (Srivastava and Singh, 2008).

**Inorganic fertilizer scheduling:** Soil provides nearly all the nutrients essential to complete the life cycle of a plant. Different soil properties primarily determine the extent of a fertilizer response and the crop rotation on some recently

Table 1. Nutrient optima-based diagnostic limits for different citrus cultivars grown in India

Nutrients	Mandarins ( <i>Citrus reticulata</i> Blanco)			Sweet oranges ( <i>Citrus sinensis</i> Osbeck)			Acid lime
	Nagpur mandarin	Kinnow* mandarin	Khasi mandarin	Mosambi sweet orange	Sathgudi sweet orange	Malta sweet orange	( <i>Citrus aurantifolia</i> Swingle)
Soil test- based diagnostics							
N (mg kg <sup>-1</sup> )	94.8 –154.8	114.3- 121.2	161.0- 418.7	107.4- 197.2	120.1-152.2	110.5-124.6	106.3-118.2
P (mg kg <sup>-1</sup> )	6.6 – 15.9	7.8-12.3	4.5 – 8.7	8.6-15.8	10.1-12.3	9.2-14.6	9.2-14.6
K (mg kg <sup>-1</sup> )	146.8 –311.9	96.4-131.3	82.3 -287.5	186.4- 389.2	162.3-206.4	131.6-181.2	102.4-146.6
Ca (mg kg <sup>-1</sup> )	408.1 616.0	89.4-248.6	148.8- 285.4	512.1- 728.4	582.3-812.2	210.6-294.3	210.3-318.7
Mg (mg kg <sup>-1</sup> )	85.2-163.2	72.3-89.6	31.3 – 84.4	119.4- 182.3	123.8-198.7	72.9-94.6	89.6-106.3
Fe (mg kg <sup>-1</sup> )	10.9-25.2	5.8-11.1	39.5 – 180.9	1.76-4.70	11.2-16.4	9.8-14.2	4.6-12.3
Mn (mg kg <sup>-1</sup> )	7.5- 23.2	4.3-6.9	27.0 – 80.3	0.44-1.03	10.1-18.3	6.9-9.2	3.2-10.1
Cu (mg kg <sup>-1</sup> )	2.5 – 5.1	0.45-0.69	0.67 – 2.90	0.31-0.57	2.2-3.6	0.82-1.10	0.80-1.40
Zn (mg kg <sup>-1</sup> )	0.59 – 1.26	0.62-0.78	2.84 – 5.14	0.09-0.16	0.54-1.10	0.81-0.96	0.78-0.89
Yield (kg tree <sup>-1</sup> )	47.7 –117.2	32.8-56.2	31.6 – 56.3	76.6-137.9	82.9-158.2	23.1-38.9	22.0-41.2
Leaf analysis-based diagnostics							
N (%)	1.70 – 2.81	2.22-2.32	1.97 –2.56	1.98-2.57	2.01-2.42	2.14-2.31	1.53-2.10
P (%)	0.09 – 0.15	0.11-0.15	0.09 – 0.10	0.091-0.17	1.12-1.82	0.10-0.14	0.10-0.15
K (%)	1.02 – 2.59	1.10-1.41	0.99 – 1.93	1.33-1.72	1.93-2.73	1.10-1.56	0.96-1.66
Ca (%)	1.80 – 3.28	2.32-2.79	1.97 – 2.49	1.73-2.98	0.36-0.53	2.89-3.41	3.05-3.43
Mg (%)	0.43 – 0.92	0.38-0.61	0.24 – 0.48	0.32-0.69	53.5-82.1	0.39-0.52	0.40-0.60
Fe (ppm)	74.9 – 113.4	22.4-58.3	84.6 – 249.0	69.5-137.1	48.7-79.3	42.6-81.4	0.25-0.29
Mn (ppm)	54.8 – 84.6	26.3 -56.2	41.6 – 87.6	42.2-87.0	3.7-8.9	28.1-54.3	117-194
Cu (ppm)	9.8 – 17.6	4.2-7.2	2.13 – 14.4	6.6-15.8	16.5-23.2	4.2-8.9	21-63
Zn (ppm)	13.6 – 29.6	21.3-26.9	16.3 – 26.6	11.6-28.7	12.8-23.1	21.3-26.9	8.68-14.8
Yield (kg/tree)	47.7 – 117.2	32.4-56.1	31.6 – 56.3	76.6-137.9	82.9-158.2	23.1-38.9	56.4-70.0

Source: Srivastava and Singh (2003a; 2003b; 2005; 2007; 2008b)

Table 2. Ready reckoner for soil test-based fertilizer recommendation at various targeted fruit yield levels of Nagpur mandarin (*Citrus reticulata Blanco*)

Soil N (kg ha <sup>-1</sup> )	N-Recommendation										
	100	120	140	160	180	200	220	240	260	280	300
100	107.20		159.56		211.92		264.28		316.64		369.00
140	104.83		157.19		209.55		261.91		314.27		366.63
180	102.46		154.82		207.18		259.54		311.90		364.26
220	100.09		152.45		204.81		257.17		309.53		361.89
260	97.72		150.08		202.44		254.80		307.16		359.52
300	95.35		147.71		200.07		252.43		304.79		357.15
340	92.98		145.34		197.70		250.06		302.42		354.78
380	90.61		142.97		195.33		247.69		300.05		352.41
420	88.24		140.60		192.96		245.32		297.68		350.00
Soil P (kg ha <sup>-1</sup> )	P- Recommendation										
	100		140		180		220		260		300
5	34.58		53.78		72.98		92.18		111.38		130.58
10	21.17		40.37		59.57		78.77		97.97		117.17
15	7.75		26.95		46.15		65.35		84.55		103.75
20	-5.66		13.54		32.74		51.94		71.14		90.34
25	-19.07		0.125		19.32		38.52		57.72		76.92
30	-32.49		177.67		269.83		361.99		454.15		546.31
Soil K (kg ha <sup>-1</sup> )	K – Recommendation										
	100		140		180		240		260		300
100	130.0		197.78		265.46		366.98		400.82		468.50
140	114.6		182.14		249.82		351.34		385.18		452.86
180	98.82		166.5		234.18		335.70		369.54		437.22
240	75.36		143.04		210.72		312.24		346.08		413.76
260	67.54		135.22		202.90		304.42		338.26		405.94
300	51.90		119.58		187.26		288.78		322.62		390.30
340	36.26		103.94		171.62		273.14		306.98		374.66
380	20.62		88.3		155.98		257.50		291.34		359.02
420	4.98		72.66		140.34		241.86		275.70		343.38

Source: Srivastava et al. (2010)

published review articles changes in physico-chemical and biological properties of soil (Srivastava and Ngullie, 2009). One of the major obstacles of conventional practices of addressing nutritional requirements of citrus either through soil fertilization or through foliar feeding, is the precise diagnosis if the nutrient constraint type, their doses as per crop age and soil type, with the result more often such practices have not been able to facilitate the realisation of potential productivity of citrus (Srivastava et al., 2008). Neither any due consideration is given to exploit the nutrient reserve of the plant's rhizosphere (native nutrient supplying capacity of soil) while formulating the fertilizer doses. And most importantly in perennial fruit crops, nutrient doses need to be recommended in tandem with level of fruit yield targeted, a nutrient dose optimum for one fruit yield target will become suboptimum for higher targeted fruit yield level in couple in subsequent years. Where is such nutrient monitoring tool to

keep vigil on nutrient input and output relationship, a kind of nutrient budgeting. Treatment involving foliar spray of 0.50% FeSO<sub>4</sub> + 0.50% MnSO<sub>4</sub> + 0.50% ZnSO<sub>4</sub> + 0.25% borax + ammonium molybdate + 10ppm 2, 4-D + 1% urea at anthesis, pea size, marble size and initiation of fruit enlargement, produced much superior response on different growth parameters, fruit yield, fruit quality parameters, plant assimilable nutrients in soil, leaf nutrient composition, in addition to rhizosphere microbial diversity (Srivastava and Singh 2009a). The complete scheduling of micronutrients through soil application and foliar application has been further summarized. (Table 4).

**Citrus-based microbial consortium for better nutrient-use-efficiency vis-a-vis carbon sequestration:** Exploiting microbial synergisms is one of the popular methods of substrate dynamics and associated changes in nutrient environment of rhizosphere as a part of rhizosphere

Table 3. Soil suitability criteria for Nagpur mandarin (*Citrus reticulata* Blanco) and sweet orange cultivar Mosambi (*Citrus sinensis* Osbeck) grown in Marathwada region of Maharashtra

Soil parameters	Nagpur Mandarin		Mosambi Sweet orange	
	0-15	15-30	0-15	15-30
Soil pH	7.6-7.8	7.9-8.0	7.4-7.9	7.6-8.1
Soil EC (dS m <sup>-1</sup> )	0.12-0.24	0.21-0.28	0.22-0.34	0.26-0.44
Free CaCO <sub>3</sub> (%)	11.4-12.8	15.6-18.2	11.2-14.9	12.6-16.8
Particle size distribution (%)				
Sand	20.8-40.1	19.0-32.7	24.2-38.2	22.3-32.5
Silt	26.8-30.4	11.2-26.8	21.2-31.5	29.3-34.2
Clay	42.8-48.8	54.2-56.1	45.3-52.4	48.5-55.2
Water soluble cations (mg l <sup>-1</sup> )				
Ca <sup>2+</sup>	168.3-182.3	192.50-212.45	182.1-216.8	192.6-248.3
Mg <sup>2+</sup>	39.4-42.7	32.20-42.10	38.2-46.9	49.2-74.6
Na <sup>+</sup>	0.98-1.1	0.68-1.23	0.62-0.98	0.58-0.82
K <sup>+</sup>	12.1-28.2	11.40-12.8	11.4-21.2	11.6-18.3
Exchangeable cations [cmol(p <sup>+</sup> ) kg <sup>-1</sup> ]				
Ca <sup>2+</sup>	31.9-32.3	38.1-41.2	35.8-40.2	34.2-44.8
Mg <sup>2+</sup>	8.5-10.1	9.2-10.0	10.1-12.2	11.8-14.2
Na <sup>+</sup>	0.68-1.23	0.8-1.1	0.42-1.06	0.46-0.98
K <sup>+</sup>	3.2-4.1	4.5-4.6	4.3-5.8	3.8-4.9
Fertility status (mg kg <sup>-1</sup> )				
Available N	118.4-121.2	92.8-110.2	130.1-142.2	120.4-128.6
Available P	9.2-10.3	7.2-8.0	9.8-11.4	9.2-10.8
Available K	178.4-232.5	204.2-228.1	182.4-210.3	192.2-222.2
Available Fe	12.4-16.2	10.6-12.3	13.2-18.6	11.2-18.9
Available Mn	8.6-12.2	7.2-9.1	14.6-22.6	15.2-21.8
Available Cu	2.1-2.3	1.0-1.2	2.16-2.42	2.10-2.56
Available Zn	0.98-1.10	0.72-0.78	0.98-1.21	0.81-0.92
Yield (Tons ha <sup>-1</sup> )	11-15	7-10	24.1-26.2	11.8-12.3

Source: Srivastava and Singh (2004b; 2004c)

engineering (Caldwell, 2005). Formation of associations with other organisms to promote protection from potentially inhibitory environmental factors where such associations reflect synergistic lifestyles facilitating more effective and efficient growth and biogeochemical cycles than individual populations as a community (Berg, 2009). Such associations are often called microbial consortium in which members of the consortium maintain metabolic and ecological compatibility for individual niches to exist in the close proximity in soil. Such microbial consortium is more resistant to environmental changes, and can compete much better than single micro-organism (Harzarika and Ansari, 2007). When different microbial strains are made into an inoculum consortium, each of the constituent stains of the consortium not only out-compete with others for rhizosphere establishments, but complement functionally for plant growth promotion. Different microbial components in a microbial consortium should possess: i. high rhizosphere competence, ii. high competitive saprophytic ability, iii. ease



for mass multiplication, iv. safe to environment, v. broad spectrum of action, vi. excellent and reliable efficacy, vii. compatible with other rhizosphere microbes, and in able to tolerate other abiotic stresses, viii. strong compatibility with inorganic fertilizers and different organic manures. Very limited efforts have been made in citrus using these directions, which is so important from nutrient conservation point of view (Safeguarding both indigenously available and externally applied) to have complete stock of nutrient budgeting in an orchard. Such attempts will serve dual purpose, improve soil and plant resilience and offer ecological service through effective orchard floor management.

The microbial diversity existing within rhizosphere soil from high yielding citrus orchards was characterized and isolated the promising microbes viz., *Micrococcus yunnanensis* (Asymbiotic N-fixer), *Bacillus pseudomycolides* (Silicate-solubilizer), *Paenibacillus alvei* (P-solubilizer), *Acinetobacter radioresistens* (P-solubilizer), *Aspergillus flavus* (P-solubilizer). Pure culture of these microbes in value added form ( $10^8$ - $10^{10}$  cfu mL<sup>-1</sup>) was developed in broth, and prepared a mixture called microbial consortium. The microbial activity of all the five component microbes was further followed as 15 days interval upto 60 days of storage to find out the shelf life of such microbial consortium. Microbial activity of consortium remained active upto 60 days (Srivastava, 2017, unpublished data).

**Biometric response of microbial consortium :** The response of microbial consortium on rough lemon seedlings showed a significant increase in various growth parameters (9.59 g

root weight, 24.86 g shoot weight, and 11.9 mm stem diameter) over control (2.99 g root weight, 9.08 g shoot weight, and 8.6 mm stem diameter) on per plant basis. Similar observations were made on buddlings also. There was a significantly higher growth with microbial consortium treated buddlings (11.76 g root weight, 26.41 g shoot weight, and 28.51 mm stem diameter on per plant basis) compared to untreated control (4.10 g root weight, 10.72 g shoot weight, and 20.20 mm stem diameter). Same microbial consortium in combination of 50% inorganic fertilizers + 50% vermicompost produced a much better quantitative as well as qualitative response compared to treatment without microbial consortium in bearing Nagpur mandarin orchard. Such an attempt has an excellent potential for carbon accreditation as a climate resilient option, against potential soil health deterioration (Srivastava et al. 2012).

**Integrated nutrient management:** Citrus, by its avid nutrient absorbing capacity is considered highly nutrient responsive perennial fruit crop (Srivastava and Singh 2005). Differential efficacy of two conventional methods of fertilization (soil versus foliar application) has, although helped in improving the quality citrus, but of late, continuous fertilization has failed to sustain the same yield expectancy on a long term basis due to depletion of soil carbon stock and consequently,

emerged multiple nutrient deficiencies, irrespective of soil type (Ferguson, 1990). The menace of multiple nutrient deficiencies would be further triggered through increase in air temperature via changes in microbial communities and activities within the rhizosphere in the light of climate change (Fageria et al., 2008). Such changes will dictate adversely on the orchard's productive life in long run. Gradual shift from purely inorganic to organic fertilizers started gaining wide scale use for enhanced biogeochemical nutrient cycling (Srivastava et al., 2008). Long term data accrued on response of organic manuring versus inorganic fertilizers demonstrated that important soil quality indices like soil microbial diversity, soil microbial biomass nutrient ( $C_{mic}$ ,  $P_{mic}$ , and  $N_{mic}$ ) and organic carbon partitioning displayed significant changes, but without much difference in quantum of fruit yield (Srivastava, 2009; 2010a). The other approaches involving multiple microbial inoculation along with enrichment of organic manures through inorganic fertilizers known as substrate have further been highlighted as a part of INM module to provide an understanding on mechanism involved in C stabilization in soils for regulating soil C sequestration and associated nutrient dynamics under INM-based production system in citrus orchards. Integration of such microbial consortium with organic manures and

Table 4. Fertilizer schedule for different citrus cultivars

Fertilizer Source	Total fertilizer (g/tree/ year)	Soil application						Foliar application					
		<i>Ambia</i> (g/ plant)			<i>Mirg</i> (g/ plant)			<i>Ambia</i>			<i>Mirg</i>		
		Apr.	Aug.	Nov.	Sept.	Nov.	Jan.	Apr.	Aug.	Nov.	Sept.	Nov.	Jan.
<b>Nagpur mandarin</b>													
Urea	1300	433	433	434	433	433	434	-	-	-	-	-	-
Single super phosphate	1260	630	630	-	630	630	-	-	-	-	-	-	-
Muriate of potash	180	-	-	180	-	-	180	-	-	-	-	-	-
FeSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
MnSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
ZnSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
<b>Acid lime</b>													
Urea	1740	580	580	580	580	580	580	-	-	-	-	-	-
Single super phosphate	1260	630	630	-	630	630	-	-	-	-	-	-	-
Muriate of potash	180	-	-	180	-	-	180	-	-	-	-	-	-
FeSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
MnSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
ZnSO <sub>4</sub>	200	50	50	-	50	50	-	0.50%	-	0.50%	0.50%	-	0.50%
<b>'Mosambi' Sweet orange</b>													
Urea	1740	580	580	580	580	580	580	-	-	-	-	-	-
Single super phosphate	1260	630	630	-	630	630	-	-	-	-	-	-	-
Muriate of potash	180	-	-	180	-	-	180	-	-	-	-	-	-
FeSO <sub>4</sub>	300	75	75	-	75	75	-	0.50%	-	0.50%	0.50%	-	0.50%
MnSO <sub>4</sub>	300	75	75	-	75	75	-	0.50%	-	0.50%	0.50%	-	0.50%
ZnSO <sub>4</sub>	300	75	75	-	75	75	-	0.50%	-	0.50%	0.50%	-	0.50%

In order to prepare 0.5% of FeSO<sub>4</sub> solution, dissolve 500 g iron sulphate in 100 liters of water and spray on the plant till drench, likewise prepare the solutions of other micronutrients.

Source: Huchche et al. (1996), Srivastava (2013 a 2013c), Srivastava et al. (2008)

chemical fertilizers (basis for INM-based nutrient management) in addition to concepts like sensor based-programmable fertigation and precision oriented site specific nutrient management exploiting spatial variation in soil fertility and leaf nutrient composition could further provide the much desired niche in the production sustainability through engineering nutrient dynamics within the rhizosphere under changing climatic scenario (Srivastava and Ngullie, 2009; Srivastava et al., 2012).

### Organic management module in Nagpur mandarin

Citrus requires 16 essential elements for normal growth, production, and quality irrespective of the source (Zekri, 1995). Renewed and intensified efforts are in progress during the past 10-15 years to grow citrus organically ever since the depleting soil fertility has attained a serious concern with the practice of high density orcharding coupled with heavy use of chemical fertilizers that were immediately available to the plants for nutrient uptake (Kohli *et al.*, 1998; Srivastava and Singh, 1999) bringing unprecedented reduction in soil organic matter. Organic citrus cultivation is often considered amongst one of the sustainable agricultural practices, if used appropriately, promises to offer rich dividends on a long term basis. Opinions vary greatly about organic farming, being perceived as a part of sustainable agriculture (Ferguson, 1990b).

Concerns about improving nitrogen use efficiency, reducing nitrate pollution, contamination due to byproducts of various chemical pesticides in use, and continued gradual loss of soil organic matter have always been the major core

issues, and more so, in organic citrus (Ferguson, 1994). But, the organic cultivation has yet not received the priority, it deserves, with the result, soil physical, chemical, and microbiological health have not been so favouring to consistently high yield (Dahama, 1994; Paroda, 1999; Ghosh, 2000). In addition to changes in land use pattern, unfavourable climatic conditions have further enhanced the rate of decomposition of soil organic matter and its further depletion (Velayutham *et al.*, 1999). These problems warrant revision of ongoing agricultural practices, and adaptation of some alternative strategies whose origin is presumed to be age old, popularly known as organic farming or natural farming (Srivastava et al., 2002).

Traditional agricultural practices with special reference to rotation, use of green manures and rural agricultural waste as compost, tank silt application would all help to build soil organic matter base; a reliable index of fertility. This is long-term endeavour but once attained all parameters, physical, chemical, and biological work at optimum. Bacterial fertilizers *Rhizobium*, *Azospirillum*, etc. become redundant. The indigenous flora will be functional at peak efficiency. A special reference is necessary to vermicompost. Each farmer can at best prepare compost on his farm and apply.

The earthworms thus transferred would work as the soil is hospitable. But to commercialise the process of sale of earthworms in plastic bags or washings in suitable carriers is at best a gimmick. Recent most queer and uncommon claims in favour of earthworms are misplaced. Naturally occurring in the soil is a recognized indication of agro-

Table 5. INM-Schedule recommended for Ambia (Spring bloom) and Mrig crop (Monsoon bloom) of Nagpur mandarin

Components of INM	Ambia crop			Mrig crop		
	April	August	November	August	October	January
<b>Soil application</b>						
Vermicompost (kg)	5.0	5.0	5.0	5.0	5.0	5.0
Inorganic fertilizers (g/tree)	300g urea	300g urea	300g urea	300g urea	300g urea	300g urea
	260g SSP	260g SSP	260g SSP	260g SSP	260g SSP	260g SSP
	110g MOP	110g MOP	110g MOP	110g MOP	110g MOP	110g MOP
Microbial consortium (ml/ plant)	50.0	50.0	50.0	50.0	50.0	50.0
<b>Foliar spray</b>	Month of spray					
	April	June	September	September	October	December
0.50% FeSO <sub>4</sub> +0.50% MnSO <sub>4</sub>	*	*	*	*	*	*
0.50% ZnSO <sub>4</sub>	*	*	*	*	*	*
0.25% Borax	*	*	*	*	*	*

Source: Srivastava et al. (2012, 2015)

\*FeSO<sub>4</sub> (0.50%) to be prepared by dissolving 500g FeSO<sub>4</sub> in 100 L water; MnSO<sub>4</sub> (0.50%) to be prepared by dissolving 500g MnSO<sub>4</sub> in 100 L water; ZnSO<sub>4</sub> (0.50%) to be prepared by dissolving 500g ZnSO<sub>4</sub> in 100 L water; Borax (0.25%) to be prepared by dissolving 250g borax in 100 L water.

\*SSP and MOP stand for single superphosphate and muriat of potash, respectively.

ecosystem's health for stable aggregation of clay-organic matter complexes and efficient nutrient recycling. Bugg (1994) has updated our knowledge on the role of earthworm involvement in nitrification.

Alteration of heavy with light crop is a common feature in citrus (Reuther, 1973; Moss *et al.*, 1981; Kihara *et al.*, 1995; Haggag *et al.*, 1995). Alternate bearing is more pronounced from tree to tree basis in Kinnow mandarin, without any significant difference in feeder root density compared between on and off year trees (Jones *et al.*, 1975). The present citrus production trends are characterized by either frequent crop failure or recurrence of alternate on and off year setting a substantial monetary loss to the industry (Jones *et al.*, 1975; Rojas, 1998; Dass *et al.*, 1998). These uncertainties in production, arising out of nutritional constraints could be resolved to a greater extent by organic cultivation of citrus through improved organic carbon stock, and improved the plant metabolism (Kohli *et al.*, 1998; Ghosh, 2000). Besides, these merits of organic citrus, the mobilization of unavailable nutrients could also be effected by speeding up the rate of mineralization of various organic substrates.

Use of microbial biofertilizers on one hand, and the utilisation of VAM fungi as bioprotectors, bioregulators and biofertilizers in citrus (Manjunath *et al.*, 1983; Ishii and Kadoya, 1996) on the other hand is likely to bring a desirable changes in the quality production, besides beneficial impact on soil health. A comprehensive review on the subject (Srivastava *et al.*, 2002) has shown, the necessity of adopting organic citrus culture by using domestically produced organic manures and enriching them through nutrient enrichment techniques on one hand, and using the biofertilizers including VAM mycorrhizae on the other hand have to be an integral part of this programme, since mobilization of tapped nutrients in the soil is equally important if sustainable improvement in soil fertility is to be brought about. Thus, sustainable and organic systems are anticipated to meet nutritional needs to a great extent by managing soil biology, chemistry and structure to optimise soil fertility and nutrient cycling.

The application of vermicompost loaded with microbial consortium (100% N- equivalent basis) + IPM<sub>2</sub> (foliar application of Horticulture Mineral oil (2%) followed by *Beauveria bassiana* @ 5g/1 and Azadirachtin (1%) @ 4 ml/1) + IDM<sub>1</sub> - Bordeaux paste (CuSO<sub>4</sub>: Lime: Water = 1:1:10) as pre monsoon / post monsoon trunk application along with *Trichoderma harzianum* native antagonistic strain, NRCfBA29 (100g/ plant) with carrier material of FYM (1kg) as soil application at root zone recorded maximum production and productivity coupled with soil health. the

comparative economics of conventional and organic production of Nagpur mandarin further demonstrated an additional income of Rs 1,57,954/- hectare through organic production of Nagpur mandarin (Srivastava *et al.*, 2006).

### Fertigation scheduling

Citrus production depends upon the application of water and fertilizers in appropriate amount at proper time (Shirgure *et al.*, 2000; 2001a; 2001b). The market prices of fertilizers required for citrus crops are rising up day-by-day and farmers cannot afford to buy the required fertilizers. Therefore, it is the time need to apply fertilizers efficiently at proper time when plant needs. The application of fertilizers through basin irrigation goes waste (40 - 50% fertilizers according to an estimate) through leaching, evaporation and fixation in the soil. Fertigation is application of water soluble solids as well as liquid fertilizers through the irrigation on weekly / monthly basis so as to reach each and every plant regularly and uniformly. In the area of scarce water resource and insufficient rainfall, fertigation offers the best and sometimes the only way of ensuring the nutrients enter the root zone of acid lime (Shirgure *et al.*, 2002; 2003a; 2003b). It has many advantages like increasing fertilizer-use efficiency, ensured supply of water and nutrients, labour saving and improvement in growth, yield and quality.

Zekri and Koo (1994 a) evaluated micro-nutrients through fertigation using different sources and rates. Inorganic forms were ineffective in evaluating micro elements levels in oranges. But chelated sources of Fe, Mn, Zn and Cu were very effective and their rates of application were comparable with rates through foliar applications. Zekri and Koo (1994 b) later studied that the use of conventional soil and foliar spray applications to correct micronutrient deficiency in citrus has not been completely satisfactory. The effectiveness of fertigation with micronutrients was observed to depend on the fertilizer source. Application of chelated Fe, Mn and Zn through irrigation system increased the concentration of these micronutrients in the leaves. The nitrate forms of Fe, Mn and Zn were ineffective, as was the sulphate form of Zn. The sulphate form of Mn was occasionally effective, but the sulphate form of Cu was very effective. Such variability needs to be evaluated with different citrus cultivars on a variety of soils.

Syvetsen and Smith (1996) studied the nitrogen uptake efficiency and leaching losses from lysimeter grown trees fertilized at three nitrogen rates. The average N uptake efficiency decreased with increased N application rates, overall canopy volume and leaf N concentration increased with N rate, but there was no effect of N rate on fibrous root dry weight. Foguet *et al.* (1998) showed that the growth of

Valencia orange trees was positively influenced by irrigation and not so much by nitrogen fertilization in the province of Tucuman, Argentina.

A field experiment was conducted on Nagpur mandarin (*C. reticulata*) during 1998-2010 at the experimental farm of NRC for Citrus, Nagpur. The treatments were 4 levels of irrigation (10%, 20%, 30% and 40% depletion of available water content) and 3 levels of fertigation (600, 200 and 100 g; 500, 140 and 70 g and 400, 80 and 40 g N, P and K / plant). The incremental plant height (0.46 m), girth (19.9 cm) and canopy volume (14.3 m<sup>3</sup>) was more with irrigation scheduled at 20 % depletion of available water and 500, 140 and 70 g N, P and K / plant fertigation. The fruit yield (26.1 kg-1 tree), fruit weight (135.1 g), total soluble solids in fruits and juice percentage (47.32 %) were higher with irrigation scheduled at 20 % and 500, 140 and 70 g N, P and K / plant fertigation (Shirgure et al., 2001b). The incremental height (0.40 - 0.60 m), stock girth (4.07 - 4.26 cm) and canopy volume ( 6.93 m<sup>3</sup>) of bearing acid lime was more in irrigation scheduled at 30 % depletion of available water content with 500:140:70 fertigation. The combined effect of irrigation at 30 % depletion of available water content and fertigation with 500:140:70 gave better growth and yield of acid lime. The average fruit yield was 15.83 kg/ tree in 30 % depletion of available water content. The average fruit weight and total soluble solids were 30.1 g and 8.1 % in irrigation scheduled at 30 % depletion of available water content with 500: 140: 70 fertigation. The juice percent and acidity with irrigation scheduled at 30% depletion of available water content and 500:140:70 fertigation was more (42.5% and 7.0%) as compared to other treatments (Shirgure et al., 2003b;

2004b; 2004c). Authors developed a complete fertigation schedule for Nagpur mandarin. (Table 6)

Potassium is one such essential nutrient known for improving the fruit quality. Conventional method of fertilization suffers from not producing the consistent response of fertilizers application. The fertilization using drip irrigation has proved very effective in sustaining the quality production of Nagpur mandarin. The fruit yield was highest (25.52 t/ha) with sulphate of potash fertigation followed by fertigation with 50 g K<sub>2</sub>O/plant at 30 days interval (23.67 t/ha). The fruit quality was influenced with different potassic fertilizers. Maximum juice TSS (9.63 0Brix) and fruit weight (163.3 g) was observed with K fertigation with 40 g K<sub>2</sub>O/plant at 30 days interval. The highest TSS/ acidity ratio was observed with K fertigation with 40 g K<sub>2</sub>O/ plant at 30 days interval (10.0).

Fertigation with 40 g K<sub>2</sub>O/ plant at 30 days interval using sulphate of potash fertilizer through micro-irrigation proved to be very effective for better fruit yield and quality of Nagpur mandarin (Shirgure *et al.*, 2006a). In the treatments of evaluation of different potash fertilizers in K fertigation for Nagpur mandarin consisted of fertigation with potassium chloride, potassium nitrate, sulphate of potash and mono potassium phosphate with dose as 150 g k<sub>2</sub>O/ plant. The Nagpur mandarin yield was highest (31.13 t/ha) with fertigation of mono potassium phosphate (150 g K<sub>2</sub>O/ plant) followed by fertigation with potassium nitrate (150 g k<sub>2</sub>O/ plant) at 15 days interval (29.4 t/ha). The fruit quality is also affected with different potash fertilizers. Highest fruit TSS (10.54 0Brix) and fruit weight (159.28 g) was observed in

Table 6. Fertigation scheduling of Nagpur mandarin (*Citrus reticulata* B lanco) under sub-humid tropical climate of central India

Month	Crop stage	Macronutrients (g/ plant)			Micronutrients (g/ plant)			
		N (g/ plant)	P <sub>2</sub> O <sub>5</sub> (g/ plant)	K <sub>2</sub> O (g/ plant)	ZnSO <sub>4</sub> (g/ plant)	FeSO <sub>4</sub> (g/ plant)	MnSO <sub>4</sub> (g/ plant)	Borax (g/ plant)
April	Flush	60	-	-	-	-	-	-
May -June		Stress period for flowering						
July	Flowering	60	30	15	50	50	50	25
August	Fruit set	60	30	15	50	50	50	25
September	Pea size	-	-	-	-	-	-	-
October	Marble size	60	30	15	50	50	50	25
November	Fruit Devp.	60	30	15	50	50	50	25
December	Fruit Devp.	60	30	15	-	-	-	-
January	Fruit Devp.	60	30	15	-	-	-	-
February	Maturity	60	-	-	-	-	-	-
March	Color break	-	-	-	-	-	-	-
Total		480	180	90	200	200	200	100

Source: Shirgure (2012; 2013), Shirgure and Srivastava (2013; 2013)

fertigation with potassium nitrate (150 g k<sub>2</sub>O/plant) at 15 days interval. The highest TSS / acidity ratio was observed in fertigation of mono potassium phosphate (13.7) followed by potassium sulphate (13.1).

### **Futuristic goals**

Despite many cutting edge technologies, addressing a variety of core issues on role of soil type-based nutrient management (Lipecki and Berbec, 1997) in raising the productivity of perennial fruits is the major research and developmental issue. Fruit crops, despite some distinct developments, are confronted with number of soil fertility challenges. These challenges could be convincingly elaborated as: sustaining the sustainable soil fertility management, we need to define role of rhizosphere in ecological service (CO<sub>2</sub> sink), integrating soil nutrient and microbial pool over different spatial and temporal scales cropwise, soil fertility resilience and human health, plant-soil-microbial interface (For example, crop microbiome), coupled reaction processes in soil to add new frontiers of soil fertility management, besides robust and dynamic crop-based nutrient modelling duly tested spatio- temporally.

Until recently, research has focused on those organisms that are culturable. However a wealth of information is now being collected from both culturable and, as yet, unculturable organisms.

Functions of the soil microbial population impact many processes and, therefore, productivity (Kennedy and Gewin, 1997), if mechanisms involved in the plant-microbe interaction are better understood, since, a plant manufactures microbial communities according to its metabolic requirements. The microbial biomass is one of the biological properties of soil that undergoes immediate change in response to fertilizer like input. Studies, therefore, need to be undertaken with a view to explore the possibility of which soil microbial property could be used as a potential tool for finding out soil health related constraint instead of concentration of available nutrients in soil using some indicator fruit crop(s). While the genetic, functional and metabolic diversity of soil microorganisms within the rhizosphere of wide range of fruit crops is important, the capacity of soil microbial communities to maintain functional diversity of those critical soil processes could ultimately be more important to ecosystem productivity and stability than mere taxonomic diversity (Caldwell and Bruce, 2005).

In this context, it remains to be assessed how nutrient-microbe synergism is associated with productivity of perennial fruits. New research methods involving molecular techniques will extend our understanding of taxonomic and

functional diversity in soil systems. With the availability of more technical know-how on combined use of organic manures, prolonged shelf life of microbial bio-fertilizers, and inorganic chemical fertilizers, an understanding on nutrient acquisition and regulating the water relations would help switch orchards to CO<sub>2</sub> sink (expanding carbon capturing capacity of rhizosphere) so that a more sustainable fruit-based integrated crop production system under biotic and abiotic stress could be evolved. The molecular approach to breeding of mineral deficiency resistance and mineral efficiency would facilitate to produce nutritionally efficient biotypes in order to maximise the quality production of fruit crops on sustained basis. The work related to microbial inoculants for mass production, formulation coupled with innovative marketing, interaction and signalling with the plant and soil environment need further redressal to reorient fruit nutrition research. The further efforts on homologous microbes as rhizosphere microbes versus plant endophytes would further after way forward approaches in identifying more crop endosphere competent microbes for elevated crop response. It remains to be investigated, how nutrient-microbe association could bring better dividends to accurate estimation of orchard C budget vis-a-vis time scale and feedback mechanisms of changes in soil carbon pool and steady state level under specific fruit crop in order to expand potential of C credits through perennial fruit crops.

The above nutrient management-based issues and strategies would find their worth only when backed up with sound methodologies of nutrient constraints diagnosis. The currently available leaf nutrient standards for different fruit crops have certain distinct limitations in terms of: i. Sampling index plant part(s) leaving very short time for remediation of identified constraints, ii. application of diverse interpretation tools bring out varying limits of nutrient concentration and iii. do we need to apply some correction factor when such nutrient standards are applied in fruits under fertigation. A better rationale of nutrient constraints diagnosis as early as possible in a standing crop would surely pave the way for precision-based nutrient response accruing in elevated productivity. Proximal sensing, preferably hyper-spectral analysis would add a new dimension in this regard, since the current basis of nutrient constraints diagnosis is skewed more towards next season crop than current season crop. An early warning system exploiting the metallo-enzyme sensor could be another viable option in years to come. Delineation of production management zones linked with variable rate fertilizer application as per the crop phenology is expected to tailor the fertilizer requirement without altering the fertilizer requirement of a crop soil fertility based spatial variogram would further act as a decision support tool for

precise fertilizer recommendation. Evaluating nutrient response at a cellular, sub-cellular, tissue level and plant part level instead of whole plant basis, would lay a solid foundation of nutrient management strategy in fruit crops. Eventually, such attempts warrant for developing Nutrient Experts based on 4R Stewardship Concept advocated by International Plant Nutrition Institute, Gurgaon which have displayed some definite yield advantages in cereal crops, but such serious efforts are direly needed in fruit crops, if nutrient management is to be linked with nutrient use efficiency. On the line of 4R in plant nutrition, there is also a need to look 4W in terms of irrigation management, so that 4R and 4W operate complimenting each other to facilitate not only the sustained quality production, but aid in moderating the climate change – related issues as well.

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# Comparative response of organic, chemical and integrated mode of cultivation towards yield and sustainability of basmati rice (*Oryza sativa*) based cropping system

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## Abstract

Among the different modes of cultivation studied, organic mode of cultivation sustained the productivity of basmati rice after one decade which was 52.96 per cent increased over first year rice grain yield ( $2266 \text{ kg ha}^{-1}$ ). However, inorganic and integrated mode of cultivation maintained more or less same yields. Bulk density of soil improved appreciably. It decreased by 8.03 per cent over initial value after ten years of experiment ( $1.24 \text{ g cc}^{-1}$ ) under organic mode over initial ( $1.37 \text{ g cc}^{-1}$ ) followed by integrated mode ( $1.33 \text{ g cc}^{-1}$ ) and inorganic ( $1.44 \text{ g cc}^{-1}$ ). Organic mode of cultivation was found superior in improving the organic carbon (1.15 %) status of soil followed by integrated mode (1.00%) after ten year of experimentation as compared to initial (0.65%). The per cent increases in organic carbon were 76.9 and 53.8 per cent over initial, respectively with organic and integrated modes. Likewise, availability of nitrogen and sulphur increased to a greater extent under sole organic mode registering 58.4 and 31.1 per cent increase over initial year, respectively as compared to inorganic and integrated modes. Micronutrient status of soil after ten years of continuous cropping system improved with organic mode of cultivation emanating 61.9, 18.7, 85.0 & 295 per cent increase in availability of Zn, Cu, Fe and Mn, respectively over initial. Thus, the best alternative for sustaining the soil fertility in long term without compromising the productivity is to use organic manures as compared to sole use of inorganic fertilizers.

**Key words:** Cropping systems, Basmati rice, Organic, Inorganic, Integrated, Soil fertility, System Productivity.

The increased crop output with the use of high amount of fertilizers and pesticides result in decreased food quality and soil fertility, degradation of cultivated land, water and air which threatens food safety and food security (Zhoa *et al.* 2007). Sustainability of exhaustive cropping system like rice-wheat is threatened due to indiscriminate exploitation of natural resources and non-judicious use of agricultural inputs without considering the carrying capacity of soil. Escalating cost of chemical fertilizers and no or less use of organics has lead to decline in soil quality. The soils under exhaustive cropping sequence are now showing signs of fatigue and are no longer exhibiting increased productivity even with increase in input use. The stagnating crop yields have generally been attributed to declining nutrient supplying capacity of soil, imbalanced nutrition and little and no addition of organic manure affecting physico-chemical properties. The organic farming probably is seldom practiced and there is dearth of data on the comparative yield and economics of crops with pure organic farming versus intensive farming. Whatever little organic farming that is being practiced in India seems to be taken up mainly as a part of contract farming. For getting optimum yields, crop plants require balanced plant nutrition, through sources, which could provide the required nutrients in

sufficient quantities and in readily available form. This could be best possible through fertilizers, and hardly through organic sources, which not only are bulky, have extremely low analysis and their nutrients are slowly available to plants. For plant protection, the organic sources and biological methods that have been tried so far have not met with considerable success in the country. However, organic manures promotes the growth and activity of useful microorganisms in soils. Organic matter binds soil particles into structural units thus improves soil structure and maintains favourable condition for aeration and permeability. The rate of infiltration and percolation of water is enhanced by application of soil organic matter and also increases the water holding capacity (Das *et al.* 2000). In this context, an experiment was taken up to evaluate the organic farming practices on high value cropping sequence, especially the Basmati- rice based cropping sequence. In organic farming systems, the nutrient needs of plants have to be met through organic sources *viz.* inclusion of legumes in cropping systems, green manures (GM), farm yard manure (FYM) etc. Green manure is cheaper alternative to mounting price of fertilizer nitrogen and has become an effective technology in economizing the agriculture production system, ensuring productive capacity of soil without causing

any impoverishment and combating many ecological and environmental problems (Bana and Pant, 2000). The experiment was initiated with the objective of finding out the impact of organic, inorganic and integrated management practices on yield of basmati rice based cropping system and on soil health including the soil physic-chemical properties in terms of bulk density, water holding capacity, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium and sulphur and micronutrients.

## MATERIALS AND METHODS

Field experiments were conducted at Breeder's Seed Production Centre of G.B.Pant University of Agriculture and Technology, Pantnagar for last one decade during 2004-13 under the Network Project on Organic Farming funded by Indian Council of Agriculture Research. The experimental soil was silty loam in texture (31.40% sand, 45.8 % silt and 22.8% clay), medium in organic carbon (0.65%), available N (238 kg ha<sup>-1</sup>), P (16.7 kg ha<sup>-1</sup>), K (156 kg ha<sup>-1</sup>) and high in available sulphur (29.3 kg ha<sup>-1</sup>). Electrical conductivity and pH were 0.34 dS m<sup>-1</sup> and 7.4, respectively. Three management practices *viz.*, 100 per cent organic, 100 per cent inorganic and integrated (50% organic and 50% inorganic) as horizontal strip and four cropping systems *viz.* basmati rice-wheat, basmati rice-lentil, basmati rice-vegetable pea and basmati rice-*Brassica napus* as vertical strips were tested in strip plot design. The *Sesbania* were incorporated as green manure prior to basmati rice only. Soil application of rockphosphate @ 300 kg ha<sup>-1</sup> was done prior to *kharif* crop after fourth year of experimentation. Under inorganic treatments, recommended dose of N, P and K were 120, 60 and 40 kg ha<sup>-1</sup> for rice, wheat and *B. napus* and 25, 60 and 40 for lentil and vegetable pea. Organic manures (FYM) were applied as basal and inorganic forms of nitrogen in three equal splits in rice as basal, active tillering and at panicle initiation stages, however, in *rabi* crops it was in two equal splits as basal and after first irrigation. Full dose of P and K were applied as basal. Irrigation were applied on the basis of critical physiological stages of different crops. Varieties 'Pusa basmati-1' of rice, 'PBW-343' of wheat, 'Pant lentil-406' of lentil, 'Arkel' of vegetable pea and 'GLS-1' of *Brassica napus* were taken in experiment. Two hand weeding were done at 20 and 40 DAT/DAS for *kharif/rabi* crops to control the weeds. Trichocards (1 card/acre; 5 releases) and pheromone traps (20 traps ha<sup>-1</sup> @ 5 mg trap<sup>-1</sup>) were used within a week of transplanting of rice crop in organic plots to control the insects pests. Cow urine mixed with neem leaves sprayed @ 10 per cent (2-3 sprays) before flowering and at every 15 days interval to control insects pests in both *kharif* and *rabi* seasons in organic mode. Seed treatment with *Pseudomonas* & *Trichoderma* @ 5 g kg<sup>-1</sup> seed each prior to

sowing was done to control soil and seed borne pathogens in both *kharif* and *rabi* crops. Spraying *Pseudomonas fluorescence* (PSF) & *Trichoderma* each @ 5 g litre<sup>-1</sup> were done before soil preparation to control soil borne pathogens in *rabi* crop under organic and integrated plots. Streptocycline @ 6g ha<sup>-1</sup> and copper oxychloride @ 15 g ha<sup>-1</sup> was sprayed on both inorganic and integrated mode to control the bacterial leaf blight in rice. The observation on important yield attributing characters and grain & straw yield were recorded after every crop and crop cycle. Surface soil samples (0-15 cm) were collected from all the treatments after harvest of *rabi* crop every year. Electrical conductivity of 1:2 soil: water supernatant (kept overnight) was estimated using solubridge. Total organic carbon was estimated using Walkley and Black (1934) rapid titration method. Water holding capacity and nutrient estimation in soil in terms of organic C, available N, P, K, S, Zn, Cu, Fe and Mn was done as per methods described under AOAC. Measurements on CH<sub>4</sub> and N<sub>2</sub>O emissions were taken during 2012. In each plot CH<sub>4</sub> and N<sub>2</sub>O emissions were measured seven times. During the measurements the soil was dry. The mean CH<sub>4</sub> and N<sub>2</sub>O emissions among plots under the different nutrient managements were compared by means of ANOVA and Tukey test.

## RESULTS AND DISCUSSION

### Basmati rice grain yield

Basmati rice grain yield during ten years of experimentation showed a increasing trend ranging from 22.66 q ha<sup>-1</sup> in first year (2004) to 35.03 q ha<sup>-1</sup> in the last year (2013) i.e. an increase of 52.96 per cent over initial grain yield (Figure 1). This trend in grain yield over the years clearly signifies that organic mode after 3 years of conversion period was helpful in maintaining yield sustainability. Similar

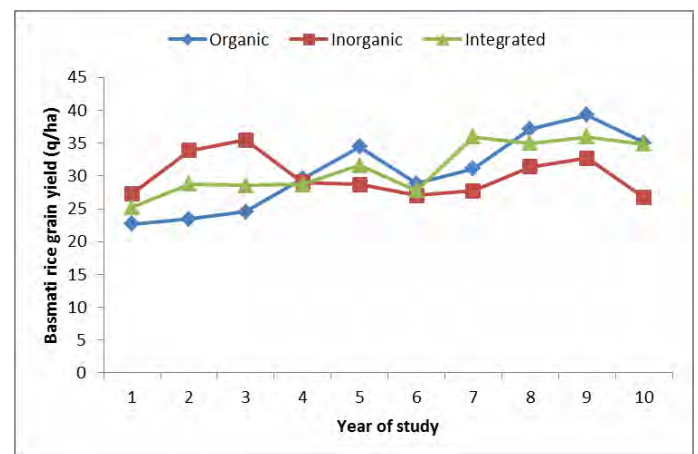


Figure 1. Basmati rice grain yield over ten years of experimentation (2004-13).

results of gradual increase in grain yield of rice with the use of organics over a period of time was also observed by Surekha (2007). The highest yield under organic treatments was mainly due to build up of organic matter, accumulation of nutrients over years and improvement in physico-chemical properties of soil. Similar trend was also reported by Mankotia (2007) where higher yield of rice was obtained due to *in situ* green manuring with *Sesbania* & with application of FYM. Though, a similar transition in grain yield was observed in the plots which received 50 per cent nutrients through organic & 50 per cent through inorganic sources but the increase was not much higher as compared to organic showing only 38.1 per cent increase in grain yield of basmati rice over ten years. However, 100 per cent inorganic plots showed highest grain yield of rice up to three years and a decreasing trend is observed in the subsequent years of experimentation as compared to organic and integrated modes of cultivation.

### Rice grain equivalent yield (RGEY)

The average data over ten years of experimentation regarding rice grain equivalent yield (Figure 2) revealed that higher rice grain equivalent yield ( $44.8 \text{ q ha}^{-1}$ ) was obtained in integrated plots followed by inorganic plots ( $43.2 \text{ q ha}^{-1}$ ) and comparably equivalent yield in organic mode ( $42.8 \text{ q ha}^{-1}$ ). Rice grain equivalent yield in organic mode over ten years increased to about 59.1 per cent over initial as compared to inorganic mode where increase in yield was 25.9 per cent over initial year. modes (193 per cent).

### Methane and nitrous oxide emissions from Basmati rice fields

Neither  $\text{CH}_4$  emissions (Fig. 3) nor  $\text{N}_2\text{O}$  emissions (Fig. 4) differed significantly between plots under inorganic,

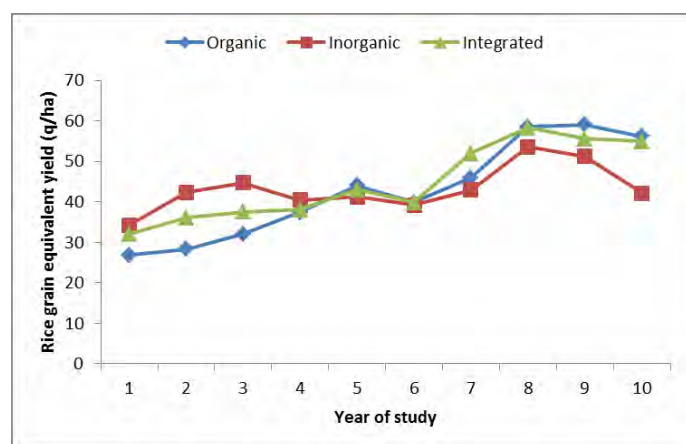


Figure 2. Rice grain equivalent yield over ten years of experimentation (2004-13).

integrated and organic nutrient management. Results also show that plots which received the same amount of N through different rates of organic amendments did not significantly differ in their  $\text{N}_2\text{O}$  emissions compared to purely urea fertilized plots (Fig. 4). Although  $\text{CH}_4$  emissions were not significantly different, plots fertilized with organic amendments (Integrated, Organic) tended to emit less  $\text{CH}_4$  compared to the plots under inorganic nutrient management (Fig. 3), which contradicts many previous studies. Over several seasons Wassmann *et al.* (1996) found that rice fields, which received  $120 \text{ kg N ha}^{-1}$  through rice straw (high organic input) had higher  $\text{CH}_4$  emissions compared to the fields which received the same amount of N through urea (low organic input). Also substitution with organic amendments (*Sesbania* GM,  $60 \text{ kg N ha}^{-1}$ ; urea,  $90 \text{ kg N ha}^{-1}$ ) has been shown to enhance  $\text{CH}_4$  emissions compared to urea treatments ( $150 \text{ kg N ha}^{-1}$ ) (Wassmann *et al.*, 2000).

### Transition in soil fertility

The electrical conductivity of the organic system decreased from  $0.34 \text{ dS m}^{-1}$  to  $0.30 \text{ dS m}^{-1}$  under organic mode, however, in that of inorganic system it increased to  $0.45 \text{ dS m}^{-1}$ . Here, with the increase in dose of organic manure

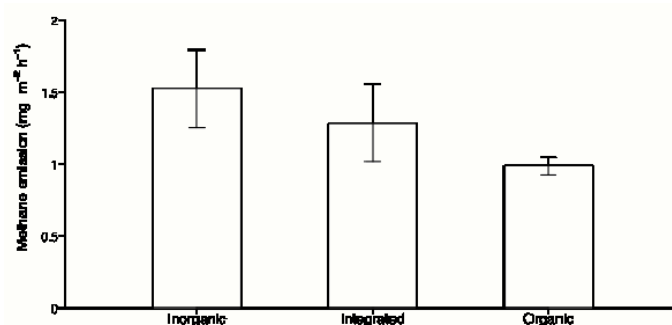


Figure 3: Mean  $\text{CH}_4$  emissions ( $\text{mg m}^{-2} \text{ h}^{-1}$ ) from plots under inorganic, integrated and organic nutrient management.

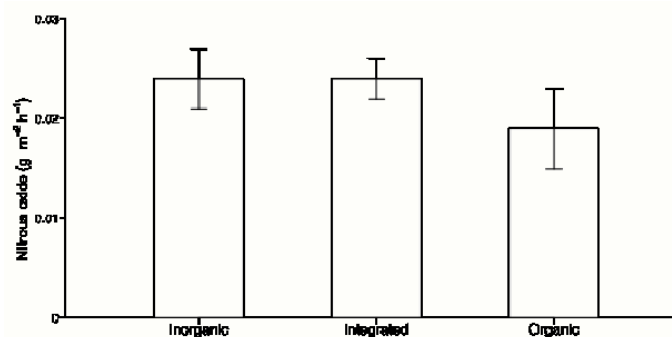


Figure 4:  $\text{N}_2\text{O}$  emissions ( $\text{g m}^{-2} \text{ h}^{-1}$ ) from plots under inorganic, integrated and organic nutrient management.

applied, the EC value decreased (Table 1). The lower EC value in the organic plots may be due the increase in the WHC of manure treated plots due to improvement of soil aggregation thus reducing the salt concentration (Duhan and Singh, 2002). It is evident that bulk density of soil improved appreciably (it decreased by 8.03 per cent over initial value) to a great extent after ten years of experiment under organic mode (1.24 g cc<sup>-1</sup>) over initial (1.37 g cc<sup>-1</sup>) followed by integrated mode (1.33 g cc<sup>-1</sup>) and inorganic (1.44 g cc<sup>-1</sup>). The lowering of bulk density in organic mode plots and with integrated mode may be due to higher organic carbon, more pore space and good soil aggregation. Similar results have been reported by Francis et al. (2006). Organic C, available nitrogen and sulphur increased to a great extent with the addition of sole organic mode as compared to inorganic and integrated modes. Better response of sole organic mode in increasing organic C of soil to the extent of 76.9 per cent as compared to inorganic mode which is only 30.8 per cent was observed (Table 2). These organic sources besides adding organic carbon itself to the soil enhance root growth, resulting in addition of greater root biomass and root exudates to the soil which ultimately increases soil organic carbon. This confirms the results reported earlier by Tripathi et al, 2007. Maximum increment in available nitrogen (58.4 per cent) and sulphur (31.1 per cent) over initial after ten years of experimentation was recorded under organic mode

**Table 1: Changes in soil properties over initial after ten years of experimentation**

		E.C (dS m <sup>-1</sup> )	Bulk Density (g cc <sup>-1</sup> )	WHC (%)	
				Field capacity	Saturation
100% Organic	Value(after 10 years)	0.30	1.24	25.0	33.3
	Per cent change	-11.7	-9.5	44.5	6.1
100 % Inorganic	Value(after 10 years)	0.45	1.44	14.3	29.0
	Per cent change	32.4	85.1	-17.3	-7.6
Integrated (Org. + Inorg.)	Value(after 10 years)	0.35	1.33	23.7	30.5
	Per cent change	2.9	-2.9	37.0	-2.9
Initial		0.34	1.37	17.3	31.4

**Table 2: Changes in soil properties over initial after ten years of experimentation**

		Organic C (%)	Available N (kg ha <sup>-1</sup> )	Available P (kg ha <sup>-1</sup> )	Available K (kg ha <sup>-1</sup> )	Available S (kg ha <sup>-1</sup> )
100% Organic	Value(after 10 years)	1.15	377	50.8	244	38.4
	Per cent change	76.9	58.4	204	56.4	31.1
100 % Inorganic	Value(after 10 years)	0.85	354	52.4	250	33.2
	Per cent change	30.8	48.7	214	60.3	13.3
Integrated (Org. + Inorg.)	Value(after 10 years)	1.00	369	53.1	243	38.1
	Per cent change	53.8	55.0	218	55.8	30.0
Initial		0.65%	238 kg/ha	16.7 kg/ha	156 kg/ha	29.3 kg/ha

as compared to integrated mode and inorganic modes. The availability of phosphorus remained more or less similar under inorganic (214 per cent) and integrated modes (218 per cent), however availability of phosphorus of the magnitude of 204 per cent was observed in organic mode of cultivation. Likewise macronutrients, availability of micronutrients viz., Fe, Cu and Zn in soil after ten years of continuous crop cycles under sole organic mode of cultivation increased to the extent of 85.0, 18.7 and 61.9 per cent, respectively as compared to integrated and inorganic modes (Table 3). However, the availability of Mn in soil highly increased under integrated mode (398.0 per cent) as compared to organic (295 per cent) and inorganic modes (193 per cent).

Organic farming in basmati rice based cropping system in *tarai* region of Uttarakhand could have wide range of ramifications in rural development, economic sustainability and remunerative agriculture. Shifting towards organic farming in low productive areas where most of the farmers are resource poor who cannot bear heavy prices of chemical fertilizers could sustain basmati rice productivity and soil health in long run.

**Table 3: Changes in soil properties over initial after ten years of experimentation**

		Available Zn (mg kg <sup>-1</sup> )	Available Cu (mg kg <sup>-1</sup> )	Available Fe (mg kg <sup>-1</sup> )	Available Mn (mg kg <sup>-1</sup> )
100% Organic	Value(after 10 years)	1.36	3.69	55.94	12.35
	Per cent change	61.9	18.7	85.0	295
100 % Inorganic	Value(after 10 years)	0.97	2.55	35.43	9.16
	Per cent change	15.5	-15.0	17.2	193
Integrated (Org. + Inorg.)	Value(after 10 years)	1.02	3.33	51.35	15.59
	Per cent change	21.9	11.0	69.8	398
Initial		0.84 mg/kg	3.00 mg/kg	30.24 mg/kg	3.13 mg/kg

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# Effect of poplar clones and wheat varieties on biomass accumulation, soil carbon storage and nutrient status under agroforestry system

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## ABSTRACT

Field experiments conducted at Agroforestry research unit of G.B.P.U.A. & T., Pantnagar, Uttarakhand during *rabi* seasons of 2013-14 and 2014-15 to study the effect of DBW-17, PBW-502, UP-2748 and HD-2967 varieties of wheat in association with  $S_7C_8$ , G-48, W-39 and Kranti poplar clones on biomass accumulation, soil properties and carbon stock revealed that the wheat varieties HD-2967 and DBW-17 produced at par but significantly higher total biomass than UP-2748 and PBW-502. Poplar clone  $S_7C_8$  ( $4.25 \text{ t ha}^{-1}$ ) in 2013-14 Kranti ( $12.28 \text{ t ha}^{-1}$ ) in 2014-15 recorded the highest total tree biomass. Soil properties viz., organic carbon, bulk density and total soil carbon stock were the maximum with the clone Kranti. Wheat varieties failed to affect soil properties and carbon stock significantly. The available soil nitrogen was significantly higher with clone Kranti, while soil available phosphorus and potassium remain unaffected by the poplar clones.

**Key words:** Agroforestry, poplar clones, wheat varieties, biomass accumulation, soil organic carbon, bulk density, available NPK, soil carbon storage

Agroforestry is an ideal land use option as it optimizes tradeoffs between increasing food production, poverty alleviation and environmental conservation. Agricultural lands are believed to be a major potential sink and can absorb large quantities of carbon, if trees are introduced and judiciously managed with crops. From agriculture and allied sectors huge amount of green house gases is released into the atmosphere. Carbon is the key constituent of these gases. Locking carbon for a long period is the added advantage of tree component in the agroforestry system. Trees on the farm store carbon in different tree components and in the soil underneath. Introduction of trees in the agricultural landscapes can be a useful tool to lock up the carbon and increase soil carbon status. The carbon storage in the agroforestry system in above/below ground biomass and soil has been expected to be greater than that in a conventional agricultural operation (Paul *et al.*, 2002; Sauer *et al.*, 2007).

Wheat is popular crop being grown in inter tree spaces of the poplar trees. Gill *et al.* (2009) found variable responses among different varieties tested in poplar based system. Chauhan *et al.* (2011) observed decrease in wheat growth and yield with increase in poplar age. However, the loss in biomass of under grown crop is compensated by the increased biomass of the tree component. Nair *et al.* (2011) found that agroforestry system store more amount of carbon as compared to single species canopy and grazing systems. Due to fall of considerable amount of leaves from the tree species, the soil properties get benefitted. Gupta and Sharma (2008) found that soil physical properties such as porosity,

density and water holding capacity and chemical properties such as pH, availability of nutrients, soil organic carbon etc. improved significantly under poplar plantation compared to sole cropping of wheat. Arora *et al.* (2014) reported that the soil carbon stock increases with age of *Populus deltoides* (1-11 yrs) from  $61.2 - 66.8 \text{ Mg ha}^{-1}$  and decreases with soil depth.

Therefore, the present study envisaged to quantify the biomass production of crop and tree components and carbon sequestration potentials in soil under varying wheat varieties and poplar clones.

## MATERIALS AND METHODS

Field experiments were conducted for two years at Agroforestry research center of G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand ( $29^\circ\text{N}$  Latitude,  $79^\circ 30' \text{ E}$  longitude and at an altitude of 243.84 m above mean sea level) commencing from *rabi* season of 2013-14. The soil texture of study site was sandy loam rich in organic carbon (1.175%). The available nitrogen, phosphorus and potassium contents of soil were, respectively, 260, 20 and  $190 \text{ kg ha}^{-1}$ . The site is characterized by a humid sub-tropical, cold and hot dry summers with 1400 mm mean annual rainfall, of which 80 to 90% is received between June and September. The remaining 10 to 20% rainfall is received during wheat-growing season (November to April).

The experiment was conducted in split plot design with tree species in main plots and varieties in sub-plots and treatments, replicated thrice. Four clones of poplar viz.,  $S_7C_8$ , G-48, W-39 and Kranti were planted in 2012 at spacing of

7.0 m × 3.0 m. Four wheat varieties (DBW-17, PBW-502, UP-2748 and HD-2967) were sown at a 20 cm rows apart on both sides of the tree line using 100 kg seed ha<sup>-1</sup>. The wheat was supplied with 120:60:40 kg N- P<sub>2</sub>O<sub>5</sub>- K<sub>2</sub>O ha<sup>-1</sup>. The half dose of N and full dose of P and K were applied as basal. The remaining nitrogen in equal splits was applied after crown root initiation stage and pre-heading stage, respectively. Three irrigations were applied to the crop coinciding with crown root initiation (21 days after sowing), late jointing (65 DAS) and milking stage (105 DAS) during both the years. For weed control, Clodinafop + MSM @ 150 g ha<sup>-1</sup> was applied in 5<sup>th</sup> week after sowing.

Intercrop dry biomass was estimated in 1.0 m × 1.0 m quadrat. The tree stem biomass was calculated by the equation developed by Arora *et al.* (2014) for *tarairegion*. The biomass of tree branches and leaves was done by oven drying the samples. The below ground biomass of trees was calculated by using the guidelines of IPCC (1996). The average root: shoot ratio for poplar tree has been reported as 1:0.21. The soil bulk density and nutrient analysis was done using the standard procedures. The soil organic stock (t ha<sup>-1</sup>) was determined using the following formula given by Joa *et al.* (2001)

Soil organic carbon stock (t ha<sup>-1</sup>) = Soil organic carbon (%) × depth (cm) × bulk density (g cm<sup>-3</sup>).

Data were analyzed by using standard statistical procedure for split-split plot design (Panse, and Sukhatme, 1967) with the help of OPstat statistical package.

## RESULTS AND DISCUSSION

### Intercrop and tree biomass accumulation

Carbon stock is directly related to the biomass accumulation. Wheat total biomass did not differ significantly under different poplar clones (Table 1). However, it was the maximum under the clone S<sub>7</sub>C<sub>8</sub> in 2013-14 and clone Kranti in 2014-15. Higher wheat biomass may be attributed to improved soil conditions (Table 2) under these clones. During both the years, wheat total biomass did not vary significantly between HD-2967 and DBW-17 but was numerically higher than other varieties. Improved soil organic carbon owing to addition of higher tree biomass might have helped these varieties to gain more biomass.

The poplar tree total biomass differed significantly only at harvest of wheat crop second year (Table 1). During 2013-14 poplar clone S<sub>7</sub>C<sub>8</sub> produced the maximum tree total biomass. At termination of the investigation, poplar clone Kranti recorded significantly the highest tree biomass (24.55 t ha<sup>-1</sup>). Among remaining clone it was in the order of W-39 (20.95 t ha<sup>-1</sup>) > S<sub>7</sub>C<sub>8</sub> (20.93 t ha<sup>-1</sup>) > G-48 (20.13 t ha<sup>-1</sup>). Spanos (2006) found higher biomass in newly developed clones and

the lowest in the local poplar clone É-214. The variable potential of different poplar clones to accumulate biomass may be ascribed to their genetic potential and are in line with Mishra *et al.* (2010).

### Organic carbon content in soil

The organic carbon content of top 0-15 cm soil layer was higher than the lower layer (15-30 cm). The increase in carbon content of top layer might be due to incorporation of leaves and small twigs into the soil. The increase in the soil organic carbon stocks at the surface soil layer was attributed to greater carbon input from litter fall, dead roots and root exudates (Rahhan *et al.*, 1996; Chauhan *et al.*, 2009).

At harvest of second year wheat i.e. termination of the study, the organic carbon content in top 0-15 cm soil layer varied significantly among the clones (Table 2). Among the clones Kranti, W-39 and S<sub>7</sub>C<sub>8</sub>, the organic carbon content did not differ significantly, but clone Kranti recorded significantly higher organic carbon content than clone G-48. Variation in soil organic carbon may be ascribed to variable biomass addition by different clones (Table 1). At this stage wheat varieties differed non-significantly for soil organic carbon content and the order of organic carbon was HD-2967 > DBW-17 > UP-2748 > PB-502.

The organic carbon content below layer (15-30 cm), did not exhibit much changes unlike top 0-15 cm layer. At harvest of second year wheat crop, clone W-39 had the maximum organic carbon content (1.048%) while the lowest was noted with clone G-48 (1.042%). Due to wheat varieties the organic carbon content remained unaffected significantly. In 2014-15, variety DBW-17 showed superiority over other varieties for organic carbon content.

### Bulk density of soil

At completion of the study, the bulk density of soil (0-15 cm) was not affected significantly due to various clones of poplar (Table 2). At harvest of the second year wheat, it was the lowest under clone Kranti (1.385 g cm<sup>-3</sup>) and the highest under clone G-48 (1.431 g cm<sup>-3</sup>). The order of BD value was G-48 > W-39 > S<sub>7</sub>C<sub>8</sub> > Kranti. Reduction in bulk density was due to addition of organic matter in the form of litter in the surface layer. Bulk density decreased with increase in soil organic carbon. Such inverse relationship of the bulk density and soil organic carbon (%) has also been reported by Gupta and Sharma (2008) and Singh *et al.* (2004).

Wheat varieties failed to cause significant variation in the bulk density values (Table 2). At harvest of second year wheat, the maximum bulk density was noted with variety PBW-502 and the lowest with variety HD-2967. Variety DBW-17 recorded the next lowest bulk density. Bulk density of the 15-30 cm of soil layer was not influenced by poplar clone as

Table 1. Intercrop and poplar tree total biomass at harvest of wheat crop as influenced by poplar clones and wheat varieties at end of study.

Treatment	Total wheat biomass (t ha <sup>-1</sup> )		Total tree biomass (t ha <sup>-1</sup> )	
	2013-14	2014-15	2013-14	2014-15
<b>Poplar clone</b>				
S <sub>7</sub> C <sub>8</sub>	8.99	8.25	4.25	10.30
G-48	8.62	8.20	3.60	10.23
W-39	8.66	8.15	3.47	10.47
Kranti	8.86	8.39	3.87	12.28
SEm±	0.20	0.01	0.29	0.22
CD 5%	NS	NS	NS	0.78
<b>Wheat variety</b>				
DBW-17	9.13	8.49	3.96	11.05
PBW-502	8.52	8.09	3.71	10.43
UP-2748	8.42	7.83	3.72	11.00
HD-2967	9.05	8.59	3.80	10.81
SEm±	0.15	0.10	0.08	0.18
CD 5%	0.45	0.30	NS	NS

well as wheat varieties (Table 4.31). The bulk density was higher in the lower layer compared to upper layer. The variation in bulk density was not appreciable among the clones as well as wheat varieties.

#### Soil carbon stock

At harvest of wheat 2014-15, the values for soil carbon stock in top layer were almost comparable among the clones and clone Kranti recorded the highest value of 25.94 t ha<sup>-1</sup>. In second layer also same clone resulted in the highest soil carbon stock. The total soil carbon stock differed significantly among the clones and clone Kranti sequestered the highest C-stock (49.63 t ha<sup>-1</sup>). Among other clones, the order was W-39>S<sub>7</sub>C<sub>8</sub>>G-48, respectively being 49.33, 48.19, 48.01 t ha<sup>-1</sup>.

The total soil organic carbon stock (SOC) was observed to decrease with increasing the soil depth and the upper soil layer (i.e., up to 15cm) showed the maximum and higher soil organic carbon stock as compared to lower soil depth (15-30 cm) under all the poplar clones. These results are well supported by the findings of Smith and Heath (2002) and Sharma (2004). The lower values of soil carbon stock may be related to the fact that most of the changes in soil carbon and BD occurred in the top layer owing to addition of leaf and root biomass.

Inclusion of different wheat varieties did not cause significant variation in C sequestration. At harvest of second year wheat crop the highest values for total C stock were noted with variety HD-2967 and the lowest with variety PBW-502.

#### Soil available N P K

At harvest of the wheat crop, only available nitrogen was influenced significantly due to various clones of poplar (Table 3). Among different clones of poplar, clone Kranti recorded the maximum available nitrogen (275 kg ha<sup>-1</sup>) followed by S<sub>7</sub>C<sub>8</sub> (274 kg ha<sup>-1</sup>). Both these clones recorded significantly higher N than clone G-48. The more addition of leaf litter favours the higher nutrient status of the soil (Shehnaz, 2014). Similar findings were also observed by Singh and Sharma (2007). Variations in available nitrogen among different clones of *P. deltoids* owing to their variable genetic potentials with respect to litter fall have also been reported by Mishra *et al.* (2010). Wheat variety HD-2967 recorded the highest available nitrogen (274 kg ha<sup>-1</sup>), which was followed by the variety DBW-17. The lowest and similar available N was noted with varieties PBW-502 and UP-2748.

The order of available phosphorus in different clones

Table 2. Organic carbon content and bulk density and total soil carbon stock as influenced by poplar clones and wheat varieties at end of study (2014-15).

Treatment	Soil organic carbon (%)		Bulk density (g cm <sup>-3</sup> )		Soil carbon stock (t ha <sup>-1</sup> )		
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	Total
Poplar clone							
S <sub>7</sub> C <sub>8</sub>	1.216	1.047	1.358	1.501	24.73	23.53	48.19
G-48	1.183	1.042	1.388	1.507	24.61	23.53	48.01
W-39	1.250	1.048	1.368	1.508	25.65	23.70	49.33
Kranti	1.280	1.046	1.351	1.500	25.94	24.51	49.63
SEm±	0.019	0.012	0.019	0.015	0.43	0.47	0.32
CD 5%	0.068	NS	NS	NS	NS	NS	1.13
Wheat variety							
DBW-17	1.238	1.048	1.363	1.507	25.29	24.68	48.92
PBW-502	1.210	1.044	1.377	1.508	24.99	23.60	48.74
UP-2748	1.222	1.044	1.366	1.506	25.02	23.58	48.53
HD-2967	1.258	1.046	1.358	1.495	25.64	23.42	48.98
SEm±	0.013	0.006	0.008	0.021	0.33	0.32	0.38
CD 5%	NS	NS	NS	NS	NS	NS	NS

Table 3. Available N, P K content of soil (0-15 cm) as influenced by poplar clones and wheat varieties at completion of the study.

Treatment	Soil available nutrient (kg ha <sup>-1</sup> )		
	Nitrogen	Phosphorus	Potassium
<b>Poplar clone</b>			
S <sub>7</sub> C <sub>8</sub>	274	20.68	191.5
G-48	269	20.15	188.0
W-39	271	20.71	192.8
Kranti	275	21.58	193.6
SEm±	1.11	0.58	1.16
CD 5%	3.93	NS	NS
<b>Wheat variety</b>			
DBW-17	272	20.88	190.4
PBW-502	271	20.27	191.1
UP-2748	271	20.87	190.1
HD-2967	274	21.09	194.2
SEm±	1.49	0.35	1.11
CD 5%	NS	NS	NS

was; Kranti > W-39 > S<sub>7</sub>C<sub>8</sub> > G-48. Among the varieties of wheat, HD-2967 recorded the maximum (21.09 kg ha<sup>-1</sup>) available phosphorus which was followed by the varieties DBW-17 (20.88 kg ha<sup>-1</sup>) and UP-2748 (20.87 kg ha<sup>-1</sup>). Among poplar clones, Kranti recorded the highest value for available K content (193.6 kg ha<sup>-1</sup>). The lowest value for available K was found with clone G-48 (188.0 kg ha<sup>-1</sup>). The order of average K at this stage was Kranti > W-39 > S<sub>7</sub>C<sub>8</sub> > G-48. Among wheat varieties, the highest available K was found with variety HD-2967 and decreased in the order of Kranti > PBW-502 > DBW-17 > UP-2748.

The study concludes that to achieve higher biomass and better impact on soil health and long term carbon stock in soil, poplar clones Kranti and S<sub>7</sub>C<sub>8</sub> (age 2 and 3 years) and wheat varieties DBW-17 and HD-2967 be taken in an agroforestry system in *tarai* region of Uttarakhand.

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# Phosphorus management in maize using PSB (*Phosphorus solubilising bacteria*) in Vertisol

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## Abstract

The field experiment conducted at farmer field during kharif season with deferent treatment of phosphorus solubilising bacteria combination of deferent fertilizers showed that the application of PSB with phosphoric fertilizer gave higher effects on growth and yield of maize. PSB increased the solubility of phosphate in soil and enhanced the plant growth by improving biological fixation. Application of PSB helped in reducing 30-40 per cent consumption of P fertilizer, control soil and water pollution and also balance the physical, biological and chemical soil fertility.

**Keyword:** Phosphorous, PSB, fertilizer, biofertilizer, vertisol

Phosphorus is a second most important nutrient in soil for crop production and there is no large atmospheric source which can be made biologically available [1]. The main role of P to plant is root development, stalk and stem strength, flower and seed formation, crop maturity and production. It has a deferent role in plant metabolism such as cell division, development, photosynthesis, breakdown of sugar, nuclear transport within the plant, transfer the genetic characteristics from one generation to another and regulation of metabolic pathway. The phosphorous content in average soil is about 0.05% (w/w) but only 0.1 per cent of the total phosphorous is available to plant because of fixation and poor solubility in soil [2]. The phosphorus available for plant growth depends not only on the total amount of phosphorus in the soil but also on its solubility. Large amount of P applied as fertilizer (DAP, SSP, DSP and TSP etc) enters in to the immobile pools through precipitation reaction with highly reactive  $Al^{3+}$  and  $Fe^{3+}$  in acidic, and  $Ca^{2+}$  in calcareous or normal soils [3,4]. Microorganisms with phosphate solubilizing potential increase the availability of soluble phosphate and enhance the plant growth by improving biological fixation [5,6]. Some bacterial species have solubilization and mineralization potential for inorganic and organic phosphorus, respectively [7]. Application of PSB will help in reduced the conception of P fertilizer and also reduced the cast of cultivation of farmers.

## MATERIAL AND METHODS

The experiment was conducted at farmer's field during kharif season of the year 2016. The geographical location of the site is situated between 22°09'40.77" N and 76°04'24.46 E with an altitude of 641 m above the mean sea level. The

average annual rainfall is nearly 910 mm. The soil of the experimental area was classified as typic Haplustert sub group of "vertisol". The soil of the area has medium depth, black colour and clay loam texture and sandy clay loam in texture, alkaline in reaction.

The experiment consisted of eight treatments viz., T-1 Control, T-2 PSB, T-3 NK (100%), T-4 NK (100%) + PSB, T-5 NK (100%) + 50% P (SSP), T-6 NK (100%) + 50% P (SSP) + PSB, T-7 NPK (100%), and T-8 NPK (100%) + PSB were tested in RBD (randomized block design) with three replications. The entire field was divided into micro plots of equal size (2 m x 1.5 m) and all the treatments were randomly allocated to different plots in each replication. Sowing of hybrid maize (Pioneer 30V92) was done uniformly in all the plots with at 45 cm row to row and 30 cm plant to plant spacing manually on 30/06/2016. Recommended fertilizer dose 120-60-40 kg N,  $P_2O_5$ ,  $K_2O$  per hectare was applied through Urea, SSP and MOP (KCl) respectively, Recommended PSB dose 8 kg ha<sup>-1</sup> were applied. Application of 'N' in three split doses - 60kg as basal, 30 kg at knee high stage and 30 kg at flowering stage. FYM @ 1 t ha<sup>-1</sup> uniform to all plots i.e. 300 g FYM plot<sup>-1</sup> as basal. The crop was harvested at 105 days. After harvesting the crop, plant samples (grain and shoot) were collected and successively dried at 70 °C to a constant weight.

Soil sample was collected from experimental field for pre physicochemical parameter and available phosphorous analysis. Samples were completely air-dried and passed through 2 mm sieve and stored in properly labeled in plastic bags for pre analysis.

Freshly prepared bio-fertilizer of PSB with (Lignite based) was purchased at BPD unit, JNKVV (Jawaharlal Nehru Krishi Vishvavidyalaya), Jabalpur (M. P.).

The soil pH and EC was determined in 1:2.5, soil: water suspension [5]. Organic matter was determined by wet oxidation method [9]. Cation exchange capacity (CEC) was calculated by the summation of exchangeable acidity and bases [10]. The available P of soil was analyzed with sodium bicarbonate method [11]. Total phosphorus of root and shoot of maize was measured by digestion method [12].

## RESULTS AND DISCUSSION

A perusal of the data presented in the Figure- 2 and 3 indicated that biomass yield (grain and stover) were significantly affected by the application PSB with deferent combination of fertilizers. The soil treated with PSB (no any fertilizer) recorded highest grain and stover yield ( $3.97 \text{ t ha}^{-1}$  and  $5.41 \text{ t ha}^{-1}$ ) as compared to the control ( $3.12 \text{ t ha}^{-1}$  and  $5.26 \text{ t ha}^{-1}$ ), which was 27 and 3 per cent more over the control (Fig-1). Many researchers who applied phosphorus solubilizing bacteria (PSB) with NPK fertilizers in wheat crop

and reported that yield was  $2.63 \text{ t ha}^{-1}$  in control,  $3.41 \text{ t ha}^{-1}$  with NPK only and the highest ( $3.80 \text{ t ha}^{-1}$ ) with NPK+PSB [13]. There was no difference in the agronomic parameters of T-4 (NK 100% + PSB) and T-5 (NK 100% + 50% P) (Plate-7) similar to T-6 (NK 100% + 50% P + PSB) and T-7 (NPK 100%) treated plant (Fig- 2,3,4 and 5). The phosphate solubilizing potential is increase with application of PSB [6]. Biomass yield and agronomic parameters of maize grown in without PSB

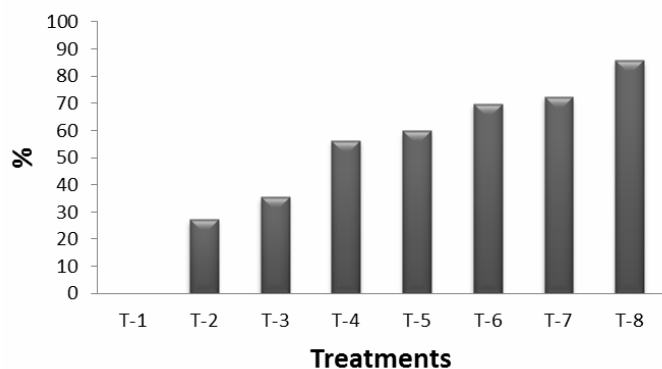


Figure 1: Increased yield (%) of grain over control (maize)

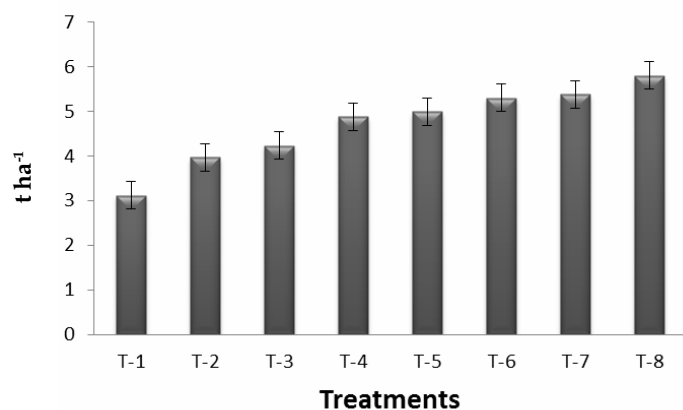


Figure 2: Biomass of grain (maize)

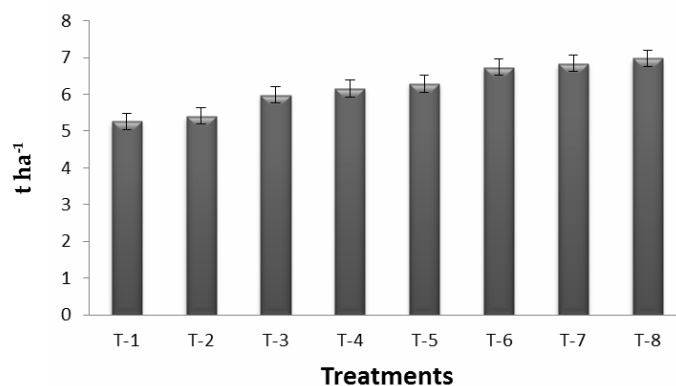


Figure 3: Biomass of stover (maize)

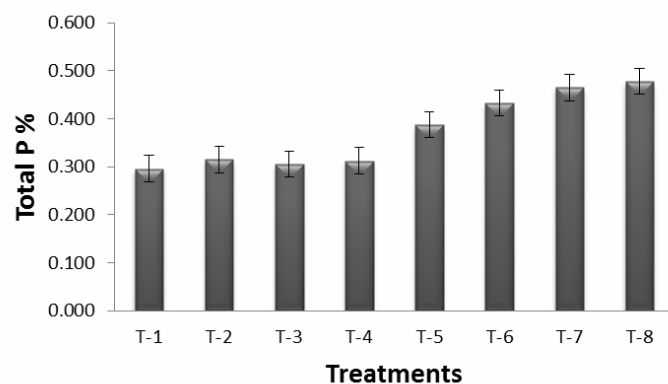


Figure 4: Total P content of grain (maize)

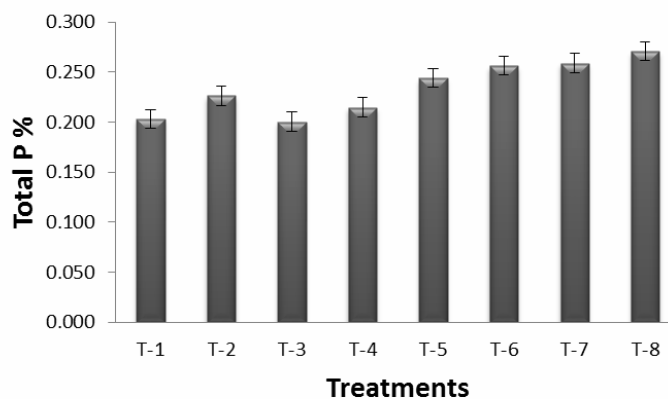


Figure 5: Total P content of stover (maize)

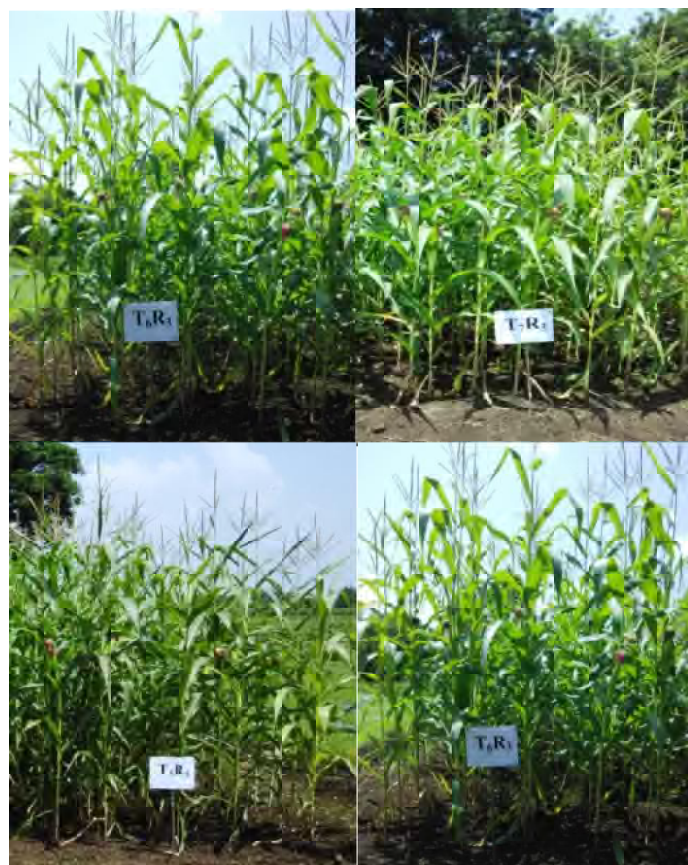
treatments were significantly lower than treated of soil with PSB. Higher crop yields result from solubilization of fixed soil P and applied phosphates by PSB [14,15]. There was decreased grain yield and size of cobs in plots which no treated with PSB. The highest straw yield was obtained with phosphate solubilizing bacteria [16]. The conjunction of PSB with single super phosphate and rock phosphate reduces the P dose by 25 and 50 per cent, respectively [17]. The P content was increased with application of PSB both grain and stover compare to control (Fig-4 and 5). Phosphorus content was significantly increased of cotton plant with *Bacillus meliloti* combined with phosphorus as compared to

uninoculated plants growing in the control soil [18]. Similar findings about the increase in P-uptake by wheat plant due to PSB inoculation was reported [19].

The study concludes that the application of PSB with phosphoric fertilizer gave higher effects on growth and yield of maize. It increased the solubility of phosphate in soil, enhanced plant growth by improving biological fixation, helped in reducing the consumption of P fertilizer as also as the cost of cultivation. On environmental point of view, it controls soil and water pollution and also balances the physical, biological and chemical soil fertility.

**Table 1:** Physicochemical parameter of experimental soil

Parameter	Value
pH	7.72
EC dms	0.92
Organic Carbon (%)	0.60
Available Phosphorus (kg/ha)	12.6
Cation exchange capacity (CEC) (cmol (p+)/kg)	43.3



**Plate 1:** Comparison between T-6 (NPK 100%), T-7 (NK 100% +50%P +PSB), T-5 (NK 100% +50%)

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# Growth performance and herbage yield of different colocasia (*Colocasia esculenta* L.) genotypes under Konkan climatic conditions

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## ABSTRACT

The growth and herbage yield performance of sixteen colocasia (*Colocasia esculenta* L.) genotypes was evaluated at Central Experiment Station, Wakawali during kharif season of the year, 2016. The genotypes exhibited highly significant variation for all the growth characters except days to first leaf emergence. The variation studied indicated that the growth characters, viz, the plant height (60.34 cm) and petiole length (57.55 cm) were recorded maximum in AC-20 genotype. The genotype Sree Pallavi showed maximum leaf length (55.86 cm), leaf breadth (42.50 cm) and petiole girth (7.13 cm). Whereas, leaf thickness, leaf area and number of leaves per plant were significantly higher in Mahim (0.538 mm), Khed Shiravali (747.29 cm<sup>2</sup>) and M-9-111 (17.47 plant<sup>-1</sup>) genotypes, respectively. The genotype M-9111 found to be the best genotypes for herbage yield in terms of per plant (276.93 g), per plot (2.49 kg) and per ha (10.26 ton) followed by Sanjivini and Sree Pallavi. Whereas, Devakibai Walanga produced lowest herbage yield per plant (158.57 g), per plot (1.43 kg) and per ha (5.87 ton).

**Key words:** Colocasia, Growth parameters, Herbage yield

Colocasia (*Colocasia esculenta* L. Schott) also known as 'edode' or 'arvi' is a tropical tuber crop belonging to the monocotyledonous family 'Araceae' of the order Arales, whose members are known as 'aroids' (Henry, 2001 and Van Wyk, 2005). It is the most ancient complex of domesticated plants, comprising of nearly 110 genera and more than 2000 species. Colocasia is believed to have originated in South Central Asia, perhaps in Eastern India or Malaysia (Sturtevant, 1919; Onwueme, 1978 and Watt, 1989). Depending on the manner of corm development, colocasia is grouped into two varietal types. These are *Colocasia esculenta* var. *esculenta* (bunda type) which produces a large edible corm with few cormels and *Colocasia esculenta* var. *antiquorum* (edode type) which has a small or medium-sized corm with a large number of edible cormels and is prevalent in India. The 'Edode' type is commonly called 'Arvi' and 'Bunda' type as 'Dasheen'. Edode type is most prevalent as vegetable.

Colocasia is well adapted to shade and can withstand drought to a great extent. The tuber crop is found to thrive well in acidic as well as alkaline soils as leafy vegetable under Konkan during kharif season. It is a rich source of starch and reasonably good source of major components of the diet viz., proteins, minerals and vitamins. All parts of the plant including corm, cormels, rhizome, stalk, leaves and flowers are edible and contain abundant starch (Bose *et al.*, 2003).

However, so far not much work towards development of high yielding suitable types has been done in this crop except few attempts of germplasm collection and their evaluation. Hence, it was felt necessary to undertake well planned research work to evaluate suitable genotypes of colocasia for growth performance and herbage yield under hot and humid climate of konkan region.

## MATERIALS AND METHODS

The experiment was carried out during the period of June to November, 2016 (Kharif season crop) at Central Experiment Station, Wakawali that falls under tropical humid zone receiving an average rainfall of 3000 mm and situated at an altitude of 242 m above MSL. The geographical situation is 17° 48' N latitude and 73° 78' E longitude. The experiment was laid out in Randomized Block Design with 16 treatments (genotypes) in 3 replications. Each plot, measured in 1.35 × 1.8 m, consisted of three rows with 3 plants per row. Accordingly, 9 plants spaced at 60 × 45 cm apart, were accommodated per plot. Observations were recorded from five randomly selected plants in each treatment and replication and their mean values were worked out. Observations on morphological characters were recorded at 15, 30, 45, 60 and 75 days after planting except days to 1<sup>st</sup> leaf emergence. Cumulative herbage yield was recorded from 45, 60 and 75 days after planting observation. The data was statistically analyzed for the evaluation of genotypes of colocasia as a leafy vegetable as per the methods prescribed by Panse and Sukhatme (1985).

## RESULTS AND DISCUSSION

The data on growth performance of different colocasia genotypes presented in Table 1 show no significant difference among different colocasia genotypes for days to first leaf emergence. The first leaf emergence was observed in the range of 7.53 to 8.73 days after planting. The time of emergence (sprouting) of new shoots or leaves depends on the dormancy status of the planting material. The plant develops leaves by using preserve carbohydrates in seed corms. The similar sprouting phenomenon was reviewed by Ravi *et al.* (2011) in elephant foot yam.

The significant variation in plant height, leaf thickness, leaf area, leaf size and number of leaves was observed among different colocasia genotypes (Table 1). The plant growth of colocasia was superior in AC-20 (G<sub>14</sub>) genotype which was closely followed by Sanjivani (G<sub>1</sub>). Mahim found to be superior for leaf thickness (0.538 mm). The variation in leaf thickness can be attributed to genetic variation in different genotypes and environmental effects. The thickness of leaves increased with crop growth. The variations in plant height and leaf thickness of different taro collections were also reported by Angami *et al.* (2015) and Bassey *et al.* (2016).

The leaf area was maximum in Khed Shiravali genotype (747.29 cm<sup>2</sup>) and least was in M-12-429. The leaf area might be interrelated to leaf shape, size and number of leaves. The

variation in leaf area might be attributed to the plant architecture which is decided by the genetic makeup of respective genotypes and its interaction with the environment. The total number of leaves production upto 75 DAP (Cumulative) indicates that the maximum number of leaves (17.47 leaves) were produced in M-9-111 (G<sub>10</sub>) followed by Sanjivini (G<sub>1</sub>) and Sree Pallavi. Leaves play a vital role in the production of carbohydrates through the process of photosynthesis and ultimately increase the vigour of plant. As a leafy vegetable, it is the key feature of the herbage yield in colocasia. The variations in number of leaves plant<sup>-1</sup> in different colocasia genotypes were also reported by Choudhary *et al.* (2011), Paul and Bari. (2011) and Sibyala (2013).

The genotype Sree Pallavi exhibited the longest leaf length in its growing period. While NDB-9 had the shortest leaf length. Highest leaf breadth (42.50 cm) was observed in genotype Sree Pallavi and it was at par with Devakibai Walang (40.13 cm). The minimum leaf breadth (31.52 cm) was recorded by Kelva genotype. Similar observations were made by Chadha *et al.* (2007), in different colocasia genotypes and they reported that the variability in leaf breadth among the genotypes might be due to genetic variation. Further, attaining higher leaf length/ width is a good indicator as the leaf area of colocasia plants has important role on the interception of solar radiation and on biomass production

Table 1.

Genotypes		FLE (DAP)	PH (cm)	LT (mm)	LA (cm <sup>2</sup> )	CNL (plant <sup>-1</sup> )	LL (cm)	LB (cm)	PL (cm)	PB (cm)
G <sub>1</sub>	Sanjivini	8.07	59.03	0.511	481.76	16.00	48.15	35.35	55.14	6.10
G <sub>2</sub>	NDB-9	8.13	53.85	0.515	483.36	14.13	43.03	33.05	50.60	4.84
G <sub>3</sub>	M-12-429	8.67	50.85	0.493	464.06	14.00	46.88	35.35	47.88	6.53
G <sub>4</sub>	Mahim	8.47	47.77	0.538	612.35	14.07	50.87	38.59	46.88	6.02
G <sub>5</sub>	Devkibai Walanga	8.73	50.97	0.513	640.93	13.00	45.12	40.13	52.93	5.49
G <sub>6</sub>	Sawantwadi	8.07	46.89	0.515	649.13	13.27	43.74	37.32	45.25	5.53
G <sub>7</sub>	Muktakeshi	8.47	47.70	0.495	602.28	12.73	49.20	32.79	53.23	5.26
G <sub>8</sub>	Kelva	7.93	52.22	0.473	577.57	13.20	51.14	31.52	52.62	5.86
G <sub>9</sub>	BCC -11	7.53	45.82	0.503	681.14	13.07	40.03	34.02	46.26	5.59
G <sub>10</sub>	M-9-111	8.20	53.13	0.517	482.03	17.47	54.06	32.08	50.53	5.40
G <sub>11</sub>	Sree Pallavi	8.20	53.45	0.499	739.72	15.13	55.86	42.50	54.14	7.13
G <sub>12</sub>	Khed Shiravali	8.00	46.37	0.515	747.29	12.93	49.80	37.59	43.14	5.46
G <sub>13</sub>	Talsure	8.27	49.25	0.525	715.37	13.33	47.09	34.80	53.40	6.91
G <sub>14</sub>	AC -20	8.47	60.34	0.493	480.30	13.13	51.01	37.03	57.55	6.19
G <sub>15</sub>	NDB-22	8.33	58.28	0.497	482.17	13.87	47.78	37.06	56.07	5.50
G <sub>16</sub>	Khopoli	8.33	46.13	0.484	611.04	12.27	45.84	34.82	45.85	5.62
Range		7.53 to 8.73	-----	-----	-----	-----	-----	-----	-----	-----
Mean		8.24	51.38	0.505	590.66	13.96	48.10	35.87	50.72	5.84
SEm (±)		0.25	0.31	0.004	7.63	0.70	1.37	1.19	0.82	0.18
CD at 5%		NS	0.9	0.010	22.02	2.02	3.94	3.44	2.36	0.53

FLE-first leaf emergence, PH-Plant height, CNL-Cumulative number of leaves, LT-Leaf thickness, LA- Leaf area, LL-Leaf length, LB-Leaf breadth, PL-Petiole length, PB-Petiole breadth.

(Bernardes *et al.* 2011). The genotype Sree Pallavi consistently produced maximum length and breadth of the leaves.

The petiole length and girth of different colocasia genotypes also varied significantly. The highest petiole length (57.55 cm) was recorded in genotype AC-20 and it was at par with NDB-22 (56.07 cm). Whereas, the lowest petiole length (43.14 cm) was recorded by Khed Shiravali genotype. The reason for high petiole length in certain colocasia genotypes may be attributed to phenotypical characters of that particular genotype. The petiole length in colocasia is also associated with plant height. Maximum petiole girth (7.13 cm) was recorded in Sree Pallavi. Whereas, minimum petiole length (4.84 cm) was recorded by NDB-9.

The data on yield of herbage in different colocasia genotypes are presented in Table 2. The genotype M-9-111 exhibited the highest (276.93 g) cumulative herbage yield plant<sup>-1</sup>. While Devakibai Walang had the lowest (158.57 g) cumulative herbage yield plant<sup>-1</sup>. The genotype M-9-111 recorded highest herbage yield (2.49 kg plot<sup>-1</sup>) and the lowest herbage yield plot<sup>-1</sup> (1.43 kg) was recorded in Devkibai Walanga (G<sub>5</sub>) and Muktakeshi (G<sub>7</sub>). The genotype M-9-111 recorded the highest herbage yield hectare<sup>-1</sup> (10.26 t ha<sup>-1</sup>) followed by Sanjivini (9.43 t ha<sup>-1</sup>) and Sree Pallavi (8.77 t ha<sup>-1</sup>). The lowest herbage yield (5.87 t ha<sup>-1</sup>) was recorded in Devkibai Walanga followed by Muktakeshi (5.88 t ha<sup>-1</sup>) respectively. The variation in the herbage yield might be attributed to the vegetative growth (foliage) in different

colocasia genotypes and it is a peculiar character especially in tuber crop. Chauhan (2016) observed the variation in the herbage yield of indigenous genotypes of water spinach.

It is concluded that the colocasia genotypes viz., M-9-111, Sree Pallavi and Sanjivini performs best in terms of growth parameter, herbage yield and its attributes. All these parameters of genotypes should be tested for two to three seasons for valid conclusion. These genotypes can be recommended for commercial cultivation as a leafy vegetable during *kharif* in the Konkan region.

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Table 2. Herbage yield of different colocasia genotypes

Genotypes		CHY plant <sup>-1</sup> (g)	CHY plot <sup>-1</sup> (kg)	CHY ha <sup>-1</sup> (ton)
G <sub>1</sub>	Sanjivini	254.63	2.29	9.43
G <sub>2</sub>	NDB-9	204.65	1.84	7.58
G <sub>3</sub>	M-12-429	201.37	1.81	7.46
G <sub>4</sub>	Mahim	210.08	1.89	7.78
G <sub>5</sub>	Devkibai Walanga	158.57	1.43	5.87
G <sub>6</sub>	Sawantwadi	161.98	1.46	6.00
G <sub>7</sub>	Muktakeshi	158.65	1.43	5.88
G <sub>8</sub>	Kelva	163.06	1.47	6.04
G <sub>9</sub>	BCC-11	182.59	1.64	6.76
G <sub>10</sub>	M-9-111	276.93	2.49	10.26
G <sub>11</sub>	Sree Pallavi	236.82	2.13	8.77
G <sub>12</sub>	Khed Shiravali	185.61	1.67	6.87
G <sub>13</sub>	Talsure	189.75	1.71	7.03
G <sub>14</sub>	AC-20	187.53	1.69	6.95
G <sub>15</sub>	NDB-22	194.79	1.75	7.21
G <sub>16</sub>	Khopoli	182.39	1.64	6.76
<b>Mean</b>		<b>196.84</b>	<b>1.77</b>	<b>7.29</b>
<b>SEm (±)</b>		4.61	0.04	0.17
<b>CD at 5%</b>		13.31	0.12	0.49

CHY denotes cumulative herbage yield

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# Interrelationships between yield and yield components in nigella (*Nigella sativa* L.)

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## Abstract

The experiment was carried out at experimental farm of Department of Horticulture, T.C.A., Dholi, Muzaffarpur (Bihar) under AICRP on spices during 2016-17. Genotypic and phenotypic correlation and path coefficient analysis were carried out in nigella using sixteen diverse genotypes for ten quantitative characters. Analysis of variance revealed highly significant differences in genotypes for all the characters under study. In general, magnitudes of genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficient, suggesting a strong inherent relationship in different pairs of characters. Grain yield plant<sup>-1</sup> had positive and highly significant correlation with plant height, number of fruits plant<sup>-1</sup>, length of fruit, number of primary branches plant<sup>-1</sup>, number of grains fruit<sup>-1</sup> and days to maturity. This indicated that these characters could be considered as criteria for selecting high yielding genotypes of nigella.

**Keyword:** Nigella, correlation and path coefficient analysis.

Nigella (*Nigella sativa* L.) is an important minor seed spices crop commercially cultivated in Punjab, Bihar, West Bengal and Assam. It is called Karunjangan, Kalonji, Mangarail, Kalonkir also. Nigella is an annual herbaceous seed spices crop belonging to the family Ranunculaceae. The seeds are known as black cumin. Mature seeds are consumed for edible and medicinal purpose. The seeds of nigella are used in seasoning of vegetables, legumes, pickles and different type of baked products (Atta, 2003 and Datta *et al.*, 2012). The essential oil of nigella have been found to contain about 67 constituents, many of which are capable of inducing beneficial pharmacological effects in humans (Aboutable *et al.* 1986). The black cumin is extensively used in traditional medicines for healing various respiratory and gastrointestinal diseases in the various countries. The whole seed and their extracts have anti diabetic, anti inflammatory, anti microbial, anti tumor. Its seeds contain thymoquinone, and monoterpene having variety of therapeutic effects on digestive disorder gynecological disease and respiratory system (Baskkady and shahabi, 1997). Nigellone and non-carboxyl fractions are reported to protect guinea pigs against histamine-induced broncho-spasm. Phenolic fractions obtain from seeds has been reported anti-bacterial. The understanding of association of characters is of prime importance in developing an efficient breeding programme. The co-relation studies provide information about association between any two characters. The path co-efficient analysis provides the portioning of co-relation co-efficient into direct and indirect effects giving the relative importance

of each of the casual factors. The present study was undertaken in order to find out the interrelationship among different characters and the direct and indirect contributions of these characters towards yield.

## MATERIAL AND METHODS

The experiment was carried out at experimental field of Department of Horticulture, Tirhut College of Agriculture, Dholi, Muzaffarpur during 2016-17 under All India Coordinated Research Project of Spices to evaluate sixteen (16) diverse genotypes of nigella germplasm. The experiment was laid out in Randomized Block Design (RBD) with three replications. The experiment was sown on 30<sup>th</sup> October, 2016 in net plot size of 3.0 m x 1.0 m accommodating ten lines of 30 cm apart with 10 cm plant to plant spacing maintained. Observations were recorded from ten randomly selected plants to each genotypes in each replication for ten characters *viz*: plant height (cm), number of primary branches plant<sup>-1</sup>, number of secondary branches plant<sup>-1</sup>, days to 50 per cent flowering, length of fruit (cm), days to maturity, number of fruits plant<sup>-1</sup>, number of seeds fruit<sup>-1</sup> and grain yield plant<sup>-1</sup>. All the recommended agronomical package and practices were performed to get the healthy crop stand. Mean values of ten plants were used for statistical analysis. For estimation of the genotypic and phenotypic correlation coefficient for all possible combination, the formula used suggested by Johnson *et al.* (1995) and Hanson *et al.* (1956). Path coefficient analysis was done following by the formula of Dewey and Lu (1959). Details of genotypes are given in table-1.

Table 1: Name, source and collection year of the nigella genotypes.

Name of genotypes	Source of genotypes	Collection year
RN-1	Samastipur, Bihar	1994
RN-2	Samastipur, Bihar	1994
RN-3	Samastipur, Bihar	1994
RN-4	Muzaffarpur, Bihar	1995
RN-5	Muzaffarpur, Bihar	1996
RN-6	Vaishali, Bihar	1996
RN-7	Samastipur, Bihar	1997
RN-8	Vaishali, Bihar	1997
RN-9	Muzaffarpur, Bihar	1997
RN-10	East Champaran, Bihar	1998
RN-11	East Champaran, Bihar	1998
RN-12	West Champaran, Bihar	1999
RN-13	Begusarai, Bihar	1999
RN-14	Aurangabad, Bihar	2000
RN-15	Samastipur, Bihar	2000
Rajendra Shyama (Check)		Release variety

## RESULTS AND DISCUSSION

The genotypic and phenotypic correlation among the yield and yield components in nigella are presented in table-2. In general, the estimates of genotypic correlation coefficient were higher than their corresponding phenotypic ones,

suggesting strong inherent association among the characters studied. In the present investigation, seed yield was positively correlated with number of fruits plant<sup>-1</sup>, length of fruit, number of primary branches plant<sup>-1</sup>, number of grains fruit<sup>-1</sup> and days to maturity. Therefore, these characters should be considered while making selection for yield improvement in nigella. These results are in accordance with the results of Garg *et al.* (2003) and Bardideh *et al.* (2013) for plant height and number of branches plant<sup>-1</sup>, Singh and Mittal (2002) and Salmati and Bagheri (2014) for plant height and seeds umbel<sup>-1</sup> in fennel and Yadav *et al.* (2013) also reported number of branches plant<sup>-1</sup>, number of umbels plant<sup>-1</sup>, number of umbellets umbel<sup>-1</sup> and weight of grain umbel<sup>-1</sup> exhibited positive and significant correlation with seed yield in fennel. Significant correlation coefficient of characters suggested that there is much scope for direct and indirect selection for further improvement.

Positive and significant correlation with seed yield plant<sup>-1</sup> was found with height of the plant, number of primary branches plant<sup>-1</sup>, number of secondary branches plant<sup>-1</sup>, length of fruit, width of fruit, number of fruits plant<sup>-1</sup> and number of grain fruit<sup>-1</sup> and thus, these characters are considered as main components for seed yield plant<sup>-1</sup>. The results are in agreement with the findings of Jindal & Allah-Rang (1986).

Table 2: Genotypic and phenotypic correlation coefficient for ten quantitative characters in nigella.

Characters		Height of the plant (cm)	No. of primary branches (plant <sup>-1</sup> )	No. of secondary branches (plant <sup>-1</sup> )	No. of days to 50% flowering	Length of fruit (cm)	Width of fruit (cm)	Days to maturity (No. of days)	No. of fruits (plant <sup>-1</sup> )	No. of grains (fruit <sup>-1</sup> )	Yield in g (plant <sup>-1</sup> )
Height of the plant	G	1.000	0.551**	0.543**	-0.184	0.943**	0.575**	0.271	0.641**	0.656**	0.621**
	P	1.000	0.307	0.349*	-0.049	0.396*	0.438	0.091	0.225	0.461**	0.478**
No. of primary branches per plant	G		1.000	0.992**	-0.066	0.903**	-0.077	0.482**	0.752**	0.526**	0.934**
	P		1.000	0.518**	-0.045	0.459**	0.093	0.232	0.457**	0.263	0.521**
No. of secondary branches per plant	G			1.000	0.214	0.944**	0.026	0.572**	0.956**	0.211	0.759**
	P			1.000	0.033	0.502**	0.352*	0.356*	0.598**	0.183	0.398*
No. of days to 50% flowering	G				1.000	0.327	0.143	0.917**	0.362*	-0.279	-0.234
	P				1.000	0.042	0.210	0.461**	0.103	-0.201	-0.046
Length of fruit (cm)	G					1.000	0.669**	0.428*	0.904**	0.493**	0.852**
	P					1.000	0.199	0.323	0.576**	0.304	0.446*
Width of fruit (cm)	G						1.000	0.225	0.176	0.848**	0.304
	P						1.000	0.062	0.003	0.440*	0.197
Days to maturity	G							1.000	0.558**	0.053	0.259
	P							1.000	0.368*	0.024	0.124
No. of fruits per plant	G								1.000	0.259	0.649**
	P								1.000	0.161	0.428
No. of grains per fruit	G									1.000	0.624**
	P									1.000	0.481**
Yield per plant (g)	G										1.000
	P										1.000

\*and \*\* indicate significant of values at p=0.05 and 0.01, respectively.

Table 3: Genotypic and phenotypic direct and indirect effect of different characters on seed yield plant<sup>-1</sup> in nigella.

Characters		Height of the plant (cm)	No. of primary branches (plant <sup>-1</sup> )	No. of secondary branches (plant <sup>-1</sup> )	No. of days to 50% flowering	Length of fruit (cm)	Width of fruit (cm)	Days to maturity (No. of days)	No. of fruits (plant <sup>-1</sup> )	No. of grains (fruit <sup>-1</sup> )	Yield (plant <sup>-1</sup> ) (g)
Height of the plant	P	<b>0.0133</b>	0.0711	0.0807	-0.0114	0.0918	0.1016	0.0212	0.0523	0.1070	0.4781
	G	0.2318	0.0073	0.0072	-0.0025	0.0147	0.0077	0.0036	0.0085	0.0087	0.6215
No. of primary branches per plant	P	0.0881	0.2872	0.1488	-0.0132	0.1320	0.0269	0.0668	0.1315	0.0756	0.5212
	G	0.2276	<b>0.4133</b>	0.4512	-0.0272	0.4145	-0.0319	0.1993	0.3108	0.2173	0.9349
No. of secondary branches per plant	P	0.0013	0.0020	0.0038	0.001	0.0019	0.0001	0.0013	0.0023	0.0007	0.3980
	G	0.1515	0.3046	<b>0.2790</b>	0.0598	0.2911	0.0074	0.1595	0.2945	0.0590	0.7593
No. of days to 50% flowering	P	-0.0039	-0.0037	0.0027	0.0796	0.0034	0.0168	0.0367	0.0082	-0.0160	-0.0468
	G	-0.0436	-0.0156	0.0507	<b>0.2366</b>	0.0773	0.0339	0.2406	0.0859	-0.0662	-0.2341
Length of fruit (cm)	P	0.0270	0.0313	0.0342	0.0029	0.0681	0.0136	0.0220	0.0392	0.0207	0.4463
	G	0.2253	0.2048	0.2131	0.0667	<b>0.2042</b>	0.1367	0.0875	0.1847	0.1006	0.8522
Width of fruit (cm)	P	-0.0402	-0.0086	-0.0032	-0.0193	-0.0183	-0.0917	-0.0057	-0.0003	-0.0404	0.1974
	G	-0.1135	0.0152	-0.0052	-0.0283	-0.1322	<b>-0.1974</b>	-0.0445	-0.0349	-0.1675	0.3041
Days to maturity	P	-0.0084	-0.213	-0.0326	-0.0422	-0.0296	-0.057	-0.0915	-0.0337	-0.0022	0.1244
	G	-0.0896	-0.1595	-0.1890	-0.3363	-0.1417	-0.0746	<b>-0.3307</b>	-0.1847	-0.0178	0.2595
No. of fruits per plant	P	0.0405	0.0822	0.1074	0.0186	0.1035	0.0005	0.0662	0.1796	0.0290	0.4287
	G	-0.0968	-0.1136	-0.1595	-0.0549	-0.1367	-0.0267	-0.0844	<b>0.1511</b>	-0.0387	0.6491
No. of grains per fruit	P	0.1419	0.0809	0.0564	-0.0619	0.0936	0.1353	0.0074	0.0496	0.3074	0.4818
	G	0.3473	0.2783	0.1119	-0.1480	0.2609	0.4491	0.0285	0.1355	<b>0.5294</b>	0.6248

G- R. source-0.4843, residual effect= 0.7181; P- R. source- 0.8120, residual effect= 0.4336

The results on path coefficient analysis (direct and indirect effects) as presented in table-3 revealed that number of grain fruit<sup>-1</sup> had highest positive and direct effect (0.5294) on yield plant<sup>-1</sup> followed by number of primary branches plant<sup>-1</sup> (0.4133), number of secondary branches plant<sup>-1</sup> (0.2790), number of days to 50 per cent flowering (0.2366), height of the plant (0.2318), length of fruit (0.2042) and number of fruits plant<sup>-1</sup> (0.1511) indicating that if other factors are held constant, an increase in these characters individually will reflect in the increased seed yield, which indicating these are the main contributor to grain yield plant<sup>-1</sup>, days to maturity (-0.3307) had highest negative effect on grain yield plant<sup>-1</sup> followed by width of fruit (-0.1974) at genotypic level as presented in table-3. Number of grains fruit<sup>-1</sup> (0.3074) had highest positive and direct effect on grain yield plant<sup>-1</sup> followed by number of primary branches plant<sup>-1</sup> (0.2872), number of fruits plant<sup>-1</sup> (0.1796), number of days to 50% flowering (0.0796), length of fruits (0.0681), height of the plant (0.0133) and number of secondary branches plant<sup>-1</sup> (0.0038) including that if other factors are held constant, an increased yield whereas, width of fruit (-0.0917) had highest negative direct effect on grain yield plant<sup>-1</sup> followed by days to maturity (-0.0915) at phenotypic level. This findings are in agreement with Agnihotri *et al.* (1977) for seed yield plant<sup>-1</sup> and umbel per plant and Yadav

*et al.* (2013) reported days to maturity had highest direct effect on seed yield followed by days to 50 per cent flowering and number of umbels plant<sup>-1</sup> in fennel. Number of grains plant<sup>-1</sup> had highest positive correlation with seed yield plant<sup>-1</sup> via indirect effect of width of fruit. Similarly, number of primary branches plant<sup>-1</sup>, which had highest positive correlation with grain seed yield plant<sup>-1</sup> also had next highest positive direct path. The value of residual effect (G-0.7181 & P = 0.4336) indicated that there may be some other secondary components that should not be ignore.

In the light of the above finding, it may be concluded that improvements in the characters like- plant height, number of primary branches plant<sup>-1</sup>, number of secondary branches plant<sup>-1</sup>, number of days to 50 per cent flowering, length of fruit, width of fruit, number of fruits plant<sup>-1</sup> and number of grains fruit<sup>-1</sup> will help in improving the seed yield in nigella both direct and indirect. Therefore, these characters should be considered for yield improvement in nigella breeding programme.

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# Marketing strategies for vegetable crops

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## Abstract

The marketing strategies of fruits and vegetables, and that this is leading to high and fluctuating 3-4 times of consumer price and only a very small share of the consumer rupee reaching the farmers. Marketing of vegetables crop is complex especially because of permissibility, seasonality and bulkiness. The examine of their marketing focusing particularly on wholesale markets for vegetables which have been established to overcome deficiencies and improve the marketing efficiency. The high percentage of margin to farmer-consumer price difference is inductive of large inefficiency and relatively poor marketing efficiency. There is great need to improve the marketing of vegetables. One important measure would be to bring more market under regulation and supervision of well represented market committee. Another measure would be the promotion and perhaps enforcement of open auctions in the markets. Yet other measures could be efforts to bring more buyers and sellers into the market, bringing them closer perfect markets. The direct participation of farmers should be increased. Market infrastructure should be improved through storage (go-down) facilities cold storage, loading and weaning facilities. Improvement of road network, and cold-chain facilities are also of substantial importance. Greater transparency of operations through supervision and systems can also help substantially. The market integration and efficiency can also be improved by making up-to-date market information available to all participants through various means, including a good market information systems, internet and good telecommunications facilities at the markets. In order to ensure quality of food, the cultivation practices adopted by farmers need to be relooked and awareness to be disseminated among farming community to enhance food quality and fetch good price for the vegetable produce.

**Keywords:** Marketing strategies, vegetable crops

Global horticultural industry has grown several-fold in the last 50 years. Current world fruits production is estimated at 676.9 million tonnes, while vegetable production is estimated at 879.2 million tonnes. Horticulture industry is flourishing and opening up new prospects R&D and employment emerging from awareness about present life style and dietary habits. The Asia-Pacific region accounts for nearly 60 percent of the total area under production, with China and India dominating this space. The challenges of overcoming malnutrition to majority of global population are yet to be fulfilled. Hence, there is need to increase and sustain production and productivity. Horticulture sector has been the mainstay of Indian agriculture with a contribution of about 30 percent to the agricultural GDP from about 14 percent area and 40 percent of total export earnings from agriculture as a whole. At present, area under horticultural crops is 23.69 million hectare with production of 283.47 million tones in India, the second largest producer of fruits and vegetables with the claim of largest producer of mango, banana, cucurbits, cauliflower, coconut, cashew, papaya and pomegranate and the largest producer and exporter of spices. Vegetables plays a crucial role in Indian agriculture as it is essential, not only to meet the food and nutritional security to the people and provide livelihood and income in the rural areas, but also to meet the export demand and requirement of raw material/inputs for the processing industries in the domestic front. The diversified climatic and soil

characteristics have helped the country in producing various types of vegetable crops based on their suitability to the specific environment which gives the country an opportunity to produce a wide range of varieties of a particular vegetable crop with specific characteristics and taste. India in vegetable seeds have contributed immensely in enhancing productivity and production of vegetables in our country but still there exists a gap of 10.1 per cent in national productivity in comparison to global scenario. Further, 62.1 per cent (18 out of 29 states) states in the country are having lower productivity in comparison to national productivity of vegetable (17.8 t ha<sup>-1</sup>). Vegetables are rich sources of vitamins, minerals and plant fibers which provide food and nutrition security. These also generate high income and employment, particularly for small farmers. There has been a revolution in the vegetable production in India in the early years of 21<sup>st</sup> century. The vegetable production of India was very low, less than 20 million tons during 1947, at the time of Independence. The production of vegetables till 1961-65 was about 23.45 million tones which increased to 28.36 million tons in 1967-71 and to 39.99 million tons in 1986. During 1991-1992, the total production was 58.54 million tons from 5.593 million ha with a productivity of 10.5 t ha<sup>-1</sup>. During the year 2000-2001, India produced 93.92 million tons of vegetables from 6.25 million ha raising the productivity to 15.0 t ha<sup>-1</sup>. During 2016-17, the country produced about 108 million tons of vegetables from 7.2 million ha with

unchanged productivity of about 15 t ha<sup>-1</sup>. The current requirement of vegetables in India is close to 137 million ha to meet the requirement of 1.25 billion population of India taking 300 g vegetable per day per individual as recommended by food and nutrition experts. Thus, production and/or productivity need to be increased to meet the actual requirement of vegetables in India. This will require increasing productivity without putting extra pressure on cultivated land which is limited and shrinking day by day. This is also to be noted that vegetables being a rich and cheap source of vitamins and minerals, occupy an important place in the food basket of Indian consumers, a majority of whom are vegetarian by either choice or lack of access. This persistent vegetarianism couple with rising per capita income is fuelling a rapid growth in consumption of vegetables. This will further call for reduction of post-harvest losses, strong support of infrastructure and encouraging policy environment. The rice and wheat are the two major food grains, whose production growth determines the self-sufficiency of the country. Per capita production of rice and wheat has substantially increased from 120 kgs in 1981 to over 144 kgs during the recent year. Meanwhile, the food basket has become much more diversified. Dramatic changes in food consumption patterns have taken place in India in the post green revolution period. Consumers' preference is more towards non-cereals and among cereals the preference is rice and wheat to coarse cereals. Coarse grains are now increasingly used as cattle or poultry feed and hence their importance in food grain availability for human consumption is considerably reduced. Marketing is an area for the "second generation" of green revolution problems. Indian Marketing is undergoing a significant metamorphosis because of economic liberalization and globalization. The successes of marketing strategies and macro-economic policies in developing countries are influenced by the availability of infrastructure development, which plays a significant factor in present era of vegetable marketing. Today, we are experiencing a significant transformation of horticulture sector. In past, horticulture was driven by bid, at present it is driven by command using technological interventions in the marketing process. However, we can articulate that agriculture will be driven by technology in the future in order to provide potential technological opportunities and realize benefits. The monetary potential of technology use in agriculture is not recognized (Kaaya, 1999; Phougat, 2006). Though modern Information Technology (IT) revolution, has helped in not only market information system but also has changed the nature of market functioning altogether by making several intermediaries redundant, reducing the cost of information, lowering the transaction cost and increasing the competition. Farmers perceive that marketing as the

major constraint rather than production to enhancing farm incomes. Markets are the means of either prosperity or distress for the farmers. These are the places where the farmers' fate for the crops they have grown is decided. Hence, the government does everything possible to ensure that the farmers realise a better return for their produce. In addition, enactment of Model APMC Act, linking of all APMCs with National Information Network (NIC-NET) to provide the speedy and timely dissemination of market information to the growers, separate web portals for dissemination of market information, etc., are some of the efforts of the government. In order to render the marketing systems more efficient, government has introduced electronics devices into market mechanism in some markets for bringing more transparency in the markets. Electronic medium has been used for transmission of information in various industries. However, their uses in agricultural markets are relatively low (Murthy and Abhinov, 2012).

Growing demand for vegetables is considered to have

Table 1: Major vegetable producing countries in the World

Country	Area (in ha)	Production (in t)	Productivity (t ha <sup>-1</sup> )
China	24560900	573935000	23.40
India	9396057	162896911	17.30
United State of America	1104640	35947720	32.50
Turkey	1111702	27818918	25.00
Iran (Islamic Republic of)	876830	23485675	26.80
Egypt	772487	19825388	25.70
Russian Federation	790500	16084372	20.30
Spain	683294	13599497	19.90
Mexico	318971	12531000	39.30
Italy	450186	12297645	27.30
Others	19096425	261467661	13.70
<b>World + Total</b>	<b>59161992</b>	<b>1159889787</b>	<b>19.60</b>

Source: FAO Website– February 2015 (Data for 2012, 2013 N/A) and for India Data – (Data for 2013-14) Department of Agriculture & Cooperation.

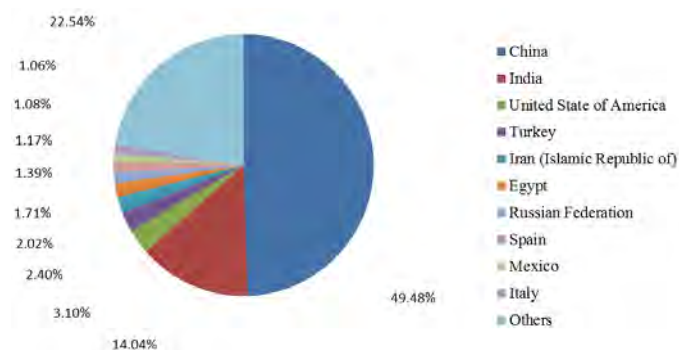


Figure 1: Leading Vegetable Producing Countries

a favorable economic effect on smallholders who dominate the Indian agriculture scenario. Small holdings contribute 78 percent of total holdings with an area share of 33 percent contribute more than half of the production of fruits and vegetables. Small holders have a distinct advantage in vegetable production; vegetable cultivation is labour-intensive and small holders have abundant labour. Moreover, most of the vegetables have a small crop-cycle and therefore provide returns round the year. The price of the horticulture commodities especially onion and potato are highly volatile. At the harvest time and soon thereafter, a steep fall in the whole sell and retail prices is normally observed. With depletion of the stored stocks, the prices tend to increase. This phenomenon is most in the case of onions and potatoes. Price volatility effects consumer in a big way. Abnormal increase in price of these commodities effect the consumers by way of increasing. The efficiency of marketing of fruits and vegetables in India has been of significant concern in the recent years. Poor efficiency in the marketing channels and inadequate marketing infrastructure are believed to be the cause of not only high and fluctuating consumer prices, but also to little of consumer rupee reaching the farmer (Kaul 1997, Ashturker and Deole 1985). Indian farmers typically depend heavily on middleman particularly fruits and vegetable marketing. The producer and consumer often get a poor deal and the middleman control the market, but do not add much value. There is also massive wastage, deterioration the quality as well as frequent mismatch between demand and supply both spatially and over time (Subbanarasiah, 1991 and M *et.al* 1985). In the light of these concerns, studies were taken-up. The economic importance

has also increased and high labour intensity in the production of most fruits and vegetables production also make them important from the employment angle as well (Sharma, 1991). An increase in area allocation under horticultural crops has often been suggested as measure for agricultural diversification, increased employment and income of farming community (Malik, 1998).

The area assessment will be carried out for the selected crops in the selected districts of major states. The crops will be selected based on the production share. The following crops and study area are being proposed by satellite data to be used are either of LISS III (23.5 m resolution) or LISS IV, depending upon the spatial extent of the crop. In the absence of availability of Indian satellite data during the crop growth, foreign satellite data will also be explored in given below.

Crop type	Crop	State (Districts)
Fruit	Banana	Tamil Nadu, Andhra Pradesh, Maharashtra, Gujarat, Karnataka
	Mango	Uttar Pradesh, Gujarat, Karnataka, Andhra Pradesh, Bihar
	Citrus	Andhra Pradesh, Maharashtra, Punjab, Madhya Pradesh, Gujarat
Vegetables	Potato	Uttar Pradesh, Bihar, West Bengal, Gujarat, Punjab
	Onion	Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Bihar
	Tomato	Andhra Pradesh, Odisha, Karnataka, Madhya Pradesh, West Bengal, Bihar
Spices	Chilli	Andhra Pradesh, Karnataka, West Bengal, Madhya Pradesh, Odisha

Source: Horticultural Statistics at a Glance -2015

Table 2: Status of vegetables production and productivity in Uttar Pradesh

Year	Area (000 ha)			Production (000 t)			Productivity (t ha <sup>-1</sup> )	
	India	U.P.	India (%)	India	U.P.	India (%)	U.P.	India
2001-02	6155.70	777.90	12.64	88622.00	15044.80	16.98	19.34	14.40
2002-03	6091.80	0.00	0.00	84815.40	0.00	0.00	0.00	13.92
2003-04	6308.90	819.50	12.99	93165.00	18190.40	19.52	22.20	14.77
2004-05	6755.60	840.90	12.45	101433.50	15792.80	15.57	18.78	15.01
2005-06	7218.00	895.50	12.41	111399.00	17337.30	15.56	19.36	15.43
2006-07	7564.00	897.60	11.87	115011.00	18190.40	15.82	20.27	15.21
2007-08	7848.30	960.80	12.24	128448.80	19790.30	15.41	20.60	16.37
2008-09	7980.70	987.80	12.38	129076.80	18950.10	14.68	19.18	16.17
2009-10	7984.80	1020.10	12.78	133737.60	22435.70	16.78	21.99	16.75
2010-11	8494.50	829.40	9.76	146554.50	17679.40	12.06	21.32	17.25
2011-12	8989.60	852.10	9.48	156325.50	18563.70	11.88	21.79	17.79
2012-13	9205.20	912.70	9.92	162186.60	19571.70	12.07	21.44	17.62
2013-14	9396.00	859.40	9.14	162897.00	18545.00	11.38	21.60	17.64
2014-15	9541.00	1145.42	12.15	168300.00	23572.30	14.00	20.58	19.94
2015-16	10106.00	1200.06	11.87	169064.00	25510.06	15.08	21.25	20.44
2016-17	10307.89	1400.13	13.59	175194.41	26407.34	15.07	19.00	17.00

Source: Various Issues Horticultural Statistics at a Glance

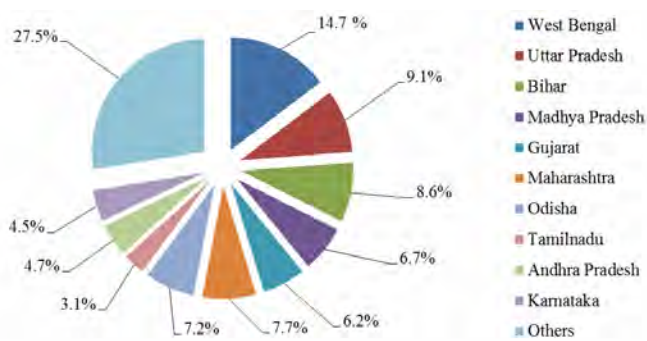


Figure 2: Leading vegetables producing states in terms of area

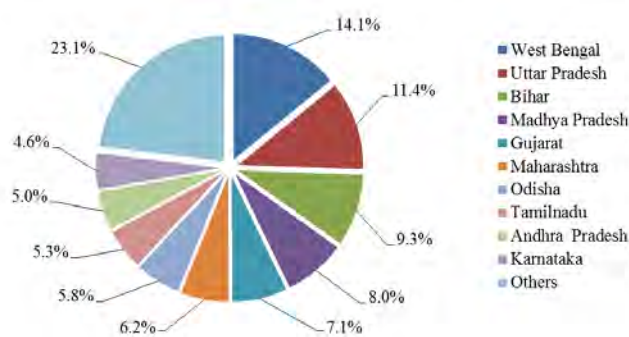


Figure 3: Leading vegetables producing states in terms of production

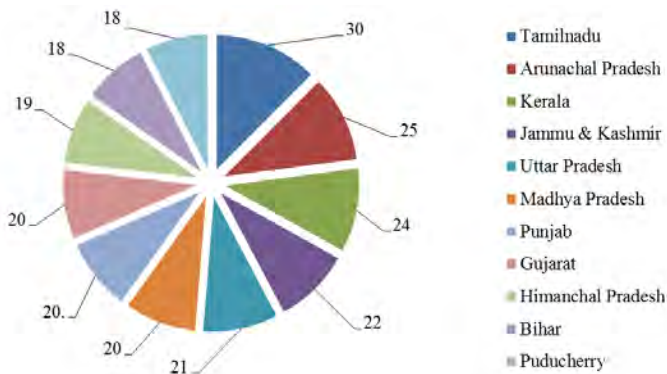


Figure 4: Leading states in vegetables productivity (in metric tonnes)

Notwithstanding these advantages, small holders confront a number of constraints in vegetable production. The production risks are high, primarily because of considerable production losses caused by pests. These are estimated to be about 30 percent of the total vegetable output. The post-harvest losses are also quite high due to their perishable nature. There is lack of marketing and processing infrastructure. Local markets are thin, and trading in distant markets is non-remunerative due to high cost of transportation. Also, prices are volatile and often fall

drastically with harvesting of normal production of vegetables and this problem gets further worsened in case of over production. The major constraints in vegetable marketing are as follows:-

- Lack of rural roads.
- Lack of cold storage facilities.
- Lack of refrigerated transport vans.
- Inadequate space.
- Inadequate processing capacity.
- Poor marketing intelligence.
- Lack of mechanical grading and packaging.
- Lack of post-harvest management and processing technologies.
- Costly transportation.
- High cost of packaging material.
- High price risk (post-harvest losses).
- Faulty weighing mechanism and price discounting.
- Delayed sale and payment.
- Lack of market information and regulation.
- Lack of forward trading.

Marketing channel in vegetables in India is complex involving large number of channels between producer and consumer. These channels are as follows:

- Village trader.
- Commission agent.
- Cooperative regulated market.
- Forwarding agent.
- Primary wholesale trader.
- Shipper.
- Secondary wholesale trader.
- Retailer.

Producers' share in the price to the consumers has often been around 40 percent. A few important observations on this issue are listed as follows:

- Farmers selling the produce directly to consumers receive higher prices.
- Farmers share is higher in off season than in normal season crop.

- Connecting markets by roads had only marginal effects on producers' share in retail price.
- Vegetables like onion, cabbage, and peas normally have higher producers' in retail price.
- As the number of channels increases, there is proportional reduction in the consumers' share of the retail price.

Various suggestions to improve producers' share in the retail price are as follows:

- Develop strong vegetable network at priority.
- Provide a platform to sell vegetables through cooperative marketing.
- Curb malpractices.
- Create healthy competition.
- Establish processing units.
- Establish cold chain facilities.

The above issues need to be addressed for improve marketing efficiency through a better infrastructure and institutional reforms and these steps will go a long way in increasing vegetable production in the country.

## RESULTS AND DISCUSSION

Several measures are recommended for improving the marketing of vegetables in the country the following major recommendations emerge from the studies reported here the marketing efficiency of vegetables. First it is important to bring more market under regulation and put them under the supervision of well represented market committee. Second is important to promote, and perhaps even enforce through rule or laws, the practice of open auction in the markets. Third it is important to more number of buyers and sellers to the wholesale markets so as to encourage healthy competition close to perfect market condition and better price realization to producer farmers. Besides above measures market infrastructure should be improved through storage (go-down) facilities cold storage, loading and weaning facilities. Improvement of road network, and cold-chain facilities are

also of substantial importance. Greater transparency of operations through supervision and systems can also help substantially. The market integration and efficiency can also be improved by making up-to-date market information available to all participants through various means, including a good market information systems, internet and good telecommunications facilities at the markets. In order to ensure quality of food, the cultivation practices adopted by farmers need to be relooked and awareness to be disseminated among farming community to enhance food quality and fetch good price for the vegetable produce. To ensure safety of perishable farm produce from spoilage during transit to the processing units, cold chain is very important, including storage capacity and refrigerated trucks.

Therefore, besides training farmers for food safety and quality, awareness among transportation personnel is a prerequisite for quality food to reach at destination because inadequate storage and temperature during transportation would result in loss of quality of the produce. It is hereby submitted to initiate a short term diploma course for transporters to obtain license for perishable commodity transport business.

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# Problems of saffron marketing in Kashmir Valley

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## Abstract

Kashmiri saffron is facing marketing problems due to its poor quality on account of traditional post harvest techniques. Technologies are available which can ensure the best quality of Kashmiri saffron, for which it is famous in the world and creation of saffron spice park under national saffron mission is a step forward in this direction. National saffron mission is likely to boost the overall saffron production of Kashmir from 15MT to 22MT. (Souvenir Saffron Exporters Brand, 2016). Expansion program in non traditional areas will further enhance the overall production to about 60MT. Therefore, there is a need to provide the solution to the farmers for the better market which at present is unorganized. Improving marketing value chain of saffron with structured marketing channels will definitely increase livelihood security of more than 16000 farm families which are associated with this trade directly or indirectly. The present study is therefore an attempt to highlight the problems of marketing of saffron in Kashmir valley so as to provide remedial measures and benefit the growers as much as possible and encourage this involvement in the saffron value chain.

**Keywords:** Saffron marketing, dalals, marketing channels

Saffron (*Crocus sativus*) plays a significant role in the economy of Jammu and Kashmir. It is the most expensive and priced spice. It is limited to the Kare was particularly in the south eastern part of the valley. As per opinion of some noted researchers it has been cultivated in Kashmir at Pampore by Maharaja Ashoka, who was follower of Buddhism, picked up some of the great principles of Ethics from various religions and these principles were styled as Dhamma which was nothing but a code of duties based on practical ethics. Therefore, the cultivation of saffron acceded in Kashmir in 250 B.C. In Kashmir four kinds of saffron are known which are Lacha, Mongra, Androciam and Perianth. Among them Mongra is the best in quality that consists of least floral waste and foreign matter. It is this quality which is exported. Kashmir stands next to Spain and occupies second rank in the international market as far as the quality of saffron is concerned. India which occupies third place in the international market as far as the saffron production is concerned is because of the state of Jammu and Kashmir where from the entire production of saffron comes. The increase in demand in national and international market makes saffron a remunerative agricultural activity because of its high value. Despite its less percentage in total cropped area in Jammu and Kashmir, its high value constitutes it the second largest commercial activity after fruit production. The hub of this activity is district Pulwama which occupies about 86 percent of the total area under saffron in the whole state of Jammu and Kashmir and out of which about 80 percent of the saffron area belongs to Tehsil Pampore alone. More than 10,000 farm families of 226 villages are associated with this

crop directly or indirectly. Saffron cultivation is highly labour intensive activity where most of the field and post harvest operations are carried out by women (Kamli *et al.*).

## Global scenario

Native of southern Europe, saffron is cultivated in Iran, Spain, France, Italy, Austria, Greece, Turkey, England, China and India. However, the major saffron producing countries of the world are Iran, Spain and India. Iran is holding a distinction of being the major shareholder both in terms of area and production. The contribution of Iran with respect to area and production in the world stands highest in the world. Contribution of Iran to global saffron production is 89% (278.6MT) while as only 5% (15MT) is J&K's contribution. Moreover, minor countries contribute 6% (18.34MT) to global saffron production (ITC, Geneva, 2016).

The leading saffron growing countries like Iran, Spain and Greece with intensive production technologies are able to achieve higher production and productivity (4-8Kg/Ha) which is much higher than J&K's productivity and posing great threat to our saffron industry as imports are increasing every year. Thus there is a need to increase production by bringing more area under cultivation and double the average productivity by adopting intensive production system, efficient processing and marketing to make it globally competitive and remunerative to growers. Major Saffron exporting countries are Iran, Spain, Portugal, France, Afghanistan, Germany, India, UAE, Italy. Exported value of saffron at the global level is 169,940 US\$ thousands in 2014. Iran's contribution in export value at the global level

is 41.23% (70,074) while as India's contribution is only 1.08% (1,850) (ITC, Geneva, 2016).

### State scenario

In India, Jammu and Kashmir state has a natural monopoly power in the production of saffron, which is cultivated on karewa lands (wudar). The cultivation of saffron is confined to districts of Pulwama, Budgam, some hamlets of Srinagar and Doda. The major saffron growing belts are Samboora, Chandhara, Letpora, Kakapora, Shar-Mandekpal, Gundbal, Ladhoo of district Pulwama and Hyatpora of district Budgam. Khunmoh, Zewan, Balhama, Sampora, Ladhoo, Chandhara, Woyan, Khrew, Shar Konibal, Dussu, Namblabal, Kadlabal, Hatiwara, Samboora and Lethpora are prominent saffron villages of Tehsil Pampore (Nehvi and Yasmin, 2011). District pulwama accounts for 75% of the total area under saffron in the state followed by district Budgam with 16.3 percent. Some pockets of District Srinagar accounts for 6.68 percent while hamlets of district Doda represent 2.5% of the total area under saffron. (Economic Survey 2010). The production in 2009-10 was 9.46 metric tonnes which increased to 15 metric tonnes in 2015-16. However the area under saffron cultivation has remained same (no improvement) at 3785ha. The National demand for Kashmiri saffron is to the tune of 100 MT and the gap is filled up by the Iranian Saffron. It is interesting to note that about 16000 farm families in Kashmir valley are dependent on saffron. (Nehvi F.A., 2011). At the same time it is very unfortunate that 85 percent families associated with saffron cultivation in Kashmir valley are small (marginal) farmers (Imtiyaz-ul-haq, 2014).

Average price of saffron increased from Rs 0.298 lakh kg<sup>-1</sup> in 2005-06 to Rs 2.701 lakh kg<sup>-1</sup> in 2009-10. Quantity of exports in 2009-10 were 1.59MT (value of Rs 342.71 in lakhs) while as that of imports were 0.30MT (of Rs 480.00 in lakhs) (source: Spice Board). There are huge price fluctuations associated with saffron. From October to November there are peak prices. From January saffron prices fall because from January Kashmiri saffron market is flooded with Iranian saffron. From April to June there are constant prices and it was Rs 1.3 lakh kg<sup>-1</sup> and Rs 1.75 lakh kg<sup>-1</sup> for Mongra and Lacha respectively in 2015-16 (Sovenier Saffron Exporters Brand, 2016).

The objectives of the study was to understand the concept of marketing in a comprehensive manner, to highlight the problems of saffron marketing in Kashmir Valley and to suggest remedial measures to efficient saffron marketing in Kashmir Valley.

### METHODOLOGY

Pulwama accounts for 75 per cent of the total area under saffron (Economic Survey 2010) and Pampore tehsil of district pulwama is known all over the world for the quality saffron it produces owing to its peculiar topography, suitable climatic conditions, soil and water table. Therefore the present study was conducted in Pampore.

The Pampore information graph explains 60613 People are living in this Tehsil, 31654 are Male and 28959 are female as per 2011 census. Expected population of Pampore in 2017 is between 58795 and 64856. Literate people are 32703 out of which 20167 are male and 12536 are female. People living in Pampore depend on multiple skills, total workers are 22631 out of which men are 16981 and women are 5650. Total 1398 cultivators are dependent on agriculture farming out of which 1294 are cultivated by men and 104 are women. 886 people work in agricultural land as a labour in Pampore, men are 860 and 26 are women. As saffron is the main crop of Pampore so majority of the cultivators are engaged in saffron cultivation. Only a handful of cultivators (roughly 20%) are engaged in cultivations other than saffron. ([www.indiagrowing.com](http://www.indiagrowing.com)).

Out of 29 villages in Pampore tehsil, one each having highest, medium and lowest saffron production, that least dispersed in terms of production, were selected. From the selected villages 4 components *viz*, growers, dalals & local traders, retailer/wholesaler and firm/sub-firm were taken into consideration (Table 1).

Since we are working with a finite population and the population size is known, we applied Taro Yamane's formula for determining the sample size.

$$n = N / 1 + N(e)^2$$

Where, n=corrected sample size, N=population size (here our population/universe is 886, assuming 80% of 886 cultivate saffron in pampore which becomes 708.8), and e=margin of error, e=0.05 based on the research condition.

A total of 102 respondents of size of 256 were interviewed for identifying problems of saffron marketing. The interview method of collecting data involved presentation of oral-verbal stimuli and reply in terms of oral-verbal responses. Both personal as well as telephonic interview was conducted to get the desired information. Interview with saffron associations, cooperative societies and experts in the field of agriculture and marketing also proved helpful for the present study.

Table 1. Details of components studied

Village	Growers	Dalal & Local traders	Retailers/ Whole-salers	Firm/ Sub-firm	Total
Ladoo	12	4	14	5	35
Namblabal	12	4	15	7	38
Khrew	12	4	10	3	29

The secondary data, obtained from Statistical Digest of State, issued by the Directorate of Economics and Statistics, Agricultural Census from Planning and Statistical Department and Economic Review issued by the Directorate of Economics and Statistics, Planning and Development Department were also used.

### Understanding marketing from broad perspective

The concept of marketing can be viewed from social and managerial perspectives. At its simplest, marketing can be defined as an exchange transaction that takes place between the buyer and seller. Marketing occupies an important position in the organisation of business unit. Traditional view of the marketing asserts that the customer will accept whatever product the seller presents to him. But this point of view of marketing has now changed. The modern concept may be viewed from the customer's point of view. Marketing is centred around the customer. It does not produce whatever he likes but whatever consumer wants. Philip Kotler has rightly remarked "Marketing is analysis, organising, planning and controlling of the firm's customer-impinging resources, policies, activities with a view to a profit". Marketing is a total system of business, an ongoing process of (1) discovering and translating consumer needs and desires into products and services (through planning and producing the planned products), (2) creating demand for these products and services (through pricing and promotion), (3) serving the consumer demand (through planned physical distribution) with the help of marketing channels, and then, in turn (4) expanding the market even in the face of keen competition. In any planned economic development programme, marketing assumes a very important role in maintaining equilibrium between production and consumption. Marketing is the basic reason for the existence of a business organisation. In the age of fast changes, marketing is the springboard of all activities. It works as a guide for all business/non-business organizations. It is a powerful mechanism which alone can satisfy the needs and wants of consumers at the place and price they desire. The success of a business depends largely on the effectiveness with which its marketing strategies are formulated and implemented. Marketing is said to be the eyes and ears of a business organisation because it keeps the

business in close contact with its economic, political, social and technological environment and informs it of events that can influence its activities as per requirements of the market. Marketing helps in having a good range of products in constant demand and suggests to the management the scope for improving and developing new products to satisfy the changing customer needs. Customer is the king of the market. Customers decide what products suit their needs. Therefore, we can say marketing satisfies our needs by providing form utility, person utility, exchange utility, place utility and time utility. Marketing can be summed up as consisting of sales in a planned way, creation of customers and creating of demand and satisfying it.

Following are the essential elements of marketing:

1. Identifying the customers who are chosen as the target of marketing efforts.
2. Understanding the needs and wants of target customers.
3. Development of products and services for satisfying the needs of the target customers.
4. Satisfying needs of target customers better than the competitors.
5. Ensuring reasonable profit by performing all these activities.

### Marketing concepts

Philip Kotler has shown five competing concepts for carrying out marketing activity in any organization:

1. Production concept: Production concept of marketing believes that customers are interested only in low priced, easily and extensively available goods; and finer points of the product are not very important to them.
2. Product concept: The product concept implies that customers favour those products that offer the most quality, performance and features.
3. Selling concept: Selling concept assumes that effective selling can push its output into the hands of customers. In other words, it assumes that consumers on their own will not buy enough of organization's products, unless the organization undertakes aggressive sales and promotional efforts.
4. Societal marketing concept: Societal marketing concept is an extension of modern marketing concept. It emphasises social welfare along with the interests of the firm and its customers. This concept includes social implications in the decision-making.

### Saffron marketing in Kashmir Valley

Saffron marketing cover the services involved in moving saffron from the farm to the consumer. It is one of the most important foreign exchange earners among the spices in India. Grown entirely in the state of J&K, about 49% of its total produce is exported outside the country (Munshi, 1990). Saffron marketing in the state and the country as a whole is highly unorganized. Marketing of saffron is concentrated in the hands of few traders because a common saffron grower cannot directly sell his meagre produce as he cannot grade, pack and store the produce at individual level (Zaki *et al.*, 2002). The grower being financially poor is prompted to sell his produce through middlemen (Dalal) and local traders to owners and private firms who in turn sell it to the wholesaler. The saffron is finally distributed to exporters and domestic markets, with negligible record regarding its quality standard and revenue realized. Exports in particular are dispatched, not from the traditional spice exporting ports but from Delhi, Mumbai, Kolkata, Chennai and Amritsar by air. Thus they escape grading and quality control and fail to attract a potential competitive foreign market.

Number of surveys of saffron families carried out in Kashmir, especially in Pampore, revealed that more than 50 percent of them comprising farmers of large, and small land holdings, sell their produce to the brokers (Dalal) and more than 30 percent to sub firms (Haq. U.I., 2014), while very less percentage sell directly to the wholesalers in Delhi, Amritsar, Mumbai, Kolkata etc., and to the cooperative societies.

According to Munshi (2002) the main marketing channels involved in saffron marketing are brokers, local traders, agents, cooperative societies, government agencies and companies. However, according to Imtiyaz-ul-haq (2014) the main marketing channels of saffron in the valley of Kashmir are as under:

#### Dalals (C1) Local Traders (C2) Agents (C3) Sub Firms (C4)

→ → →

His study revealed a price spread of more than three hundred percent between the farm gate prices and the market prices of saffron, the advantage of which is reaped by the network of intermediaries that dominate the marketing channels in saffron trade. There is much scope to increase the producer's share in consumer's rupee and marketing efficiency provided the no. of intermediaries is reduced and government's intervention in the marketing system is strengthened. His study revealed that in Pampore, the traditional saffron marketing centre of Kashmir valley, the big traders purchase the marketed surplus at relatively cheaper prices from the growers and dalals during the

months of November to January, primarily for hoarding. The growers who lack finance and storage facilities and have no idea about the demand and supply conditions at the terminal markets incur huge losses.

Wani *et al.* (2008) reported that the main market of saffron is at Pampore. Their study revealed that the complex marketing process in saffron renders the grower's to realize a lesser share which is thus considered the vital factor responsible for declining area under saffron.

The primary survey revealed the following problems in the production and marketing of saffron in the Kashmir valley:

Low productivity and production (Expansion of Geographical Coverage).

Pollution caused by cement factories in Khrew area of South Kashmir is adversely affecting saffron production and marketing. Mercury element tremendously affected its production. It has affected its corm, bulb and leaves leaving it will low production levels. Environmental science experts who have studied the effects of cement factories in Khrew on the human lives, flora, fauna and wild life, said that their presence is harmful in the short as well as long run. Khrew area is important producer of saffron. According to survey by agriculture departments Khrew is the fourth cultivator of saffron in India. As per estimates of saffron dealers of Khrew this town has a capability to grow minimum 385 Kg of saffron in a year. Upto 2004 saffron growers were producing 248 Kg of saffron but with the coming up of seven cement factories in a particular area of Khrew close to villages Pakhribal, Nagadore and Botthen the production declined to a great extent. Now the condition is even worse as they hardly get 70 Kg which is showing that the loss of capacity to grow saffron by the chemicals and dust coming out of these factories.

Lack of Standardization, Certification and Quality Assurance.

Kashmiri saffron like Afghan saffron is largely unbranded in the national/international markets.

Lack of research and development.

Low capacity / Knowledge of saffron stakeholders.

Producers are not aware of the marketing channels and market structure of saffron.

Lack of efficient post-harvest techniques like drying, grading, packing and storage facilities. This results in distress sale by the growers.

Landholdings of majority of the growers are small. Accordingly the produce is also limited with each grower with no option for the competitive markets.

Saffron growers, majority of which are marginal, are economically poor and this compels them to borrow money in advance from the dalals and other money lenders, resulting in distress sale.

Adulteration is another burning issue associated with saffron marketing. It results in the deterioration of the quality of saffron. Adulteration is one of the biggest cause responsible for decline in the demand for Kashmiri saffron in the international market. It is an emerging threat to the industry as large market share of saffron is being exported through sale of spurious saffron and thus warrants detection of adulterants and there is thus need for devising mechanism for spot detection of adulterants.

The marketing channels expropriate a substantial proportion of the profit with both the growers as well as the consumers being the sufferers. Once the marketing is regularized the demand would increase and the farmers will get better incentives and subsequently divert more land for the cultivation of this crop.

In Pampore, the traditional saffron marketing centre of Kashmir valley, the big traders purchase the market surplus at relatively cheaper prices from the growers and dalals during the months of November to January, primarily for hoarding. This was also confirmed by the study of Imtiyaz-ul-haq (2014). The growers who lack finance, storage and other facilities and have no idea about the demand and supply information at the terminal markets incur huge losses. The big traders and the wholesale firms thus make heavy profits through exploitation of these growers.

Table 2 clearly reveals that there are huge price fluctuations associated with saffron. From October to November there are peak prices. From January saffron prices fall because from January Kashmiri saffron market is flooded with Iranian saffron.

Saffron is highly remunerative and offers ample scope for employment generation. Different studies on the economic analysis of saffron indicate that the crop is economically viable. There is much scope for making this crop more profitable provided efficient marketing system to expand the area as well as increase the production of saffron in the state is made possible. Various studies have found that those countries which don't produce saffron are exporting saffron. This shows that saffron has healthy market. The price fluctuations have been the serious cause of concern to the growers and there is a need to frame minimum price support

Table 2: Market price (Rs in lakhs) 2015-16

Month	Mongra	Lacha
October	1.33	1.8
November	1.2	1.7
December	1.2	1.7
January	1.11	1.6
February	1.11	1.6
March	1.11	1.6
April	1.3	1.75
May	1.3	1.75
June	1.3	1.75
July	1.33	1.8
August	1.33	1.8
September	1.33	1.8

Source: Sovenier Saffron Exporters Brand, 2016.

policy for this particular crop. It is important to note that various studies have been conducted on production, productivity and distribution of saffron in Kashmir valley but no study has been conducted so far with regard to problems of saffron marketing and price fluctuations of saffron. There is a need to work in these areas.

Healthy value chain is that which targets grower. In other words, the value chain in which the growers get maximum benefits is said to be the most healthy value chain. There is a need to develop a policy paper to benefit the growers as much as possible and encourage involvement of them in the saffron value chain.

### Remedial measures to efficient saffron marketing in Kashmir valley

1. Increase saffron production and productivity. An extensive studies are to be conducted in agro-eco zones and sub-eco zones of Jammu and Kashmir to identify suitable area for saffron production in Jammu and Kashmir. The best way in which we can improve saffron production and productivity levels is preparation, production and distribution of quality corm.
2. Barcodes should be provided to all saffron growers.
3. Provide loans to the farmers at low rate of interest so that they will be free from the clutches of local moneylenders who squeeze them. It is said that farmer is born into debt, lives in debt and dies in debt. The poor farmers approach money lenders for investing into cultivation who levies very high rate of interest and who takes away the maximum amount of the share from the produce. In case if the crop fails due to natural calamities then the situation would be worse as the farmer is not in a position to pay his loans and ultimately he is forced to sell the land at throw away price to the money lender.

4. Generate a new distribution network that connects the farmers directly to the consumers to get maximum returns as the present channel of distribution involves multiple mediatory who takes away the major portion of profits which otherwise the farmers is supposed to get.
5. There should be stringent action against black marketers and hoarders who buy the stocks from farmers at cheap prices and create artificial demand and then sell the stocks at higher prices.
6. Creating local outlets at each village where the farmers sell their stocks directly to the consumers or the authorized buyers at fixed prices would help to a great extent. Intervention of government in this network is essential to bring the fruits to the farmers.
7. At the village level there should be counseling centers for farmers about the worth of their stocks so that they can get fair price. The crucial role of Non-Governmental Organizations (NGOs) is needed in this context. Cooperative societies and growers committee can also play great role in this regard.
8. There is a need to establish regulated markets for saffron as saffron is highly unorganized and unregulated. Moreover saffron research centers need to be established in all major saffron growing areas which will provide timely marketing information to saffron growers.
9. There should be proper provision for standardization and grading of the produce for ensuring good quality to the consumers and better prices for the farmers. There is a need to establish standard/modern processing centers, employing modern technology for cleaning, drying and packaging of saffron at the district and the provisional level. Government should enable the Jammu and Kashmir saffron companies/associations and firms/sub-firms to get ISO certification. Need of the hour is to create and approve the National Standards for Kashmiri saffron suitable for quality production, processing and packaging.
10. There should be promotion of Kashmiri saffron at national and international markets. Kashmiri saffron should be exempt from taxes for export purposes till it becomes internationally strong and competitive. Government of India in general and ministry of foreign affairs in particular can play an important role in promoting Kashmiri saffron at exhibitions and trade fairs and assisting the saffron growers and traders in networking. Saffron growers, traders, firms/sub-firms should be given good chance in participating in the national /international conferences, seminars and workshops. Media help should be taken to raise public awareness about the nutritional and health benefits of saffron.
11. Research sector is key in economic growth (Romer, 1986). It is ideas rather than natural resources that are more important for growth and development. Japan is best example. Fewer natural resources cannot affect economic growth. Japan imported machines from US and later dismantled them to see how they worked and manufactured their better prototypes. Japan proves that 'Ideas are essential for the growth of an economy.' Good amount of research is done on production and distribution of saffron in the state of Jammu and Kashmir but no comprehensive research is conducted so far with regard to marketing and development of saffron exports. Therefore, extensive research is required in the field of saffron marketing and the present paper attempted to highlight some of the problems of saffron marketing in the Kashmir Valley. Government should establish Satellite Sites under the supervision of National Saffron Research and Development (R&D) Institute in different saffron growing areas. Various Research studies confirm the high positive correlation of research and development (R&D) and the growth rate of output. All those countries that allocate a larger share of output to research and development (R&D) are better off in terms of growth and development. Our economy also needs to allocate a larger share of output to research and development (R&D), education and human capital formation.
12. Government should lend support to those who are involved in saffron production, processing and packaging such as saffron associations, cooperative societies, firms/sub-firms and honor those academic scholars who are contributing to our knowledge of saffron through different research papers and publications.
13. Establishment of farmer schools in villages in general and saffron growing areas in particular can help in the capacity building of saffron stakeholders. Lucas (1988) assumes that investment in education leads to the production of human capital which is crucial determinant in the growth process. He makes a distinction between the internal effects of human capital where the individual worker undergoing training becomes more productive, and external effects which spillover and increase the productivity of capital

and of other workers in the economy. The higher the productivity of training, the higher will be the increase in the marginal productivity of labour (MPL) that follows training and hence the higher the future wage rate. This means that the incentives to training are greater and so will be the growth rate of the economy. Technical and skilled persons and saffron growers should receive training on production, processing and marketing of saffron. Saffron cultivation being highly labour intensive activity where most of the field and post harvest operations are performed by women (*Kamli et al.*), special practical training to women saffron growers on field and post harvest operations and marketing can help in tackling the post harvest and marketing related issues. Moreover, establishment of women self help groups of saffron, who inculcate the habit of thrift among members, can raise huge amount in the form of small savings. Help from NABARD can also be taken. These self help groups can highlight all problems associated with production and marketing of saffron.

14. Since saffron is the major cash crop of Jammu and Kashmir having national and international importance, coordination of Jammu and Kashmir government with the ministry of higher education to include economics of saffron production and marketing in the curricula of schools, colleges and universities can help in understanding not only the marketing concept in comprehensive manner but problems and prospects of saffron marketing as well and accordingly address the remedial measures.

15. The existing legislations are outdated and are not in tune with the changing trends and technological inventions and the same need to be updated forthwith.

The idea of e-marketing of the agricultural and horticultural products has also been catching on lately. While "organized retail" may not be a panacea for addressing all the problems of the agricultural marketing, it could help in improving the supply chain and bring down wide margins between farm gate and consumer prices. Further, given the vastness and diversity of Indian agriculture, the country requires multiplicity of instruments, scaling up of successful experiences like cooperative marketing and organised retail to impart efficiency, competitiveness and modernization of agricultural marketing. There is also a need for the states to promote producers association, producers companies and cooperative marketing societies to improve bargaining power of producers.

16. The move towards common National Agricultural Markets announced in the Union Budget 2015-16 need to be pursued vigorously to ensure remunerative prices to farmers from the open market and to reduce the demand for price support mechanism.

The study concludes that poor economic foundation of these farmers constrains them to acquire money ahead of time from dalals coming about into distress deal. This issue needs to be handled seriously by the government by giving cheap credit facilities to the growers. Furthermore, accentuation ought to be given on instilling the soul of cooperative cultivating. By cooperative marketing the chains of middlemen can be eliminated. Coordinate connections between the ultimate consumers/end users and the growers can improve their monetary standards and provide them with the market impetuses necessary for the expansion of this generally shrinking segment. Another region of serious concern is in regards to the adulteration of this very crop by the middlemen. Adulteration has badly affected the business of this very crop. This practice has badly affected the marketing of Kashmiri saffron. Serious steps need to be taken by the government to stop it. In order to solve marketing related problems of saffron in our state, understanding marketing from the broad perspective is a *sin-qua-non*. Everybody does not know everything of anything, therefore there is need for dialogue making. It can generate solutions. All saffron stakeholders must come forward and form dialogue with both government as well as non-government bodies at national as well as international levels.

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# Biology, varietal screening and management of pulse beetles in storage

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## Abstract

The article presents detailed informations emanated out of various research reports on various aspects of biology (comparative biology on different hosts, seasons and species), varietals screening and the management of pulse beetles through eco-friendly, chemical and IPM techniques in storage conditions. There is insufficient information on long term use of various toxin grain protectants used against pulse beetles in storage, the doses required and the recovery rate of beetle species on treated seeds. Based on these, increased attention and research on adoption of better methods like host plant resistance, biopesticides etc., that meet environmental and food safety requirements, is advocated.

**Keywords:** Bruchid, *Callosobruchus* spp., Comparative biology, Pulse beetle, Resistance

Pulses are the second most important group of crops worldwide after cereals. They are excellent sources of proteins (25-40%), carbohydrates (50-60%), fats, minerals and vitamins. They are much cheaper as compared to other protein sources like meat, fish and egg. Hence, they are a good supplement to cereal and root crop based diets in developing countries including India. Based on the recommendation and expected population growth, about 38 million tonnes of pulses would be required by 2018. Even though India is the world's largest producer of pulses with a total production of about 14.7 million tonnes, still more production is needed to attain the goal of self sufficiency.

Among the various constraints responsible for the low yield of pulses, insect pests are considered to be very important. More than 200 species of insect pests have been recorded infesting pulses in India. Of these, pulse beetle belonging to the family Chrysomelidae causes considerable loss in quality and quantity of pulses. They are cosmopolitan in distribution and poses very serious threat to stored legumes. The most preferred hosts are cowpea, mungbean, peas, pigeonpea, lentil, greengram, chickpea and soybean. The important species reported from India are *Callosobruchus maculatus* (Fabricius), *Callosobruchus chinensis* Linnaeus, *Callosobruchus analis* (Fabricius), *Callosobruchus phaseoli* (Gyllenhal) and *Callosobruchus theobromae* (Linnaeus).

Generally, bruchid infestation starts from field where the adult female oviposits on pods. The grubs penetrate the pod and remain concealed within the developing seeds as hidden infestation. Such infected seeds carry the bruchid population to storage and causes the infestation. The infested seeds can be recognized by the white eggs glued on the seed

surface and the round exit holes with the 'flap' of seed coat.

There is high variability in infestation levels from season to season. Hence, a quantitative assessment of loss by these storage pests has been difficult. They can cause up to 100 per cent loss when left unattended. They cause grain loss by consumption as well as by contaminating the grains with excrement and fragments. This leads to post-harvest losses, viz., reduced weight, low viability, poor marketability etc. The infested seeds are rendered unfit for human consumption as well as for sowing purposes due to quality and germination losses and mould growth. Bruchids can damage 100 per cent of stored seeds causing weight losses upto 60 per cent (Hill, 1993).

## Biology of pulse beetle in storage

The developmental biology of pulse beetle varies with temperature and humidity, nutritional quality of pulses and competition. The adult female lays smooth, white, cigar shaped eggs on the seed surface. The incubation period averages to five to six days. It hatches into small, C shaped, pale yellowish grubs. There are four instars and the total grub period is 18-20 days. It is followed by pre-pupal and pupal stages of about seven to eight days. The total life cycle is approximately 28-32 days.

The comparative developmental biology of *C. maculatus* on different pulses was conducted in the laboratory at the Department of Agriculture, Om Parkash Jogender Singh University, Rajasthan during 2014-15 by Sharma *et al.* (2016). Five treatments i.e., five pulses [green gram (*Vigna radiate* (L.) R. Wilczek, black gram (*Vigna mungo* (L.) Hepper), chickpea (Desi) (*Cicer arietinum* L.), cowpea (*Vigna sinensis* L.) and pea

(*Pisum sativum* L.)) were replicated thrice. Significantly highest numbers of eggs (89.3) and shortest total life periods (31.6 days) was recorded on cowpea followed by green gram with 73.1 eggs and 34.6 day, respectively. No significant differences were found in oviposition period, post-oviposition period, incubation period and adult longevity on various pulses. It was concluded that of all the pulses studied, cowpea is the most susceptible host for *C. maculatus* followed by green gram which may be due to the different nutritional composition of the pulses.

A study on comparative growth performance of *C. maculatus* on three different legumes was studied by Sharma and Thakur (2014). Among three legumes studied, oviposition was preferred by soybean > cowpea > chickpea (kabuli>desi). This can be attributed to the soft and smooth seed coat of soybean. However, adult emergence and weight loss were recorded maximum in cowpea > chickpea (kabuli>desi) > soybean. This can be due to the presence of various anti-nutritional factors in soybean.

Laboratory studies on the biology of *C. maculatus* on chickpea in three different seasons was studied by Vidyasree and Thirumalaraju (2015). Observations on different parameters like incubation, grub and pupal periods, fecundity and total life span were recorded during *kharif*, *rabi* and summer seasons. There was significant difference in the total life cycle of *C. maculatus* in July-August (46.32 days), November-December (62.4 days) and April-May (35.28 days). Longer life cycle was observed during *rabi* season due to low temperatures and shorter during summer due to ideal temperatures for faster development of *C. maculatus*.

Studies on the comparative biology of pulse beetles viz., *C. analis*, *C. chinensis* and *C. maculatus* on soybean under laboratory conditions was studied by Sibi (2003) at UAS, Dharwad. The results revealed that there was a significant difference in the fecundity and total development period of the three different species. The highest fecundity (110 eggs) and lowest total development period (26 days) was observed in case of *C. analis* as compared to *C. chinensis* (80 eggs and 30 days) and *C. maculatus* (82.5 eggs and 29 days). It was concluded that soybean was most preferred by *C. analis* under Dharwad conditions.

### Screening varieties for pulse beetle resistance

Bruchid resistance of pulses can be studied by two tests:

**a) Preliminary free choice tests:** It is an antixenotic test done with the help of an olfactory chamber where the released insects have free access to all the genotypes at a time. Pre-weighed grains of each genotype are kept separately in circular disc-like craters. Five to ten pairs of freshly emerged

adults are transferred to the central cavity. This gives information about the oviposition preference of bruchids.

**b) Force choice (no choice) tests:** The genotypes showing less susceptibility in free choice tests will be further subjected to force choice tests where the genotypes are enclosed separately in different containers. There is no choice for the insects since they have access to only one genotype. This gives information about the mean development period, per cent adult emergence, per cent damage etc.

### Factors contributing to seed resistance to pulse beetles

**a) Biophysical factors:** These include seed size, lustre, colour, seed volume, seed hardness, seed coat thickness, moisture content etc.

**b) Biochemical factors:** This involves soluble and crude proteins, starch, total soluble sugars (TSS), phenols, tannins,  $\alpha$ -amylase inhibitor (AI), trypsin and chymotrypsin inhibitors, saponins etc.

Duranti and Gius (1997) reported the presence of anti-nutritional factors in soybean and classified them into two:

- i) Non protein anti-nutritional factors: Alkaloids, tannins, phytic acid, saponins and phenols.
- ii) Protein anti-nutritional factors: Trypsin and chymotrypsin inhibitors, lectins and antifungal peptides.

### Varietal screening

**Green gram:** The resistance of 85 green gram accessions against *C. analis* was evaluated by Soumia *et al.* (2015) and none was found to be resistant. Two accessions, viz., Km-12-5 and P-5-16 revealed lesser adult emergence of 12.22 and 14.29 percent, respectively. These accessions also recorded prolonged developmental period (25.67 and 26 days) and lesser susceptibility index (0.042 and 0.044, respectively).

**Soybean:** The resistance studies of 13 soybean varieties to bruchids in storage by Sharma and Thakur (2014a) revealed that all genotypes except Harasoya were highly preferred by *C. maculatus* for egg laying. The genotype Bragg was found to be resistant based on developmental behaviour. Genotypes Pb-1, Shivalik, JS-9305, JS-9560 and Harasoya were found to be relatively tolerant.

**Chickpea:** A study was conducted to evaluate the resistance of 15 chickpea cultivars by Shaheen *et al.* (2006). Seed morphological characteristics of these cultivars like moisture content, seed size, shape and seed coat characters were noted on visual basis in consultation with experts. The study showed that cultivars with hard, rough, wrinkled and thick seed coat proved to be more resistant when compared with

those having smooth, soft and thin seed coat. These characteristics demonstrated a significant harmful effect to pest appearance and grain damage. The beetles laid most of their eggs on cultivars having smooth seed coat, displaying strong non-preference for genotypes with morphologically rough seed coat.

**Pigeonpea:** Investigations on evaluation of pigeonpea genotypes against bruchid resistance under laboratory conditions and biochemical basis for bruchid resistance were carried out by Nagaraja (2006) at University of Agricultural Sciences, Dharwad. The results revealed that, among the 14 genotypes of pigeonpea tested, the genotypes with lowest protein content, highest trypsin inhibitor and highest phenol content showed significantly low per cent adult emergence, growth index value, per cent loss of germination, weight loss, highest developmental period (days) and hence, least susceptibility to *C. maculatus*. The presence of high phenols in seeds is reported to have inhibitory effect on growth and development of bruchids.

### Management of bruchids in storage

In storage, pulse beetles can be managed by different methods like manipulation of temperature and moisture, manipulation of air, use of inert dusts, use of radiation, use of traps, improved storage structures, use of botanicals, use of entomopathogens and use of chemicals.

#### a) Sun drying

The scope of utilising solar energy for disinfecting the seeds has great potential in management of pests in storage. It has two consequences on the environment of insects *viz.*, rise in temperature and decrease in relative humidity of seeds. Preliminary solar drying of seeds is recommended as an effective prophylactic means against oviposition and damage due to bruchids during the storage of pulses. Yadav (1977) reported that the absorption of heat by solar drying beds raised the temperature of the grain bulk from 50 to 55°C which was sufficient to cause mortality of *C. chinensis*. Choudary (2016) reported that, solar heat exposure for 24 hours was quite effective and gave no adult emergence of bruchids, less grain damage and less weight loss in black, blue and red polythene bags. Sharma (2017) reported that, exposure period of 24 hours to solar energy in black and blue coloured bags were the most effective in reducing adult emergence and increasing the adult mortality of *C. chinensis*.

An experiment was conducted by Pareek and Kumawat (2012) to find out the combined effect of sunshine and the colour of storage bags against *C. chinensis*. Cowpea seeds were filled in different coloured polythene bags like black, blue, red, yellow, green, brown and colourless bags. One

hundred newly emerged beetles were released into the sealed bags. The bags were exposed to solar heat from 9.00 am to 4.00 pm on the roof of the building in the month of August. The mortality of beetles was recorded at five and seven hours of exposure periods. The data on mortality of adult beetles revealed that the highest mortality of 94 per cent was observed in black coloured polythene at seven hours of exposure period, which was followed by blue, red, brown and green polythene bags at seven hours of exposure. The highest mortality was exhibited by black polythene bag as black colour absorbs maximum solar radiation and the insidious temperature of the bag might increase. The minimum adult mortality was recorded in colourless polythene bags with five hours of exposure period. The lowest mortality might be due to the fact that the temperature was relatively less.

#### b) Modified atmosphere technique

Exposure of insects to toxic concentrations of atmospheric gases *i.e.*, decreased oxygen or increased carbon dioxide has been promoted in recent years as a substitute for toxic chemicals. An alternative mixture of atmospheric gases can be imposed on a commodity in a gas-tight container. It affects the respiratory metabolism and hinders insect development. The most susceptible stages are metabolically active stages like larvae and adults. The target gas concentration for insect toxicity is 3 per cent or less of oxygen. This could be achieved by flushing an inert space like nitrogen which will displace oxygen. Applying vacuum or low pressure to an air tight chamber also decreases the concentration of atmospheric gases including oxygen. The target gas concentration for insect toxicity is 60 per cent or more of CO<sub>2</sub>. This could be achieved by pumping CO<sub>2</sub> from gas generators or by hermetic storage of infested commodity.

Higher CO<sub>2</sub> concentrations *viz.*, 40, 60 and 80 per cent not only protected red gram seeds from bruchid infestation and development; but also maintained good germination and seedling vigour index even after six months of treatment (Krishnaveni, 2012).

Studies on the management of pulse bruchid (*C. analis*) under modified atmospheric condition was undertaken in pigeonpea by Shivaraja *et al.* (2013) at Raichur. In different treatments, the concentration of O<sub>2</sub> and CO<sub>2</sub> gases varied between 0-20 percentages. Observations like egg count, adult mortality, per cent germination etc. were taken 45 days after exposure. It was reported that the CO<sub>2</sub> concentrations of 15 and 20 per cent exposed for 45 days gave per cent mortality of insects. Further, there was no adult emergence thereby egg lying and per cent weight loss were also nil. There were no adverse effects on seed germination.

An experiment was conducted by Ingabire *et al.* (2013) to study the interactive effects of different oxygen concentrations and different exposure periods on *C. maculatus* in green gram. It consisted of two factors *viz.*, oxygen concentrations (21, 14, 11, 8, 5 and 2% O<sub>2</sub> with remaining percentage being nitrogen) and exposure periods (3, 5 and 7 days). The adult mortality was found to be the highest (91.9%) at 2 per cent O<sub>2</sub> exposed for seven days compared to other concentrations. Among the three exposure periods, the highest mortality was recorded at seventh day with 71.8 per cent. The insect mortality increased by decreasing the O<sub>2</sub> concentration or by extending the exposure period to low O<sub>2</sub>. They concluded that nitrogen based modified atmosphere could be one of the promising and un-risky methods for pulse beetle management.

### c) Irradiation

Irradiation of durable stored products is legal in most of the countries and can be carried out by using ionizing radiations such as gamma rays and non-ionizing radiation such as microwaves or infrared rays. The effect of ionising rays on different stages of insects is different. Insect eggs and young larvae treated by gamma rays fail to develop into adults. The treated adults turn to be sterile, which is exploited as the Sterile Insect Technique. Radiation causes mortality of insects through cell cycle disruption following damage to DNA. Typically, doses of 0.4 kGy (kilogrey) or less are effective for killing most insects. However, radiation at dosages of upto 10 kGy for grain is safe for stored commodities. The adoption of ionizing irradiation treatments for post harvest products is practically minimal.

Soumya (2015) investigated on the effect of gamma radiation on pulse beetle, *C. chinensis* with objective of understanding the influence of gamma irradiation on its reproductive ability and various developmental stages. In order to evaluate the mating competitiveness of males and females, different mating combinations were employed after exposing them to sterile dose (50 Gy). There were significant differences in fecundity as the irradiation doses increased. The number of eggs laid were least when irradiated males paired with irradiated females. It was two-three folds lesser compared to un-irradiated treatment. The number of eggs hatched was nil in mating combinations where irradiated females were used. Hence, it was concluded that egg cells are more sensitive to radiation compared to sperms. Releasing irradiated females has a great potential in reducing the bruchid population. Further, two days old eggs were selected for irradiation studies and were exposed to irradiation doses in range of 0-20 Gy. Hatching of eggs, grub and pupae formation and adult emergence were

significantly reduced as the dose increased and it was completely inhibited at 20 Gy. Further, 15 Gy was found to be optimum to inhibit grub and pupae formation and adult emergence from irradiated eggs.

### d) Inert materials

Diatomaceous earth largely affects *C. chinensis* survival, egg laying, mating behaviour, progeny emergence; more through hindrance of reproductive behaviour of insects than straight mortality (Remya, 2007). Control of pests of stored products by desiccation can be facilitated by treatment of infested commodities with inert materials like sand, kaolin, ash, wood, clays, diatomaceous earth etc. They induce mortality by causing desiccation due to abrasion of cuticle. Based on number of adults emerged per 1000 seeds and per cent seed damage, the seed protectants *viz.*, saw dust, sand and dung cake ash were highly effective as compared to untreated control (Sharma and Devi, 2016).

Fly ash, cow-dung ash, acacia bark ash, red soil powder and turpentine oil were tested for their insecticidal potency by Shaheen and Khaliq (2005) against *C. chinensis* in stored chickpea. They were applied as post-harvest grain protectants against pulse beetles by treating 50 g of stored chickpea grains at their application rates of 1.0, 0.5 and 0.25 grams. The effectiveness of these materials were compared with the untreated grains in terms of mean days needed for 100 per cent mortality of F<sub>1</sub> emerged pulse beetles. The results revealed that fly ash @ 1.0 g per 50 g of grains showed the minimum of 5.78 days for 100 per cent mortality of released adults. All treatments were significantly superior to control except red soil powder @ 0.25 g per 50 g of grains. However, fly ash proved to be the best in reducing bruchid infestation to lower levels followed by turpentine oil and cow dung ash while red soil powder and Acacia bark ash were less effective at their lower application rates.

The efficacy of different dosages (0.025, 0.05, 0.1, 0.15, 0.2, 0.25 and 0.3%) of diatomaceous earth under room conditions were evaluated by Matti and Awaknavar (2009). Adult mortality was recorded after one, three and five days after releasing adults. Observations on seed damage, weight loss and germination were also recorded at 30 and 60 days after treatment. Significantly least number of eggs and least adult emergence were reported from diatomaceous earth @ 0.3 per cent which was followed by 0.25 per cent. No seed damage and no weight loss were recorded in diatomaceous earth @ 0.3 and 0.25 per cent. Also, diatomaceous earth @ 0.3 and 0.25 per cent recorded higher seed germination and were found to be more effective. It was concluded that the fecundity of female *C. maculatus* fell geometrically with increasing rate of diatomaceous earth content.

### e) Use of traps

Tamil Nadu Agricultural University has developed a 'Stored grain insect pest management kit' which consists of several traps. Of which the traps and devices specific for bruchids are two-in-one trap and egg removal device (<http://www.mohantrap.com>).

**Two-in-one trap:** This trap consists of a cone-shaped pitfall trap with a perforated lid and perforated tube and a collection tube. It combines the action of probe trap and pitfall trap. It is best suited for pulse beetles as the adults are seen wandering on the grain surface.

**Egg removal device:** This is a device which can successfully crush the eggs of pulse beetles. There is an inner perforated container with a rotating rod fixed with plastic brushes on all sides. The seeds can be kept in the perforated container and the rod has to be rotated one full circumference clockwise and anti-clockwise for 10 minutes. The eggs get crushed due to the splashing action of the brush in the rotating rod.

### f) Improved storage structures

Some of the improved storage structures that can provide hermetic storage include Bitumen/ coal tar drum, Udaipur bin, Stone bin, Bamboo bin, Baked clay bin, Pusa bin, Pusa cubicle and Pusa Kothar.

### g) Use of botanicals

There is a plethora of studies on the use of plant extracts or whole plant materials for insect control, but only few are used on a commercial scale. It includes the use of leaf powders, extracts, rhizome powders, edible and non-edible oils, etc. Sharma *et al.* (2016) reported that neem oil @ 10 ml/kg completely inhibited oviposition, adult emergence and seed damage by *C. maculatus*. Groundnut and mustard oils also prevented egg laying, reduced population build up and minimized seed damage as compared to control.

Keita *et al.* (2000) evaluated essential oils extracted from four West African plant species (*Tagetes minuta* L., *Hyptis suaveolens* (L.) Poit., white basil *Ocimum canum* Sims and sweet basil *O. basilicum* L.) against *C. maculatus*, and concluded that plants of the genus *Ocimum* can be used as an alternative to synthetic insecticides.

Varma and Anandhi (2010) evaluated seven plant materials, viz. dried leaf powders of neem leaf, chilli, neem seed kernel, tuls leaf, nerium leaf, lantana leaf and tobacco leaf at 4.0 and 8.0 percent w/w/100 grams of mung bean for their effects against pulse beetle. All the seven plant products tested in the study significantly caused adult mortality of the pulse beetles at 6 days after treatment in comparison to control at 4.0 and 8.0 g/100 g grains. The per cent adult

mortality after 2, 4 and 6 days after treatment increased with increase in the level of doses of each powder. The maximum adult mortality was recorded in the treatment of neem leaf powder (38.33%) at all the three doses whereas nerium leaf (4 g) was found least effective with 5.70 per cent mortality.

Nalini *et al.* (2011) used 0.5 per cent ethanolic extracts of fresh leaves of some medicinal plants viz., bael, sweet basil, poduthalai, kalihari, wild sage, physic nut, Indian privet, palas, custard apple, adalsa and pippal against *C. chinensis* in cowpea. The results revealed that ethanolic leaf extracts of *Lantana camara* L., *Clerodendron inerme* (L.) Gaertn. and *Lippia nodiflora* (L.) Greene at 0.5 percent w/v were effective grain protectants in suppressing the pulse beetle damage. Average per cent adult mortality was the highest when grains were treated with *L. camara* (100%) and *L. nodiflora* (95.8%) and they significantly differed from other medicinal plant's leaf extract and acetone control. The fecundity was significantly reduced in grains treated with above three plant extracts.

Among powders of aonla fruits, black pepper fruits and asafoetida rhizomes, black pepper powder @ 5 g/kg seed was the most effective for protection of black gram seeds against bruchids. Different doses of black pepper and asafoetida powder gave successful protection of black gram seeds up to four months of storage (Kumar, 2016).

### h) Use of entomopathogens

Recent explorations for entomopathogens resulted in collection of many isolates of EPFs with potential for control of a number of insect pests of stored grains (Adane, 2003). The lowest adult emergence (16.58%) of *C. chinensis* was observed from the treatment with *Bacillus subtilis* (Ehrenberg) Cohn followed by *B. subtilis* (Pundibari-1) (Bhattacharya and Dhar, 2015). A significant delay in the larval, pupal and total development period and 100 per cent adult mortality of *C. maculatus* was observed after treatment with *B. thuringiensis* coated ZnO nano particles @ 25 µg/ml. The LC<sub>50</sub> value was estimated to be 10.71 µg/ml (Malaikozhundan *et al.*, 2017).

Sugandi (2014) conducted the laboratory evaluation of *Beauveria bassiana* (Bals.) Vuill. and *Metarhizium anisopliae* against *C. chinensis* in storage. Desired concentrations of different isolates of *B. bassiana* and *M. anisopliae* conidia were prepared and mixed with 250 g of green gram in a glass jar and shaken gently for 2-5 minutes to ensure a thorough admixture with the grains. The percent mortality increased with the increase in concentration of the entomopathogenic fungi (EPF). At the highest concentration of  $3.5 \times 10^8$  conidia/g, 82.00 percent of the adults were killed in period of 10 days after infection and was significantly superior over all other

treatments. Significantly highest per cent mortality were recorded at 10 days after treatment in the treatment with high fungal concentration of conidia (80.00%). The per cent mortality increased with the increase in concentration of the EPF. The least (3.00%) mortality was observed in untreated control and all the treatments differed significantly with each other.

#### i) Natural enemies

There is a guild of insect natural enemies associated with pests of stored products. The important natural enemies reported from bruchids include: *Anisopteromalus calandrae* (Howard), *Dinarmus basalis* (Rond.), *Uscana lariophaga* Steffan and *Xylocoris flavipes* (Reuter).

#### j) Use of chemicals

Chemical insecticides are being utilized to save the grains for sowing purpose and for long term storage. It can be as pre-harvest application, treatment of packing materials or direct seed treatment.

Pre-harvest application of Malathion dust @ 25 kg/ha or spraying Malathion 50 EC @ 2 ml/l are commonly recommended. Duraimurugan *et al.* (2014) reported that the field application of Spinosad 45 SC in mungbean and urdbean revealed that seed damage was checked upto 6 months in storage. Hosamani (2015) elucidated that the pre-harvest application of malathion 50 EC, NSKE @ 5 per cent, castor oil @ 1 per cent and neem oil were effective in checking bruchid infestation in storage up to 5 months and high germination per cent was also observed.

Dusting of Malathion and fumigation with Aluminium phosphide are commonly recommended for disinfecting packing material. Lal and Dikshit (2001) reported that deltamethrin 2.8 EC when sprayed at 15 and 25 ml/m<sup>2</sup> on jute sacks filled with chickpea gave 76-78 per cent mortality of *C. chinensis* upto six months. Sharma (2017) reported that emamectin benzoate 5 SG @ 2 g/l was the best treatment for impregnation of packing material resulting in minimum damage by bruchids and minimum weight loss. The next effective treatment was deltamethrin 2.8 EC @ 3.5 ml/l followed by chlorantraniliprole 18.5 SC @ 0.5 ml/l.

Vidyasree (2013) studied the effect of fabric treatment on the incidence of *C. maculatus*. Insecticide solutions of particular concentrations were prepared and treated on the packaging material with 7.5 ml spray fluid for a bag of 30 x 40 cm dimension. Then the packaging material were shade dried, chickpea seeds were filled in bags and kept in laboratory under ambient condition for nine months. The interactions between treatments and packing materials revealed the least damage (0.42%) was in HDPE bags treated

by spinosad 45 SC which differed significantly with other interactions, followed by gunny bags treated with spinosad 45 SC (1.00%), HDPE bags treated with deltamethrin 2.8 EC (1.5%) and gunny bags treated with deltamethrin 2.8 EC (2.00%). The highest damage was observed in untreated control and cloth bags which differed significantly with all other interactions.

#### Seed treatment

Rajani *et al.* (2013) reported that spinosad 45 SC was found to be most effective against *C. chinensis* and *C. maculatus* with LC<sub>50</sub> values of 0.24 and 0.05 ppm, respectively. The next best treatment was deltamethrin 2.8 EC with LC<sub>50</sub> values of 0.69 and 0.76 ppm against *C. chinensis* and *C. maculatus*, respectively. Thirumalaraju and Jyothi (2016) elucidated that insect damage was the least in spinosad 45 SC @ 2 ppm at 3 months (0.09%), 6 months (0.31%) and 9 months (0.83%) after storage, closely followed by deltamethrin 2.8 EC @ 2 ppm and emamectin benzoate 5 SG @ 2 ppm. However, when considering cost benefit ratio for 3 years, spinosad 45 SC recorded highest (1:23.85) followed by deltamethrin 2.8 EC.

Parmar and Patel (2016) evaluated synthetic insecticides as seed protectants against bruchids on mung bean. Nine insecticides were evaluated based on adult mortality and impact on germination. For the purpose, each insecticide was applied at respective doses to previously sterilized bulk of 500 g mung bean grains. The bulk of mung bean seeds under each treatment was stored for six months in an airtight plastic bottle at room temperature and utilized for further observations. Among the different insecticides deltamethrin 2.8 EC at 4 ppm was found to be more effective against *C. chinensis* in mung bean under storage condition followed by cypermethrin 10 EC at 4 ppm and spinosad 45 SC at 4 ppm. These insecticides emerged as more effective seed protectants against bruchids in stored mung bean.

#### IPM in storage

- Use of less susceptible pulse varieties.
- Pre-harvest spray of malathion 50 EC @ 2 ml/l.
- Pods should be harvested as soon as they mature.
- Preliminary solar drying of seeds to optimum kernel moisture level of about 7-8 per cent.
- Broken seeds should not be stored for long periods.
- Use of improved storage structures, gunny bags, jute bags or air tight beetle-proof containers.
- Dip the old gunny bags in boiled water for 15 minutes.
- Impregnating the packing material with botanicals like

neem oil @5 per cent or sweet flag powder @2 per cent.

- Periodical spraying over the bags with malathion 50 EC @ 10 ml/l at the rate of 3 litres of spray fluid/ 100 m<sup>2</sup> or dusting of malathion 5% D.
- Mixing the seeds with inert materials like sand, ash or clay @ 30 per cent.
- Coat the seeds with small quantities of vegetable oil @10-15ml/kg or mix neem leaf powder @ 8 g/kg of seeds in the stored grain.
- Treating the seeds with chemicals like spinosad 45 SC @ 2 ppm for sowing purposes.

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# Management of major insect pests of rice through HPR and judicious insecticides application

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## ABSTRACT

The experiment was conducted at the farmer's field in village Khunte Tola of block and district Simdega in Jharkhand with eight rice varieties having three replications in the randomized block design, under protected and unprotected conditions during wet season of 2013 and 2014. Results revealed that the rice variety Naveen registered lowest silver shoot due to gall midge (*Orseolia oryzae*) (1.85%) under protected conditions, which was almost at par with 0.1 R-36 (1.98%) and Lalat (2.02%). As regards, yellow stem borer, *Scirpophaga incertulus* infestation, the Lalat variety under protected conditions showed minimum incidence of dead hearts (2.2%) against maximum of 3.5 per cent in Naveen. Varieties IR-36, Lalat and Naveen recorded lower incidence of gall midge silver shoot and yellow stem borer dead hearts as well as ear heads under protected conditions, showing tolerance against the susceptible varieties, IR-64, Birsa Mati, PAC-801, PAC-807 and TN-1. The findings suggest that pest susceptible varieties require more insecticidal protection as compared to those of the pest resistant/tolerant varieties. Moreover, need based protection measures proved effective in general irrespective of the varieties grown for enhancement of grains yield. As such, higher yield enhancement to the tune from 28.72 to 40.97 q ha<sup>-1</sup>; 24.92 to 40.85 q ha<sup>-1</sup>; 24.92 to 39.34 q ha<sup>-1</sup>; 27.20 to 37.97 q ha<sup>-1</sup> and 30.38 to 37.30 q ha<sup>-1</sup> were obtained in case of the test rice varieties viz. PAC-807, Naveen, Birsa Mati, IR-64 and PAC-801 due to enforcement of varietal intervention coupled with need based insecticidal protection. Hence, HPR and need based insecticide application could form one of the effective tool for minimizing yield loss caused by the major insect pests of rice.

**Key words:** Rice, HPR, stem borer, gall midge, insecticide, pest management, yield.

Rice (*Oryza sativa* L.) is the most important staple food crop of Jharkhand. It is grown in about 18 lakh hectare of land in wet season. Yellow stem borer (*Scirpophaga incertulas* WLK.) and gall midge (*Orseolia oryzae* WM) are two major insect pests of rice, in the state of Jharkhand, causing loss in yield from 12 to 25 percent. (Dhaliwal and Arora 1996; Pasalu *et al.* 2004; Prasad and Prasad 2006). In the rice gall midge endemic areas of Jharkhand, the pest (*Orseolia oryzae*) could be able to cause loss in yield of rice ranging from 10-40 percent depending upon the choice of rice varieties and weather conditions prevailing in the cropping season (Prasad 2011). Insecticides is the most effective tool for managing the pest of the crop. Small and marginal farmers occupy the major areas of rice in the state. They are often unable to afford the costly chemical insecticides. Hence, use of host plant resistance (HPR) in rice cultivation may be able to reduce the quantity and frequency of use of insecticides for sustainable crop production. Hence, eight commonly grown rice varieties were taken under unprotected and protected conditions for ascertaining the impact of integration of HPR and need based application of the recommended insecticide on the major insect pest viz., YSB and gall midge and their ultimate effect of yield of rice in the present experimentation.

## MATERIALS AND METHODS

The experiment was conducted in the field in wet season during 2013 and 2014 in the farmer's field in village : Khunti Toli (Block & district : Simdega) in order to study the impact of varietal resistance and need based use of the recommended insecticides. There were eight common rice varieties viz. IR-64, IR-36, Lalat, Naveen, Birsa Mati, PAC-807, PAC-801 and TN-1. These test rice varieties were grown in each of the protected and unprotected conditions. As such, 16 treatment combinations were kept in three replications in the randomized block design with plot size of 5×4 square meter. Transplanting of rice seedlings were made on 11<sup>th</sup> August during 2013 and 2014. Need based foliar spraying was provided with the alternated use of chlorpyrifos 20 EC @ 2.5 litre ha<sup>-1</sup> and monocrotophos 36 SL @ 1.5 litre ha<sup>-1</sup>. As such, two foliar sprays were provided at 25 and 75 DAT (day after transplanting). First spray with monocrotophos 36 SL @ 1.5 litre ha<sup>-1</sup> was made at 45 DAT and 2<sup>nd</sup> spray with the same insecticide was made at milking stage of the crop. Observation on the incidence of gall midge was recorded at 50 DAT and that on yellow stem borer in terms of dead heart (DH) was registered at 45 DAT and in terms of white ear head (WEH) was taken at the maturity stage of the crop. The

total number of tillers and number of silvershoots (SS) were counted on 10 randomly selected plants (hills) for calculating percentage of silver shoot (SS%) caused by gall midge. Total number of tillers and number of dead hearts (DH) and total number of panicles and number of white ears head (WEH) were counted on 10 randomly selected plants (hills) for calculating percentage of dead hearts and white ear heads (WEH) caused by yellow stem borer. Yield of grains were recorded after harvesting at attainment of proper maturity of the crop on the middle of November during both of the years of experimentation. The data were subjected to the statistical analysis after suitable transformation for their interpretation and drawing the conclusion.

## RESULTS AND DISCUSSION

### Management of gall midge (*Orseolia oryzae* W.M.)

The two year's results (Table-1) revealed that the pest incidence in the form of silver shoot (SS) ranged from 6.10 per cent SS (IR-36) to 48.0 per cent SS (TN-1) in the unprotected condition and 1.85 per cent SS (Naveen) and 13.09 per cent SS (TN-1) in the protected conditions of rice cultivation. Relatively little higher incidence of gall midge in the form silver shoot was recorded during 2013 as compared to that of 2014. In general, significantly lower incidence of SS was found under protected condition as compared to that of unprotected conditions in case of all the eight respective rice varieties, during the both the years of experimentations. IR-36, Lalat and Naveen in the protected conditions registered significantly lower incidence of the pest in form of SS (%) during both the years as compared to that of unprotected conditions. The highest incidence of silver shoot (SS%) to the tune of 55.60 and 40.50 percent were recorded in variety, TN-1 during, 2013 and 2014, respectively in the unprotected conditions. The lowest incidence of the pest (2.44% SS) was registered in case of Naveen during, 2013, which remained at par with that of Lalat (2.58 % SS) and IR-36 (2.66% SS), respectively grown under the need based protection measures during 2013. Almost similar trends in the suppression of gall midge incidence were observed in the second year of experimentations (ie. 2014) as that of the first year (ie. 2013) under the influence of varietal resistance and need based protection provided with foliar spray applied with mococrotophos 36 SL @ 1.5 lit ha<sup>-1</sup> and alternated with chlorpyriphos 20 EC @ 2.5 lit ha<sup>-1</sup>.

Based on the pooled results of two years experiment, lowest incidence of gall midge (1.85% SS) was obtained in case of Naveen in the protected condition which was at par with those of IR-36 (1.98% SS) and Lalat (2.02% SS), respectively. Prasad *et al.* (2012) reported significantly minimum incidence of gall midge in case of rice varieties

viz. Lalat, Suraksha and BG-380-2 when grown under the need based insecticidal protection measures. As such, the findings of Prasad *et al.* (2012) were in the consonance with the present studies. The over all results of the present experimentation revealed that judicious and need based protection measures proved to be significantly effective in general, irrespective of the rice variety, weather resistance/ tolerant or susceptible varieties to the pest grown for the suppression of the pest species. The findings are also in conformity with that of the results obtained by Prasad and Prasad (2011) and Prasad *et al.* (2012). Overall, it was interesting to note that significantly higher suppression of the pest in the case of the pest susceptible rice varieties viz TN-1, Birsa Mati, IR-64, PAC-801 and PAC-807, ranging from 48.05 to 13.09, 37.00 to 12.86, 27.90 to 11.10, 23.45 to 12.30 and 27.50 to 10.26 percent incidence of gall midge as compared to those of the resistant/tolerant varieties viz; Naveen, Lalat and IR-36 receiving relatively lower reduction in the pest ranging from 7.16 to 1.85, 7.04 to 2.02 and 6.10 to 1.98 percent silver shoot were obtained when need based insecticidal protection were provided in the present studies.

Table 1. Effect of host plant resistance (HPR) and insecticides on the incidence of gall midge (*Orseolia oryzae* Wood Mason) during 2013 & 2014.

Rice varieties	Control measures	Percentage of silver shoot (SS%) recorded at 50 DAT		
		2013	2014	Mean 2013 & 2014
IR-64	P0	29.50(32.90)	26.30(30.85)	27.90(31.88)
	P1	13.60(21.64)	8.60(17.05)	11.10(19.46)
IR-36	P0	6.70(15.00)	5.50(13.56)	6.10(14.30)
	P1	2.66(9.28)	1.30(6.55)	1.98(7.92)
Lalat	P0	7.88(16.22)	6.20(14.42)	7.04(15.39)
	P1	2.58(9.19)	1.46(6.92)	2.02(8.23)
Naveen	P0	8.53(16.95)	6.80(15.12)	7.16(15.50)
	P1	2.44(8.91)	1.26(8.62)	1.85(7.71)
Birsa Mati	P0	39.40(38.88)	34.60(36.03)	37.00(37.47)
	P1	15.40(23.11)	10.33(18.72)	12.86(20.96)
PAC-807	P0	29.40(32.83)	25.60(30.40)	27.50(31.63)
	P1	12.15(20.40)	8.38(16.79)	10.26(18.67)
PAC-801	P0	26.30(30.85)	20.60(26.99)	23.45(28.96)
	P1	15.00(23.19)	9.60(18.05)	12.30(20.53)
TN-1	P0	55.60(48.22)	40.50(39.52)	48.05(43.88)
	P1	14.88(22.63)	11.30(19.64)	13.09(21.22)
SEm(±)		(2.37)	(2.02)	(2.16)
CD(P=0.05)		(6.89)	(5.86)	(3.53)
CV(%)		(17.65)	(17.83)	(17.54)

Figures under the parentheses correspond to angular transformed values.

DAT- Days after transplanting P0-No protection

P1-Need based protection through insecticidal application

### Management of yellow stem borer (*Scirpophaga incertulas* Walker)

The incidence of dead heart (DH) was recorded at 50 days after transplanting (DAT) and that of white ear (WE) at maturity stage of the crop during the experiment conducted during wet season of 2013 and 2014. The result (Table-2) revealed that none of the eight test rice varieties were free from the pest attack. The extent of attack of YSB (*Scirpophaga incertulas*), in terms of dead heart (DH) and white ear (WE) was remained almost higher during the second year (2014) as compared to that of 1<sup>st</sup> year (i.e. 2013) in general under in both the protected and unprotected situations (Table-2). Significantly lower incidence of dead heart (DH) and white ear (WE) was also observed in the respective test rice varieties in the protected condition (P1). Than under unprotected condition (P0) in the corresponding varieties during both the years of experimentations.

The minimum percent of dead heart (DH) of 1.75 and 2.70 percent were recorded in case of Lalat during 2013 and 2014, respectively in the protected conditions. Varieties at IR-36 (1.8 & 3.5% DH), Naveen (2.9 & 4.12% DH) and Birsa Mati (3.8 & 5.3% DH) remained at par under the protected crop situations. Almost similar observations were recorded in case of pooled results of the two years field investigations.

It is interesting to note that unprotected crop of pest tolerant rice varieties, IR-36, Naveen and Lalat received significantly lower incidence of dead heart as compared to the susceptible varieties viz, IR-36, Birsa Mati, PAC-801, PAC-807 and TN-1 in the unprotected conditions during both the years. Prasad and Prasad (2011) reported that rice entries SKL-7-61-9-10-12 and BG-380-2 suffered from the lowest incidence of YSB where as JGL-3855, DJP-1998-11-1-1 and Birsa Mati harboured higher pest incidence.

Prasad *et al.* (2012) reported that among five common rice varieties, in general, the protected crop received lower incidence of the prevailing major insect pest species viz, gall midge, YSB and leaf folder as compared to that of unprotected crop. They observed that the pest resistant rice varieties viz., BG-380-2, Lalat and Suraksha had significantly lower incidence of all the three major insect pest species as compared to those of the susceptible varieties viz, Jaya and Pusa Basmati-(PB-1) grown in the protected condition. These findings are almost in close conformity with that of the results of the present studies.

Almost similar trends of varietal response was noticed in case of incidence of white ear head (WEH) too during both the years (Table-2). As such, judicious protection proved

Table 2. Effect of host plant resistance (HPR) and insecticides on the incidence of yellow stem borer (*Scirpophaga incertulas*) during 2013 & 2014.

Rice Varieties	Control Measures	Dead heart (DH % recorded at 50DAT)			White ear (WE% at maturity of the crop)		
		2013	2014	Mean 2013 & 2014	2013	2014	Mean 2013 & 2014
IR-64	P0	14.30(22.22)	18.30(25.33)	16.30(23.81)	9.40(17.85)	6.41(14.65)	7.90(16.32)
	P1	5.80(13.94)	6.70(15.00)	6.25(14.48)	4.36(12.04)	2.14(8.43)	3.25(10.39)
IR-36	P0	8.30(16.74)	12.50(20.79)	10.40(18.81)	6.15(14.36)	5.16(13.11)	5.65(13.69)
	P1	1.80(7.71)	3.50(10.78)	2.65(9.28)	1.56(7.15)	1.23(6.42)	1.39(6.67)
Lalat	P0	5.60(13.69)	8.50(17.05)	6.45(14.71)	6.06(14.24)	5.44(13.44)	5.75(13.81)
	P1	1.75(7.49)	2.70(9.46)	2.22(8.53)	2.15(8.43)	1.94(7.92)	2.04(8.23)
Naveen	P0	6.70(15.00)	9.95(18.34)	8.32(16.74)	7.36(15.73)	5.19(13.11)	6.27(14.48)
	P1	2.90(9.81)	4.12(11.75)	3.51(10.78)	3.14(10.22)	1.88(7.71)	2.51(9.1)
Birsa Mati	P0	12.3(20.53)	16.70(24.12)	14.50(22.38)	9.70(18.15)	7.66(16.00)	8.68(17.1)
	P1	3.80(11.24)	5.30(13.31)	4.55(12.25)	4.80(12.66)	2.18(8.45)	3.49(10.7)
PAC-807	P0	14.49(22.30)	19.30(26.06)	16.85(24.20)	12.60(20.79)	10.13(18.58)	11.36(19.68)
	P1	6.30(14.54)	7.20(15.56)	6.75(15.00)	3.40(10.63)	1.98(7.92)	2.69(9.37)
PAC-801	P0	10.70(19.09)	14.30(22.22)	12.50(20.70)	9.42(17.85)	6.80(15.12)	8.11(16.54)
	P1	5.70(13.81)	6.150(14.36)	5.92(13.18)	4.36(12.04)	2.14(8.43)	3.23(10.39)
TN-1	P0	16.40(23.89)	22.30(28.18)	19.35(26.09)	11.46(19.77)	9.38(17.80)	10.42(18.81)
	P1	8.31(16.74)	8.33(16.74)	8.32(16.74)	4.3(11.97)	2.88(9.63)	3.59(10.86)
SEm(±)		(1.60)	(1.64)	(1.62)	(0.69)	(0.61)	(0.65)
CD(P=0.05)		(4.65)	(4.76)	(2.64)	(2.02)	(1.78)	(1.05)
CV(%)		(17.99)	(15.85)	(16.90)	(8.68)	(9.15)	(8.76)

Figures under the parentheses correspond to angular transformed values.

DAT- Days after transplanting

P0-No protection; P1-Need based protection through insecticidal application

to be significantly more effective in general in the for enhancement of grain yield irrespective of the rice varieties grown in the agro-climatic condition of Jharkhand.

### Effect of HPR (host plant resistant) and insecticidal application on rice grain yield

The results shown in (Table-3) showed relatively some what lower rice grain yields during 2014 probably due to higher pest incidence than in the year 2013. It was also observed that the protected crop gave rise to higher grain yield as compared to those of unprotected ones in almost all the eight tests rice varieties during both of the year of experimentation. Pooled results of two years data followed almost similar trends in terms of yield enhancement due to protection measures provided to the crop. It is established fact that yield of different varieties is regulated by genetic yield potential of the crop varieties as well as effect of other biotic and abiotic factors prevailing in the agro-ecosystem. Higher yield enhancement to the tune of 28.72 to 40.97 q ha<sup>-1</sup>; 24.92 to 40.85 q ha<sup>-1</sup>; 24.92 to 39.34 q ha<sup>-1</sup>; 27.20 to 37.97 q ha<sup>-1</sup> and 30.38 to 37.30 q ha<sup>-1</sup> were obtained in the rice varieties, PAC-807, Naveen, Birsa mati, IR-64 and PAC-801, respectively due to enforcement of varietal intervention coupled with need based insecticidal protection. The results

Table 3. Effect of host plant resistance (HPR) and insecticides on yield of grains of rice during 2013 & 2014.

Rice varieties	Control measures	Yield of rice grains (q ha <sup>-1</sup> )		
		2013	2014	Mean 2013 & 2014
IR-64	P0	24.80	29.60	27.20
	P1	39.15	36.80	37.97
IR-36	P0	29.70	29.60	29.65
	P1	37.20	35.70	36.45
Lalat	P0	28.75	30.90	29.82
	P1	39.88	37.20	38.54
Naveen	P0	27.46	28.70	28.15
	P1	42.41	39.30	40.85
Birsa Mati	P0	26.44	23.40	24.92
	P1	38.30	40.38	39.34
PAC-807	P0	30.14	27.30	28.72
	P1	44.15	37.80	40.97
PAC-801	P0	32.16	38.60	30.38
	P1	46.30	38.30	37.30
TN-1	P0	23.75	24.50	25.62
	P1	35.33	34.70	35.01
SEm(±)		1.50	1.16	1.36
CD(P=0.05)		4.36	3.37	2.22
CV(%)		7.64	5.99	7.12

P0-No protection

P1-Need based protection through insecticidal application

pertaining to the grains yields obtained during the individual experimental years 2013 and 2014 followed more or less similar trends in the present studies. The experimental findings of Prasad and Prasad (2011) and Prasad *et al.* (2012) are in close conformity with the results of the present studies.

The perusal of results (Table-4) indicated gain in yield ranging from 23.10 percent (PAC-801) to 57.86 percent (Birsa Mati) through alternated and need based foliar sprays with monocrotophos 36 SL and chlorpyriphos 20 EC @ 1500 ml and 2500 ml ha<sup>-1</sup>, respectively over the unprotected set of the respective varieties. The result also indicated loss in yield varying from 18.77% (PAC-801) to 36.65% (Pusa Basmati-1) over the protected set of the respective varieties.

It was interesting to note a relatively higher yield losses (24.22 to 36.65%) in cases of susceptible varieties viz. IR-64 (28.36%), Birsa Mati-1 (36.65%), PAC-807 (29.89%) and TN-1 (24.22%) as against that of pest resistant (tolerant) varieties viz. IR-36 (19.20%) to Naveen (31.08%). Prasad *et al.* (2012) obtained more or less similar results indicating higher yield losses from 34.56 to 36.23 percent in cases of Jaya and Pusa Basmati-1 as against lower yield losses to the tune of 11.34, 16.80 and 20.31 percent in the resistant varieties, Suraksha, Lalat and BG-380-2, respectively. The findings thus suggest that pest susceptible varieties require more insecticidal

Table 4. Gain and loss in yield due to protection measures (based on mean yield of 2013 & 2014)

Rice varieties	Protection measures treatment	Grain yield (q ha <sup>-1</sup> )	Additional gain in yield over the un protected crop		Avoidable loss in yield (%)
			(q ha <sup>-1</sup> )	(%)	
IR-64	Protection (P1)	37.97	10.77	39.59	--
	No protection (P0)	27.20	--	--	28.36
IR-36	Protection (P1)	36.45	7.00	27.76	--
	No protection (P0)	29.45	--	--	19.20
Lalat	Protection (P1)	38.54	8.72	29.24	--
	No protection (P0)	29.82	--	--	22.62
Naveen	Protection (P1)	40.85	12.70	45.11	--
	No protection (P0)	28.15	--	--	31.08
Birsa Mati	Protection (P1)	39.34	14.42	57.86	--
	No protection (P0)	24.92	--	--	36.65
PAC-807	Protection (P1)	40.97	12.25	42.65	--
	No protection (P0)	28.72	--	--	29.89
PAC-801	Protection (P1)	37.30	7.00	23.10	--
	No protection (P0)	30.30	--	--	18.77
TN-1	Protection (P1)	35.01	8.48	33.09	--
	No protection (P0)	25.62	--	--	24.22

Total cost of two spray each of monocrotophos 36 SL @ 1500 ml ha<sup>-1</sup> and chlorpyriphos 20 EC @ 2.5 lit ha<sup>-1</sup> including cost of labour Rs. 3,800 ha<sup>-1</sup>.

protection as compared to those of the pest tolerant/ resistant rice varieties. Moreover, need based and judicious insecticidal protection measures proved to be considerably effective, in general, irrespective of the varieties grown for enhancement in their grains yield.

It may be concluded that the rice varieties IR-36, Lalat and Naveen proved to be promising and considerably resistant to gall midge and yellow stem borer, resulting in grains yields of 29.65, 29.82 and 28.15 q ha<sup>-1</sup> in the unprotected condition as well as 36.45, 38.54 and 40.85 q ha<sup>-1</sup> in the protected conditions. However, impact of need based protection measures could be more effective in susceptible varieties viz IR- 64, Birsa Mati, PAC- 807, PAC- 801 and TN- 1 in terms of reduction in the incidence of gall midge and yellow stem borer resulting in considerable enhancement of yields.

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# Impact of pre-conditioned larval parasitoid, *Goniozus nephantidis* Muesback on coconut black headed caterpillar *Opisina arenosella* Walker

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## Abstract

The investigation carried out at Bio-control laboratory, RCRS, Bhatye, Dist. Ratnagiri with three treatments viz., pre-conditioned parasitoid, unconditioned parasitoid and control in ten replications during the year 2012-13 to 2014-15 revealed that the pre-conditioning of the parasitoid *G. nephantidis* with frass and damaged coconut leaves at the time of mass multiplication of the parasitoid in the laboratory had more impact on parasitization of coconut black headed caterpillar in the field. The average number of parasitized larvae/leaflet under pre-conditioning of the parasitoid was 12.99, 11.96 and 11.46 compared 10.76, 8.49 and 6.84 with unconditioned parasitoids after first, second and third months, respectively. It is therefore recommended that the pre conditioning of the parasitoid, *Goniozus nephantidis* with frass and damaged coconut leaves should be done while rearing the parasitoid in the laboratory for maximizing parasitization of coconut black headed caterpillar.

**Keywords:** Coconut, Black headed caterpillar, *Opisina arenosella* Walker, *Goniozus nephantidis* Muesebeck

Coconut (*Cocos nucifera* L.) is one of the traditional crop known as “Kalpavriksha” grown in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Maharashtra, West Bengal and Gujarat. The crop provides food, shelter, fuel, medicine and employment to millions of people in the tropics (Venkatesan *et al.* 2008). Now a days, coconut plantation is continuously increasing and there is a wide scope to cultivate coconut as a commercial crop in future. Among various insect pests infesting coconut palm, coconut black headed caterpillar, *Opisina arenosella* Walker (Lepidoptera: Crytophasidae) stands out as predominant leaf feeder. The larvae feed on the parenchymatous tissues on the under surface of the leaflets and construct galleries along with silk and excreta. Under favourable conditions the pest multiplies rapidly and devastates the leaf lamina. The caterpillar can attack palms of any age from nursery to grown up plants causing yield reduced to half (Subaharan, 2008).

The coconut ecosystem is rich in predators and parasitoids. In India, 43 species of parasitoids and 51 species of predators have been recorded on coconut black headed caterpillar, *O. arenosella*. Among them *Goniozus nephantidis* Muesebeck is a dominant parasitoid and is responsible in controlling the populations build up of *O. arenosella* upto the extent of 60 to 70 per cent. The desirable characteristics of the parasitoid like easy mass multiplication with an alternate host, gregarious nature and high fecundity makes the parasitoid promising to be used for controlling the pest population under field condition (Nisha *et al.* 2006). Hence, *G. nephantidis* is being widely used in the biological control programme (Venkatesan *et al.*, 2007).

Keeping in mind the importance of *G. nephantidis* in the management of coconut black headed caterpillar and to increase its efficiency this field experiment was conducted.

## MATERIALS AND METHODS

The experiment was conducted at Regional Coconut Research Station, Bhatye, Ratnagiri (M.S.) from the year 2012-13 to 2014-15 on Palm with three treatments and ten replications. The larval parasitoid, *Goniozus nephantidis*, were mass multiplied in the laboratory for conducting experiment with pre-conditioning of parasitoids with a view to improve the potency of parasitization during mass production of the parasitoid. For olfactory conditioning, the parasitoids were exposed to odor of larval frass and larval damaged leaves in a test tube of 15 cm long and 3 cm diameter. Such pre-conditioned and unconditioned parasitoids were released in the coconut orchard @ 20 parasitoids palm<sup>-1</sup>. Four releases were made at the interval of 10 days during the experimental period. Each treatment was replicated on 10 palms. An untreated control check was maintained to study the natural parasitism. Randomized Block Design was used for statistical analysis.

The treatments comprised of T1-release of pre-conditioned parasitoids, T2-release of unconditioned parasitoids and T3-No release (Control)

Observations were recorded once in month on pre treatment population level of *O. arenosella* (number of larvae pupae<sup>-1</sup> palm<sup>-1</sup> (10 leaflets from middle region of the leaf), post treatment parasitization level and post treatment population of *O. arenosella*.

The number of parasitized larvae of *O. arenosella* recorded from ten leaflets of the middle region of the leaf was averaged into number of parasitized larvae per leaflet. Data thus obtained was converted into square root transformation and analyzed statistically.

## RESULTS AND DISCUSSION

Data from Table 1 (2012-13) revealed that after one month the treatments pre-conditioned and unconditioned parasitoid were statistically significant over control but at par with each other. Same trend was observed after two months of release. Whereas after three months the treatment  $T_1$  i.e. pre-conditioned parasitoids was significantly superior over other two treatments. The maximum parasitization of 18.00 larvae was observed in pre-conditioned parasitoids. During the year 2013-14, same trend was observed after one and two months. After three months the treatment  $T_1$  recorded maximum parasitized larvae (11.00) and it was significantly

Table 1: Effect of pre-conditioned parasitoid, *G. nephantidis* on parasitization of *O. arenosella* (2012-2013)

Treatment	Pre release count of unparasitized <i>O. arenosella</i> larvae	Average No. of parasitized larvae leaflet <sup>-1</sup> (Post release count after months)		
		one	two	three
$T_1$ (Pre-conditioned)	18.20 (4.37)	12.90 (3.71)	14.20 (3.87)	18.00 (4.35)
$T_2$ (Unconditioned)	18.00 (4.35)	10.30 (3.19)	12.30 (3.62)	14.10 (3.88)
$T_3$ (Control)	19.50 (4.50)	1.20 (1.45)	0.60 (1.23)	0.00 (1.00)
S.E.±	0.07	0.19	0.16	0.06
C.D. at (5%)	N.S.	0.55	0.46	0.16

\* Figures in parenthesis are square root transformation

Table 2: Effect of pre-conditioned parasitoid, *G. nephantidis* on parasitization of *O. arenosella* (2013-2014)

Treatment	Pre release count of unparasitized <i>O. arenosella</i> larvae	Average No. of Parasitized larvae leaflet <sup>-1</sup> (Post release count after months)		
		one	two	three
$T_1$ (Pre-conditioned)	17.10 (4.23)	13.90 (3.84)	12.70 (3.69)	11.00 (3.44)
$T_2$ (Unconditioned)	17.90 (4.33)	13.20 (3.74)	10.80 (3.41)	7.80 (2.93)
$T_3$ (Control)	17.40 (4.28)	1.50 (1.54)	0.60 (1.25)	0.50 (1.20)
S.E.±	0.11	0.11	0.12	0.15
C.D. at (5%)	N.S.	0.32	0.33	0.43

\* Figures in parenthesis are square root transformation

superior over rest of the treatments. During the year 2014-15, after one month the treatments  $T_1$  and  $T_2$  were statistically significant over control but at par with each other. After two and three months, treatment  $T_1$  i.e. pre-conditioned parasitoid was significantly superior over other two treatments and recorded 9.70 and 6.90 parasitized larvae of coconut black headed caterpillar by *G. nephantidis*. Pooled data of three years (Table 4) revealed that the treatments pre-conditioned and unconditioned parasitoids were at par with other after one and two months after release. Whereas the treatment, release of pre-conditioned parasitoids ( $T_1$ ) was significantly superior over rest of the treatments after three months and recorded 11.16 parasitized larvae by *G. nephantidis*.

The results revealed that the pre-conditioning of the parasitoid *G. nephantidis* with frass and damaged coconut leaves at the time of mass multiplication of the parasitoid in the laboratory had more impact on parasitization of coconut

Table 3: Effect of pre-conditioned parasitoid, *G. nephantidis* on parasitization of *O. arenosella* (2014-2015)

Treatment	Pre release count of unparasitized <i>O. arenosella</i> larvae	Avg. No. of parasitized larvae leaflet <sup>-1</sup> (Post release count after months)		
		one	two	three
$T_1$ (Pre-conditioned)	19.00 (4.46)	12.70 (3.68)	9.70 (3.25)	6.90 (2.79)
$T_2$ (Unconditioned)	18.40 (4.37)	10.40 (3.36)	4.10 (2.21)	1.80 (1.60)
$T_3$ (Control)	18.70 (4.42)	1.80 (1.59)	1.20 (1.42)	0.30 (1.12)
S.E.±	0.14	0.13	0.15	0.13
C.D. at (5%)	N.S.	0.39	0.44	0.38

\* Figures in parenthesis are square root transformation

Table 4 : Pooled data of effect of pre-conditioned parasitoid, *G. nephantidis* on parasitization of *O. arenosella* (2012-13, 2013-14, and 2014-15)

Treatment	Pre release count of unparasitized <i>O. arenosella</i> larvae	Avg. No. of parasitized larvae leaflet <sup>-1</sup> (Post release count after months)		
		one	two	three
$T_1$ (Pre-conditioned)	18.01 (4.36)	12.99 (3.74)	11.96 (3.60)	11.46 (3.53)
$T_2$ (Unconditioned)	17.92 (4.35)	10.76 (3.43)	8.49 (3.08)	6.84 (2.80)
$T_3$ (Control)	18.36 (4.40)	1.34 (1.53)	0.69 (1.30)	0.23 (1.11)
S.E.±	0.05	0.11	0.25	0.26
C.D. at (5%)	0.15	0.32	0.69	0.67

\* Figures in parenthesis are square root transformation

black headed caterpillar in the field compared to unconditioned parasitoids.

The study concludes that the pre- conditioning of the parasitoid, *Goniozus nephantidis* with frass and damaged coconut leaves helped in maximizing the parasitization of coconut black headed caterpillar in laboratory rearing of the parasitoid.

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# A pilot study for area-wide management of fruit fly in mango for the central gangetic plain

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## ABSTRACT

The management of fruit flies (Diptera: Tephritidae) in mango orchards by the male annihilation technique (MAT) is considered beneficial when deployed in a wide area involving many individual farms. This experiment assessed the patterns of invasion of flies when para-pheromone and insecticide-soaked wooden blocks were used in 24 hectares area of mango orchard at Central Institute of Subtropical Horticulture, Lucknow (India). The MAT greatly reduced the fly population in the inner parts of the protected area, while higher population was found in the outer areas. Even after twenty weeks, the population in the inner core remained at a lower level. It was concluded that MAT is efficient to protect over large areas, subject to uniform distribution of blocks. However, implementation of techniques at village level will require sound understanding of village needs, ecology and social aspects.

**Key words:** *Bactrocera dorsalis*, mango, MAT

Fruit flies are economically important insects. About 500 species are reported as pests of fruits and vegetable crops from Asia. In India fruit flies are represented by 200 species belongs to 71 genera (Kapoor, 2002). They are broadly divided into two groups, one attack orchard fruits, such as mango, guava, sapota *etc.* and the other that attack cucurbits like melon, cucumber, gourds, etc. The flies attack crops at different stages of maturity but damage is observable more at the harvest period. The loss in fruit yield ranges from 1 to 31 per cent with a mean of 16 per cent (Verghese *et al.*, 2004). Department for International Development, UK, (DFID, 2005) report indicated that fruit flies can cause 30-100 per cent economic losses annually in various crops. In mangoes losses are about 20 per cent, in sapota about 30 per cent, and in melons and gourds is around 40 per cent. The calculations indicate that annual losses at wholesale level may be Rs 17,476 million in mango, Rs 5,508 million in citrus, Rs 5,032 million in guava and Rs 1,428 million in sapota. In total, for these four crops it is about Rs 29,460 million. The program at village-level trials (ranging from 1-10 km<sup>2</sup>) by a cooperative in Gujarat, demonstrated that market quality fruit can be produced from area-wide integrated management through male annihilation technique (MAT). The yield returns were of approximately \$250,000 in extra fruit production, compared to an adjacent area with a mix of conventional individual farm treatments or no treatment.

The central gangetic plain is known for its fruits and vegetable cultivation and has great potential for export. Since, flies do direct damage to the fruits it becomes considerable even they are present in relatively small number. Further, large number of hosts and dispersal of fruit flies in wide

area, make pest management difficult in individual farms. The losses may be higher in orchards of small farmers who have limited resources and willingness towards insecticidal control. Such limitations and success of village-level management trials in Gujarat prompted us to undertake this study. Hence, before taking up area wide integrated management, a pilot study was designed to assess the success of MAT for this zone. This paper presents the finding of this study.

## MATERIALS AND METHODS

The experiment was carried out during 2016-17 at the research farm of ICAR-Central Institute of Subtropical Horticulture, Rehmankhura (26°90' N - 80°76' E), Lucknow. The design of this experiment was based on the experiment carried out in experiment station of SDAU, Sardar Krishinagar (Gujarat) under DFID R4D project (Stonehouse *et al.*, 2006). The experimental area was about 24 ha (600m x 400m) of mango trees, planted in 50 x 50m plots. General maintenance of orchard was carried out by following recommended package of practices, including plant protection measures applied for leaf webber and hoppers.

The stand was protected by MAT blocks @ 9-10 traps ha<sup>-1</sup> and were installed in the first week of May 2016. Blocks made of 2.5 x 1.0 x 1.0 cm plywood pieces were soaked in 6 : 4 : 1 v/v mixture of ethanol: methyl eugenol: DDVP (2, 2-dichlorovinyl dimethyl phosphate). All the traps were recharged at about 45 days interval. To define minimum buffer zone for fly invasion the stand was hypothetically delineated into four grids and numbered from inside to the boundary of orchard. In the layout of mango trees were

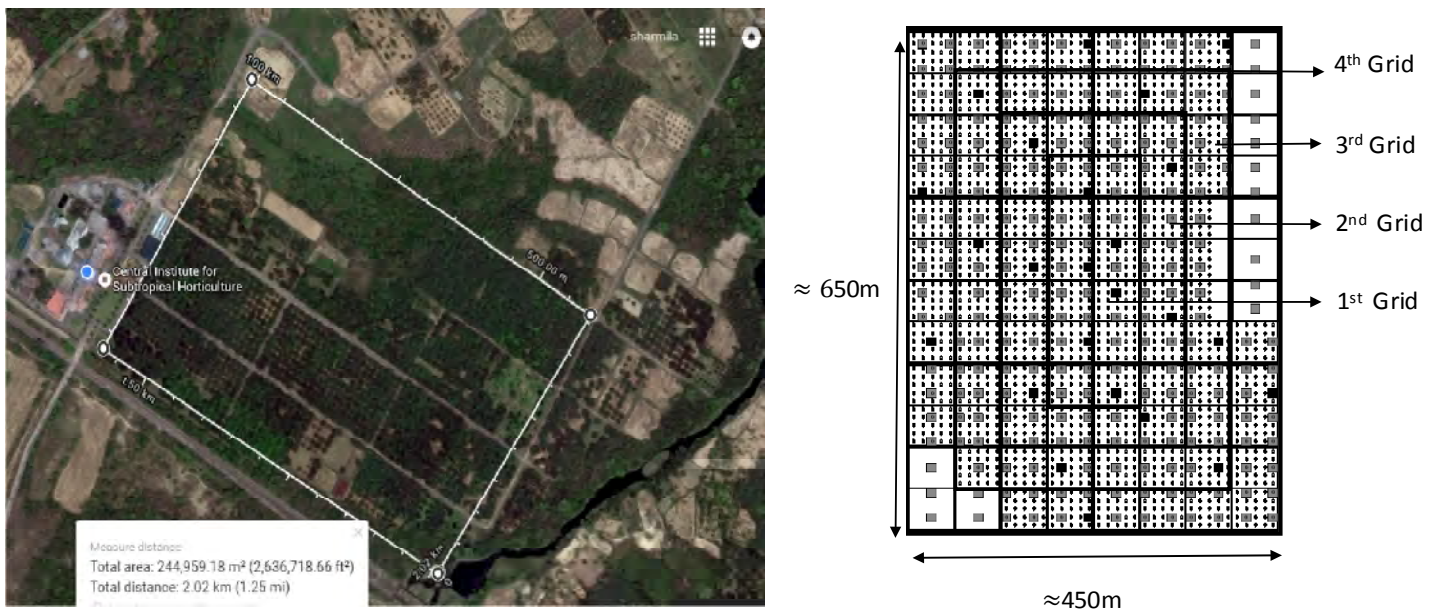


Fig 1. Arial view (Google map) of the experiment area (left) and the experiment lay out (right).

indicated as '0' and traps in grey shads (Fig. 1). The observations were taken at fortnightly interval from the selected traps (6 grid<sup>-1</sup>) (marked as black in layout), starting from 20<sup>th</sup> to 41<sup>st</sup> standard metrological week of year 2016. Prior to this pilot study, a monitoring was conducted during 2015-16 in the experimental orchard and the two nearby orchards.

## RESULTS AND DISCUSSION

The monitoring of fruit fly during 2015-16 revealed that flies were present throughout the year in orchards. But their population was below threshold (10 fly trap<sup>-1</sup> week<sup>-1</sup>) level during most part of the year, except in 26 to 37 metrological weeks. Peak population was recorded during 29<sup>th</sup>-38<sup>th</sup> SMW with mean maximum catch of >500 flies trap<sup>-1</sup> week<sup>-1</sup>. Among the prevalent species of this area, *Bactrocera dorsalis* was dominant (90.3%), while *B. zonata* and *B. cucurbitae* were about 7.9 and 2.1 per cent respectively. The pattern of distribution in 2015-16 is depicted in figure 2.

During the experiment period (May 2016-Oct 2016) the average number of flies caught trap<sup>-1</sup> was 3.771 on 1<sup>st</sup> observation, 204.13 on 2<sup>nd</sup> observation, and 195.33, 213.75, 64.00, 206.04, 91.79, 20.58, 7.00 on successive observations. Peak population was observed during 28<sup>th</sup> to 36<sup>th</sup> SMW, while lowest population was recorded during 41<sup>st</sup> SMW (Table 1). The population trend was in the line with the monitoring study conducted during March 2015 to April 2016.

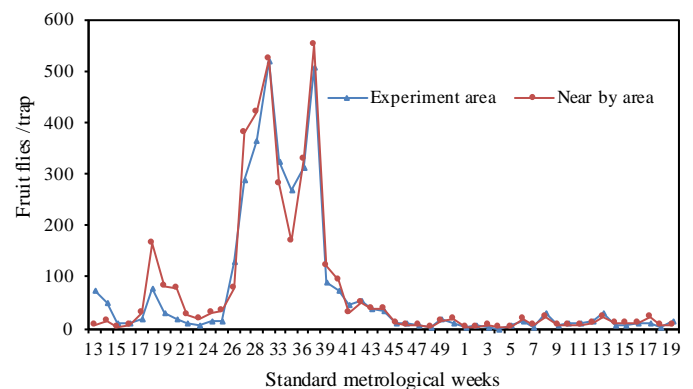


Fig. 2. Fruit fly dynamics in mango orchard during 2015-16

Overall fruit fly population was significantly lower at central zone i.e., grid 1 (100m x 300m) (70.8 flies trap<sup>-1</sup>) in comparison to grid 4, the outer most zone (196.5 flies trap<sup>-1</sup>) of the orchard. However, the traps placed at 2<sup>nd</sup> and 3<sup>rd</sup> grid areas were also recorded significantly lower population (95.3 flies trap<sup>-1</sup> and 99.7 flies trap<sup>-1</sup> respectively) (Fig. 3; Table 1). Though the fly was not eradicated but the population was significantly reduced (Table 1; CD > 0.01) over the successive observations and was maintained at that level in the grid 1. In general, fly population was reduced in about 150m x 500m area in the orchard.

MAT substantially reduced the fly population in the inner most grid of the protected area, while in the outer most grid, higher populations of fruit fly were recorded throughout

Table 1. Mean fortnightly fruit fly catch per trap from 20<sup>th</sup> to 41<sup>st</sup> SMW (delineated grids numbered in ascending order from inside to periphery of the orchard)

	Standard Metrological Weeks (SMW)									Mean
	20	23	25	28	31	33	36	38	41	
Grid 1	30.67	97.00	79.83	119.67	44.33	193.17	42.83	21.67	8.17	70.81
Grid 2	35.00	159.83	96.00	188.00	41.00	193.00	113.33	26.83	4.67	95.30
Grid 3	30.33	140.50	176.83	226.00	92.33	190.00	22.83	15.50	3.33	99.74
Grid 4	54.83	419.17	428.67	321.33	78.33	248.00	188.17	18.33	11.83	196.52
Mean	37.71	204.13	195.33	213.75	64.00	206.04	91.79	20.58	7.00	
CD (>0.01)	Grid                      36.2                      Observation Date                      54.9                      Observation Date x Grid									18.3

the experiment period. Even though the fly population was variable in the outer grids of protected area, fly population in the inner core area was reduced almost at once to the level and was found significantly low throughout the experiment. Presence of large numbers of flies in the outer grid clearly defines that fly intrusion occur from outside the orchard. Even after 22 weeks of deployment, the population in the inner core was not completely eradicated. This may be due to the population existed from previous year/ generation in the soil of the area.

The findings indicate that profoundly trapped buffer zone is needed to restrict entry of fruit flies to the actual orchard sites. The wide area management program, using MAT technique must include at least a 50m buffer zone outside the targeted area, for reducing the losses. As reported

by Stonehouse *et al.* (2007), the risk level may be decreased further by extending the buffer area to 100m or so. Trials on a larger scale may help farmers to get pesticide free economical fruit production at village level.

However, the wide area management at village level have many other social and economic issues. Stonehouse *et al.* (2004) in their study on the ecological and social implications of village-level fruit fly management highlighted five points necessities for the success of the program: (i) farm size, if large, reduces the number of farmers needed to obtain cooperative control but, if small, cooperation at individual level may be ineffective, (ii) the problem of the pest must be perceived as serious, and this seriousness apply for as many farmers as possible, (iii) sustainable cooperative control is enhanced when it can be associated with other cooperative activities, such as marketing; rather than starting from scratch, (iv) a level of social cohesion and mutual trust is important, (v) forgivingness of incomplete application of area-wide controls. When cooperative control aims to be suppressive, rather than eradicated; private control by each individual can still obtain a return, regardless of some defiant who will not cooperate with a group effort. The effect is not destroyed by a few isolated untreated areas.

Although the farm size/ orchards of this zone are of medium to small size, farmers and the existing farmers associations may be brought together for this type of program. However, there could be various ecological and social implications that need to be more accurately defined for the success of such programs.

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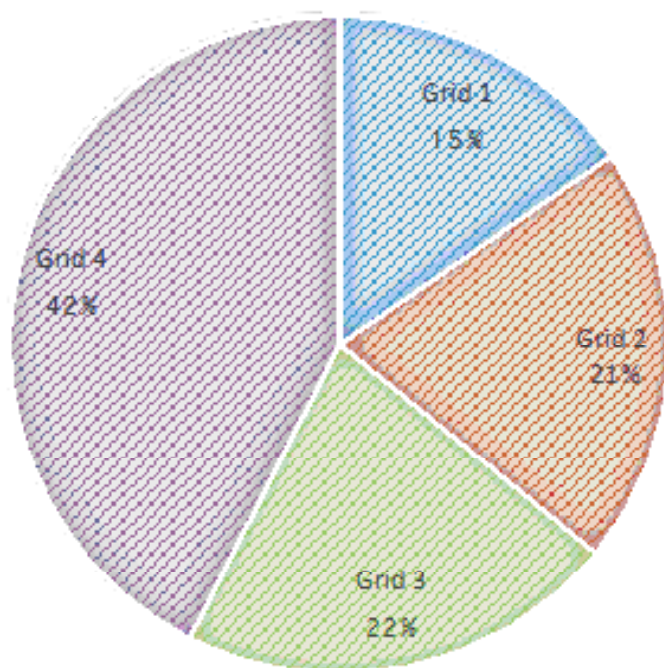


Fig. 3. Fruit fly density in experimental area (Grid 1, 2, 3, 4 from center to outer zone)

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# Relative incidence of gall midge (*Orseolia oryzae* Wood-Mason) in some rice varieties in the agro-climatic conditions of Jharkhand

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## ABSTRACT

The field experiment, conducted in the gall midge endemic district of Jharkhand during wet season in 2013 and 2014, to test 16 promising rice varieties for their relative resistance against gall midge (biotype-3), indicated that silver shoot (SS) ranged from 3.46 percent (Kavya) to 56.38 percent (MTU-7029). None of the test genotypes were free from gall midge incidence. Based on the pooled results of two year experimental results, the rice varieties receiving gall midge incidence in terms of silver shoot up to 5.00 percent were rated as highly resistant to gall midge. Accordingly four rice varieties viz, Kavya (2.91%SS), Lalat (3.91%SS), IR-36 (4.66%SS) and RD 202 (4.60%) emerged as highly resistant to gall midge. Suraksha (5.99%SS) and BG 380-2 (6.48%SS) remained moderately resistant to the pest. MTU-7029 (54.39%SS) and TN-1 (52.05%) received more than fifty percent incidence of silver shoot, caused by the pest, hence these two varieties were considered as highly susceptible to the pest. The maximum grains yield of 42.40 qha<sup>-1</sup> was realized from Lalat, which remained at par with BG 380-2 (42.15 qha<sup>-1</sup>), Abhishek (41.65 qha<sup>-1</sup>), RD-202 (40.60 qha<sup>-1</sup>), and IR-36 (37.60 qha<sup>-1</sup>). Lowest yield of 25.65 qha<sup>-1</sup> was obtained in case of the susceptible varieties TN-1, which remained at par with that of IR-64 (28.09 qha<sup>-1</sup>) and MTU-7029 (29.15 qha<sup>-1</sup>). As such, cultivation of Kavya, Lalat, IR-36 and RD-202 varieties of rice could be recommended in the gall midge endemic areas like, Simdega, Gumla, Khunti and Lohardagga districts of Jharkhand.

**Key words:** Rice varieties, gall midge, *Orseolia oryzae*, HPR, endemic areas, grains yield.

Rice (*Oryza sativa* L.) is the one of the major crops of Jharkhand. Out of 29.28 lakh hectares of total cultivated area, rice is grown in 16.92 lakh hectare, which comes to 85 percent (Anonymous, 2008-09) of about 25-30 percent area (4.5 to 5.4 lakh hectares) of total rice cultivated area in the state of Jharkhand is endemic to the gall midge biotype-3 (*Orseolia oryzae* WM) over the past 4-5 decades (Shaw *et al.* 1981) and suffers from 20-70 percent yield loss, annually (Prasad and Prasad 2010). Because of this the farmers of these areas are hesitant to grow hybrid and scented rice varieties which are usually highly prone to attack of gall midge. Especially the resource poor farmers of the pest affected area are unable to afford chemical control measures (Prasad 2011). Therefore, host plant resistance (HPR) could be one of the most economical tool for management of gall midge. In Jharkhand region, gall midge bio-type-3 is prevalent (Shaw *et al.* 1981). Hence, field screening of some promising rice varieties for resistance/ tolerance against gall midge in the endemic areas was done.

## MATERIALS AND METHODS

The experiment was conducted during wet season of 2013 and 2014 in the farmers field in the gall midge endemic area in block and district Simdega, of Jharkhand. There were 16 rice varieties, replicated thrice in sub plot size of 5X4

square meter in the randomized block design. Seeds of the test varieties were sown on 7<sup>th</sup> and 6<sup>th</sup> July 2013 and 2014, respectively. Transplanting work was done on 12<sup>th</sup> and 10<sup>th</sup> August of 2013 and 2014. The crop was raised under the recommended packages of practices without applying any plant protection measures. Total number of tillers and number of silver shoots (caused by gall midge) were counted on 10 randomly selected plants (hills) at 30 days after transplanting (DAT) to calculate percentage of silver shoot (SS%). Harvesting of the crop was completed on 16<sup>th</sup> and 11<sup>th</sup> November of 2013 and 2014, respectively. Yield of grains were recorded in kg plot<sup>-1</sup> and converted into qha<sup>-1</sup>. The data were subjected to the statistical analysis after suitable transformation.

## RESULTS AND DISCUSSION

### Varietal reaction against the Asian gall midge (*Orseolia oryzae* Wood-Mason)

The gall midge incidence recorded 30 days after transplantation (Table-1) indicated that the resistance of gall fly, in terms of incidence of silver shoot (SS) was relatively low during 2014 than in 2013, in general, in the test rice varieties/ genotypes. Incidence of silver shoot (SS) during 2013 ranged from 3.46 percent (Kavya) to 56.38 percent (MTU) 70.29. None of the rice genotype remained free from gall

midge incidence. The lowest incidence of gall midge (3.46% SS) was found in case of Kavya which remained at par with Lalat (4.60% SS), RD-202 (4.96% SS) and IR-36 (5.12% SS) followed by Suraksha (6.08% SS), BG-380-2 (7.51% SS). The varieties receiving incidence of silver shoot (SS%) below 5 percent (Kavya, Lalat, RD-202) were rated as highly resistant to gall midge. Those receiving incidence of silver shoot (SS) between 5.01 to 10.00 percent (IR-36, BG-380-2 (7.51% SS) and BVS-1 (10.33% SS) were rated as resistant to the pest. The highest incidence of gall midge (56.38% SS) was noticed in case of MTU-7029, followed by TN-1 (54.60% SS), IR-64 (39.50% SS), Birsamati (39.30% SS) and Pusa Basmati (38.80% SS). The moderate range of incidence of silver shoot (SS) were registered in cases of MTU-1010 (12.10% SS), Abhishek (15.20% SS), and Sahbhagi (16.38% SS). Almost similar trends of incidence of silver shoot (SS) were found during 2014 also. However, it was little less than 2013.

#### Incidence of gall midge as pooled mean of 2013 and 2014

The incidence of gall midge in terms of silver shoot (SS) followed almost similar trends to that of incidence of the pest recorded during 2013 in the form of varietal response of different rice varieties. Based on pooled results of the two

Table 1. Relative incidence of gall midge (*Orseolia oryzae* Wood-Mason) in some promising rice varieties during 2013 & 2014.

SI No.	Rice varieties	Percentage of silver shoot (SS%) due to gall midge at 30 DAT	2013	2014	Mean
1.	IR-64	39.50(38.94)	35.30(36.45)	37.40(37.70)	
2.	IR-36	5.12(13.16)	4.20(11.83)	4.66(12.39)	
3.	RD-202	4.96(12.79)	4.25(11.90)	4.60(12.39)	
4.	Abhishek	15.20(22.95)	13.50(21.56)	14.35(22.26)	
5.	MTU-1010	12.10(20.36)	10.45(18.86)	11.27(19.59)	
6.	MTU-7029	56.38(48.65)	52.40(46.38)	54.39(47.49)	
7.	BPT-5204	32.14(34.54)	29.80(33.09)	30.97(33.77)	
8.	Kavya	3.46(10.70)	2.36(8.81)	2.91(9.81)	
9.	Pusa Basmati-1	38.80(38.53)	34.70(36.09)	36.75(37.29)	
10.	Birsamati	39.30(38.82)	34.90(36.21)	37.10(37.52)	
11.	Sahbhagi	16.38(23.85)	13.98(21.89)	15.18(22.91)	
12.	BVS-1	10.33(10.47)	8.80(17.26)	9.56(18.00)	
13.	Lalat	4.60(12.39)	3.23(10.39)	3.91(11.39)	
14.	BG380-2	7.51(15.89)	5.46(13.50)	6.48(14.71)	
15.	Suraksha	6.80(15.12)	5.18(13.16)	5.99(14.06)	
16.	TN-1	54.60(47.64)	49.5(44.71)	52.05(46.17)	
	SEm(±)	(1.35)	(1.69)	(1.50)	
	CD(P=0.05)	(3.93)	(4.92)	(4.35)	
	CV(%)	(9.13)	(12.39)	(10.55)	

Figures under the parentheses correspond to angular transformed values.

SS-Silver shoot

DAT-Date after transplanting

years observations, the rice varieties receiving gall midge incidence in terms of percentage of silver shoot between 0.0 to 5.00 percent were rated as highly resistant to gall midge. Accordingly, the highly resistant varieties against gall midge are: Kavya (2.91% SS), Lalat (3.91% SS) IR-36 (4.66% SS) and RD-202 (4.60% SS). Prasad *et al.* (2012) reported that BG-380-2, Lalat and Suraksha proved to be resistant against gall midge and Pusa Basmati-1 and Jaya received higher incidence of gall midge resulting in yield-loss ranging from 34.5 to 36.23 percent.

#### Varietal reaction of rice varieties in terms of grains yield

The results presented in (Table-2) showed relatively higher yields of grains in almost all the 16 tested rice varieties during 2014 as compared to that of 2013, probably due to lower incidence of gall midge.

The highest grain yields of 40.60 and 44.20 q ha<sup>-1</sup> were recorded during 2013 and 2014 respectively in case of Lalat, which, in turn, remained at par with Abhishek (40.50 & 42.80 q ha<sup>-1</sup>), BG-380-2 (40.50 & 43.80 q ha<sup>-1</sup>), RD-202 (39.70 & 41.50 q ha<sup>-1</sup>) and IR-36 (36.50 & 38.70 q ha<sup>-1</sup>) during the respective years. The pooled mean yield of the two experimental years also followed almost similar trends. Accordingly, test varieties could be arranged in descending order of : Lalat (42.40 q ha<sup>-1</sup>) > BG-380-2 (42.15 q ha<sup>-1</sup>) > Abhishek (41.65 q ha<sup>-1</sup>) > RD-202 (40.60 q ha<sup>-1</sup>) > Sahbhagi (35.30 q ha<sup>-1</sup>) > Kavya (35.15 q ha<sup>-1</sup>) in terms of grains yield

Table 2. Yield of rice grains in some promising rice varieties during 2013 & 2014.

Sl. No.	Rice varieties	Yield of rice grains (q ha <sup>-1</sup> )		
		2013	2014	Mean 2013 & 2014
1.	IR-64	26.50	29.50	28.00
2.	IR-36	36.50	38.70	37.60
3.	RD-202	39.70	41.50	40.60
4.	Abhishek	40.50	42.80	41.65
5.	MTU-1010	29.80	32.90	31.35
6.	MTU-7029	27.50	30.80	29.15
7.	BPT-5204	28.20	32.50	30.35
8.	Kavya	33.60	36.70	35.15
9.	Pusa Basmati-1	32.80	33.86	33.33
10.	Birsamati	34.60	35.40	35.00
11.	Sahbhagi	34.80	35.80	35.30
12.	BVS-1	33.70	35.40	34.55
13.	Lalat	40.60	44.20	42.40
14.	BG380-2	40.50	43.80	42.15
15.	Suraksha	32.50	34.70	33.60
16.	TN-1	24.50	26.80	25.65
	SEm (±)	2.50	2.48	2.87
	CD (P=0.05)	7.25	7.19	8.17
	CV(%)	12.84	11.99	13.90

and all these seven varieties remained statistically at par. These varieties realized higher yield of grains on account of having significantly lower incidence of the insect pest species. TN-1 proved to be the most prone to attack of all the pest species, resulting in the significantly lowest grains yield of 24.50 and 26.80 q ha<sup>-1</sup> during 2013 and 2014 and 25.65 q ha<sup>-1</sup> based on mean yield of the two years of experimentations, followed by IR-64 in the present studies. Prasad and Prasad (2012) also reported significantly lower incidence of major pest complex and higher grain yields in certain rice varieties viz., Naveen, IR-36, BG-380-2, Lalat and Suraksha which is almost in agreement with the findings of the present experimentation. Findings of Prasad *et al.* (2012) also endorsed the results of present studies.

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# Seed treatment, an eco-friendly approach for the management of safflower aphids

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## ABSTRACT

The field experiment conducted during *rabi* 2015-16 at the Agricultural Research Station, Annigeri (Karnataka) for the management of safflower aphid through insecticidal seed treatment revealed that seeds treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> seeds, imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> seeds and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> seeds recorded significantly lowest aphid population of (28.04, 32.07 and 33.43 aphids 5 cm apical twig<sup>-1</sup>, respectively) which were superior over other seed treatments and recorded higher seed yield of 9.67, 9.38 and 9.16 q ha<sup>-1</sup>, respectively. The next best treatments were the seeds treated with thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> seeds and fipronil 5 SC @ 5 ml kg<sup>-1</sup> seeds which recorded aphid population of 35.70 and 35.08 aphids 5 cm apical twig<sup>-1</sup>, respectively with seed yield of 8.52 and 7.96 q ha<sup>-1</sup>, respectively which were superior over untreated control. Similarly, imidacloprid 70 WS @ 5 g kg<sup>-1</sup> recorded highest B:C ratio (1:1.95) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (1:1.89) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (1:1.85) which proved to be good in the management of aphid.

**Key words:** Aphid, B C ratio, Efficacy, Safflower, Seed treatment

Safflower (*Carthamus tinctorius* L.) is an ancient crop of the family Compositae or Asteraceae, originated in the near east and has been grown for centuries in China, India and North Africa. It is a multi-purpose species with many traditional uses. In India, safflower cultivation is being done for centuries for its orange red and yellow dye (Carthamine) extracted from the florets were once used to colour food and clothing and for its oil, rich in poly unsaturated fatty acids which are considered to reduce blood cholesterol and good for heart patients. There are several causes for low productivity in Karnataka, among them biotic factors play key role.

Among the insect pests that attack safflower the aphid, *Uroleucon compositae* (Theobald) is considered as a major pest causing severe losses to the crop throughout the world. Among different insect pests, safflower aphid, *U. compositae* is one of the most destructive pests (Akashe *et al.*, 1999), which alone causes 35-72 per cent yield loss during heavy infestation period (Anon., 2007). Seed and oil content losses due to this pest ranges from 20 to 80 per cent, which has been reported from different parts of the country (Singh *et al.*, 2000). The aphids not only reduce yields of seed and oil content but also attack petals lowering the quality of the value added product of this part of the plant (Sastry, 1997). In addition to this the quality of petals was lowered due to aphid attack (Sastry 1997). The aphid has been effectively controlled using several conventional insecticides (Upadhyay *et al.*, 1990; Dhruve *et al.*, 1993 and Ali *et al.*, 1994).

Number of insecticides have been reported for the management of safflower aphids (Shetgar *et al.*, 1993; Ghorpade *et al.*, 1994; Balikai and Yelshetty, 2001; Gurunath and Balikai, 2017).

Managing the pest in established safflower ecosystem through chemical spraying has several limitations. Farmers are unable to go for spraying due to increased cost of production of safflower, spines present on plants and effect of these insecticides on non-target organisms particularly natural enemies. Seed treatment is a very important aspect which controls the crop pest in early stages and reduces the cost of cultivation in dryland areas as it avoids spraying also because of less availability of water. Thus, the present study deals with the management of safflower aphid through seed treatment.

## MATERIALS AND METHODS

The field experiment was conducted during *rabi* 2015-16 at the Agricultural Research Station, Annigeri (Karnataka) by using safflower variety, Annigeri-1. The experiment was laid out in RCBD with six treatments and four replications. The treatments included T<sub>1</sub>-fipronil 5 SC @ 5 ml kg<sup>-1</sup> seed, T<sub>2</sub>-imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> seed, T<sub>3</sub>-thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> seed, T<sub>4</sub>-acetamiprid 20 SP @ 5 g kg<sup>-1</sup> seed, T<sub>5</sub>-imidacloprid 70 WS @ 5 g kg<sup>-1</sup> seed and T<sub>6</sub>-untreated control. The crop was raised with a spacing of 45 × 20 cm in a plot size of 5.0 × 4.5 m (10 lines of 5 m length) by following all the agronomic practices as given in the package of practices

except for plant protection measures (Anon., 2014). One blanket spray was given for head borer management as per package of practice.

The seed treatment was done a day before sowing. The required quantities of seeds were taken in plastic container and to this recommended quantity of insecticide were added. Then container was vigorously shaken to obtain uniform coating of insecticide over the seeds. The seeds were allowed to air dry in the laboratory.

Observations were recorded on number of aphids (2 tender twigs of 5 cm plant<sup>-1</sup>) on randomly selected five plants in each treatment at 55 and 70 DAS. The other growth parameters such as plant height, number of branches per plant, number of capsules per plant, on five randomly selected plants were also recorded.

Per cent reduction in aphid population over control was also worked out using the following formula.

$$A = \frac{C-T}{C} \times 100$$

Where,

A = Per cent reduction in aphid population over control

C = Aphid population in untreated control

T = Aphid population in treated plot

Finally, 100 seed weight and seed yield per plot was subjected to statistical analysis.

## RESULTS AND DISCUSSION

### Efficacy of insecticides against aphids

**Fifty five days after sowing:** Among different treatments the aphid populations ranged from 25.63 to 37.75 aphids on 5 cm apical twig per plant after 55 days after sowing with significant differences between the treatments. The seeds treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> recorded minimum aphid population (25.63 aphids on 5 cm apical twig plant<sup>-1</sup>) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (29.43 aphids 5 cm apical twig<sup>-1</sup>), acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (30.92 aphids 5 cm apical twig<sup>-1</sup>), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (31.36 aphids 5 cm apical twig<sup>-1</sup>) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (32.12 aphids 5 cm apical twig<sup>-1</sup>) and these treatments were on par with each other. Whereas, untreated check recorded maximum aphid population (37.75 aphids on 5 cm apical twig plant<sup>-1</sup>) as compared to all other treatments (Table 1).

Among different treatments reduction in aphid population over control ranged from 14.79 to 32.01 per cent

after 55 days of sowing with significant differences between the treatments. The seeds treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> recorded highest reduction in aphid population (32.01%) over control followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (21.91%), acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (18.13%), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (16.86%) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (14.79%) which were on par with each other (Table 1).

**Seventy days after sowing:** Aphid populations ranged from 30.44 to 50.97 aphids 5 cm apical twig<sup>-1</sup> with significant differences between the treatments. The minimum aphid population was recorded by imidacloprid 70 WS @ 5 g kg<sup>-1</sup> (30.44 aphids 5 cm apical twig<sup>-1</sup>) which was on par with imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (34.70 aphids 5 cm apical twig<sup>-1</sup>) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (35.94 aphids 5 cm apical twig<sup>-1</sup>). The latter two treatments were on par with thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (38.79 aphids 5 cm apical twig<sup>-1</sup>) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (39.27 aphids 5 cm apical twig<sup>-1</sup>). All the seed treatments were superior over untreated control (Table 1).

Reduction in aphid population over control varied from 23.04 to 40.23 per cent after 70 days of sowing with significant differences between the treatments. The highest reduction in aphid population over control was recorded in imidacloprid 70 WS @ 5 g kg<sup>-1</sup> (40.23%) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (31.85%) which were on par with each other. The latter treatment in turn was on par with acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (29.52%), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (23.90%) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (23.04%) (Table 1).

### Effect of seed treatments

The effect of different insecticides used as seed treatments was assessed on plant height, number of branches per plant, number of capsules per plant, 100 seed weight and seed yield and the results are presented in the Table 2.

### On plant height (cm)

Effect of different insecticides used as seed treatments was assessed on plant height and results showed that the plant height varied from 77.04 to 79.46 cm with non-significant differences between the various treatments. However, highest plant height was observed in the seeds treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> (79.46 cm) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (79.26 cm), acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (78.57 cm), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (78.26 cm) fipronil 5 SC @ 5 ml kg<sup>-1</sup> (77.48 cm) and untreated control recorded least plant height (77.04 cm).

Table 1: Management of safflower aphid, *Uroleucon compositae* through seed treatment with different insecticides

Treatments	Dosage (ml or g kg <sup>-1</sup> of seed)	No. of aphids on 5 cm apical twig plant <sup>-1</sup> *		Mean	Per cent reduction in aphids over control**	
		55 DAS	70 DAS		55 DAS	70 DAS
Fipronil 5 SC	5 ml	32.12 (5.71) <sup>ab</sup>	39.27 (6.30) <sup>b</sup>	35.70	14.79 (21.51) <sup>b</sup>	23.04 (28.53) <sup>b</sup>
Imidacloprid 600 FS	5 ml	29.43 (5.47) <sup>a</sup>	34.70 (5.93) <sup>ab</sup>	32.07	21.91 (27.41) <sup>b</sup>	31.85 (34.30) <sup>ab</sup>
Thiamethoxam 70WS	5 g	31.36 (5.64) <sup>ab</sup>	38.79 (6.26) <sup>b</sup>	35.08	16.86 (23.95) <sup>b</sup>	23.90 (29.13) <sup>b</sup>
Acetamiprid 20 SP	5 g	30.92 (5.60) <sup>ab</sup>	35.94 (6.03) <sup>ab</sup>	33.43	18.13 (24.88) <sup>b</sup>	29.52 (32.88) <sup>b</sup>
Imidacloprid 70 WS	5 g	25.63 (5.11) <sup>a</sup>	30.44 (5.56) <sup>a</sup>	28.04	32.01 (34.43) <sup>a</sup>	40.23 (39.35) <sup>a</sup>
Untreated Control	-	37.75 (6.18) <sup>b</sup>	50.97 (7.17) <sup>c</sup>	44.36	-	-
S.Em.±	-	0.20	0.19	-	2.14	1.74
C.D. at 5 %	-	0.59	0.59	-	6.61	5.38
C.V. (%)	-	6.97	6.30	-	16.23	10.64

\*Figures in the parentheses are  $\sqrt{x - 0.5}$  transformed values \*\* Figures in the parentheses are arcsine transformed values, DAS -Days after sowing

### Number of branches plant<sup>-1</sup>

Among different treatments number of branches per plant ranged from 8.60 to 9.84 with non-significant differences among the various treatments. However, maximum number of branches was observed in plots treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> (9.84 branches plant<sup>-1</sup>) followed by imidacloprid 600 FS@5 ml kg<sup>-1</sup> (9.42 branches plant<sup>-1</sup>), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (9.22 branches plant<sup>-1</sup>), acetamiprid 20 SP@5 g kg<sup>-1</sup> (9.12 branches plant<sup>-1</sup>), fipronil 5 SC @ 5 ml kg<sup>-1</sup> (8.61 branches plant<sup>-1</sup>) and untreated control (8.60 branches plant<sup>-1</sup>).

### Number of capsules plant<sup>-1</sup>

Among different treatments, number of capsules per plant varied from 20.13 to 22.73 with non-significant

differences between the various treatments. However, imidacloprid 70 WS@5 g kg<sup>-1</sup> seed recorded highest number of capsules (22.73 capsules plant<sup>-1</sup>) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (22.60 capsules plant<sup>-1</sup>), acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (21.40 capsules plant<sup>-1</sup>), thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (21.33 branches plant<sup>-1</sup>), fipronil 5 SC@5 ml kg<sup>-1</sup> (20.53 branches plant<sup>-1</sup>) and untreated control (20.13 branches plant<sup>-1</sup>).

### Seed weight (g)

Influence of different insecticides used as seed treatments on 100 seed weight was analyzed. There was a significant difference among the treatments. However, among different treatments 100 seed weight varied from 4.39 to 5.60 g. The maximum grain weight was recorded in imidacloprid

Table 2: Plant growth characters and yield as influenced by different seed treatments

Treatments	Dosage (ml or g kg <sup>-1</sup> of seed)	Plant height (cm)	No. of branches plant <sup>-1</sup>	No. of capsules plant <sup>-1</sup>	100 seed weight (g)	Yield (q ha <sup>-1</sup> )	Additional yield over control (q ha <sup>-1</sup> )
Fipronil 5 SC	5 ml	77.48	8.61	20.53	5.15 <sup>c</sup>	7.96 <sup>c</sup>	2.58
Imidacloprid 600 FS	5 ml	79.26	9.42	22.60	5.48 <sup>ab</sup>	9.38 <sup>a</sup>	4.00
Thiamethoxam 70WS	5 g	78.26	9.22	21.33	5.17 <sup>bc</sup>	8.52 <sup>b</sup>	3.14
Acetamiprid 20 SP	5 g	78.57	9.12	21.40	5.35 <sup>abc</sup>	9.16 <sup>a</sup>	3.78
Imidacloprid 70 WS	5 g	79.46	9.84	22.73	5.60 <sup>a</sup>	9.67 <sup>a</sup>	4.30
Untreated Control	-	77.04	8.60	20.13	4.39 <sup>d</sup>	5.38 <sup>d</sup>	-
S.Em.±	-	0.74	0.28	0.72	0.10	0.17	-
C.D. at 5%	-	NS	NS	NS	0.31	0.51	-
C.V. (%)	-	6.87	6.20	6.78	6.89	7.25	-

NS- Non-significant, Means followed by the same lower case letter /s in a column do not differ significantly by DMRT (P = 0.05)

Table 3: Effect of different insecticides used as seed treatment on seed yield of safflower and cost economics

Treatments	Dosage (ml or g ha <sup>-1</sup> )	Yield (q ha <sup>-1</sup> )	Percent increase of yield over control	Gross income (₹ ha <sup>-1</sup> )	Cost of cultivation (₹ ha <sup>-1</sup> )	Net income (₹ ha <sup>-1</sup> )	B:C ratio
Fipronil 5 SC	37.5 ml	7.96 <sup>c</sup>	32.41	22,281	13,808	8,473	1.61
Imidacloprid 600 FS	37.5 ml	9.38 <sup>a</sup>	42.64	26,250	13,925	12,325	1.89
Thiamethoxam 70 WS	37.5 g	8.52 <sup>b</sup>	36.85	23,842	13,902	9,940	1.72
Acetamiprid 20 SP	37.5 g	9.16 <sup>a</sup>	41.27	25,641	13,831	11,810	1.85
Imidacloprid 70 WS	37.5 g	9.67 <sup>a</sup>	44.36	27,083	13,921	13,162	1.95
Untreated Control	-	5.38 <sup>d</sup>	-	15,050	13,763	1,287	1.09
S.E.m. ±	-	0.17	-	-	-	-	-
C.D. at 5 %	-	0.51	-	-	-	-	-
C.V. (%)	-	7.25	-	-	-	-	-

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05)

70 WS @ 5 g kg<sup>-1</sup> (5.60 g), followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (5.48 g) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (5.35 g) were on par with each other. Thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (5.17 g) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (5.15 g) recorded least 100 seed weight. However, these treatments were superior to untreated check (4.39 g).

### Seed yield and cost economics

Effect of different insecticides used as seed treatment on seed yield and cost economics are presented in Table 3.

Highest seed yield of 9.67 q ha<sup>-1</sup> was recorded by imidacloprid 70 WS @ 5 g kg<sup>-1</sup> followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (9.38 q ha<sup>-1</sup>) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (9.16 q ha<sup>-1</sup>) which is on par with each other and were significantly superior over rest of the treatments. Thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (8.52 q ha<sup>-1</sup>) was the next best treatment. However, lowest yield was recorded by fipronil 5 SC @ 5 ml kg<sup>-1</sup> (7.96 q ha<sup>-1</sup>) which was found superior to untreated check (5.38 q ha<sup>-1</sup>). The highest additional yield over control was recorded by imidacloprid 70 WS @ 5 g kg<sup>-1</sup> (4.30 q ha<sup>-1</sup>) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (4.00 q ha<sup>-1</sup>) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (3.78 q ha<sup>-1</sup>).

In the present study seeds treated with imidacloprid 70 WS @ 5 g kg<sup>-1</sup> seeds, imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> seeds and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> seeds recorded significantly lowest aphid population of (28.04, 32.07 and 33.43 aphids 5 cm apical twig<sup>-1</sup>, respectively) which were superior over other seed treatments and recorded higher seed yield of 9.67, 9.38 and 9.16 q ha<sup>-1</sup>, respectively. The next best treatments were the seeds treated with thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> seeds and fipronil 5 SC @ 5 ml kg<sup>-1</sup> seeds recorded aphid population of 35.70 and 35.08 aphids 5 cm apical twig<sup>-1</sup>, respectively with seed yield of 8.52 and 7.96 q ha<sup>-1</sup>, respectively which were superior over untreated control. The results are in line with Singh *et al.* (2014) who reported that, among the seed

treatments with imidacloprid 70 WS @ 3 g kg<sup>-1</sup>, thiamethoxam 70 WS @ 3 g kg<sup>-1</sup>, acetamiprid 20 SP @ 2 g kg<sup>-1</sup>, carbosulfan @ 30 g kg<sup>-1</sup>, fipronil 5 SC @ 2 ml l<sup>-1</sup> or kg<sup>-1</sup> for 1 hour, monocrotophos 40 EC @ 3 ml kg<sup>-1</sup> for 1 hour, imidacloprid 70 WS @ 3 g kg<sup>-1</sup> was most effective.

Imidacloprid 70 WS @ 5 g kg<sup>-1</sup> seed recorded highest gross income of (₹ 27,083 ha<sup>-1</sup>) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (₹ 26,250 ha<sup>-1</sup>) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (₹ 25,641 ha<sup>-1</sup>). The next best treatments were thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (₹ 23,842 ha<sup>-1</sup>) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (₹ 22,281 ha<sup>-1</sup>). However, lowest gross returns was recorded in untreated check (₹ 15,050 ha<sup>-1</sup>).

Imidacloprid 70 WS, imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> recorded highest net income of ₹ 13,162, 12,325 and 11,810 ha<sup>-1</sup>, respectively. The next best treatments were thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (₹ 9,940 ha<sup>-1</sup>) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (₹ 8,473 ha<sup>-1</sup>). However, lowest net returns was recorded in untreated check (₹ 1,287 ha<sup>-1</sup>).

Among the different treatments imidacloprid 70 WS @ 5 g kg<sup>-1</sup> recorded highest B C ratio (1: 1.95) followed by imidacloprid 600 FS @ 5 ml kg<sup>-1</sup> (1: 1.89) and acetamiprid 20 SP @ 5 g kg<sup>-1</sup> (1: 1.85) which proved to be good in the management of aphid. Thiamethoxam 70 WS @ 5 g kg<sup>-1</sup> (1: 1.72) and fipronil 5 SC @ 5 ml kg<sup>-1</sup> (1: 1.61) showed least BC ratio as compared to other seed treatments. However, lowest B C ratio was recorded in untreated check (1: 1.09).

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# Integrated management of root-rot of guar using biological agents along with neem and fungicides

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## Abstract

In order to ecofriendly management of root rot of guar, biocontrol agents, oil based neem formulation and carbendazim were evaluated in various combinations as seed and seed + soil treatments in field condition. The seed treatment with *T. harzianum* Gn1+B. *subtilis* Ch-Kp-b-1 resulted in highest seed germination and dry biomass of plants and lowest disease incidence as compared to untreated control where seed germination and dry biomass were lowest and root rot incidence was highest. The combination of *T. harzianum* with oil based neem formulation and the combination of *B. subtilis* with both oil based neem formulation and carbendazim also proved better resulting in higher seed germination and dry biomass and reduced disease incidence as compare to control. In case of soil + seed treatment *T. harzianum* soil treatment & carbendazim seed treatment was found higher effective followed by the combination of *T. harzianum* Gn1+B. *subtilis* Ch-Kp-b-1 where disease incidence were less dry biomass were high. It has been observed that the over all disease incidence was lower and dry biomass of guar plants was higher in the treatments specially BCAs which were applied as seed treatments compared to their soil treatments. The integrated treatments were significantly superior over the individual treatment. All the treatments significantly suppressed the inoculum density of *F. solani* and *R. solani* over the untreated control. The studies on population densities of the BCAs and the two pathogens revealed that the BCAs established and multiplied well in guar rhizosphere and could also effectively suppress the pathogens. The effective BCAs- *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1, were further evaluated in micro plots by integrating the host plant resistance, chemical fungicide carbendazim, and oil based neem formulation. These were tested in different combinations with guar root-rot tolerant cultivar 'Swati-55' and highly susceptible cultivar 'Pusa Nav Bahar'. Highest seed germination was recorded in tolerant cultivar where combination of *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 was applied. This was followed by carbendazim seed treatment + drench. Combination of *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 also resulted in lower disease (ranging from 4.4 to 14.9 per cent during 30-70 days of sowing) and highest yield of green pod and dry biomass of guar plants followed by carbendazim (seed treatment + soil drench) and *T. harzianum* Gn1+B. *subtilis* Ch-Kp-b-1+ oil based neem formulation. Similar trend of the efficacy of combined treatments were also observed with susceptible cultivar 'Pusa Nav Bahar'. In this seed treatment with oil based neem formulation along with BCAs was significantly superior in suppressing the disease and higher yield of green pod and dry biomass weight of plants over control. All the treatments resulted in significant suppression of the guar root-rot pathogens as compared to untreated control in both the cultivars. The population densities of *F. solani* and *R. solani* was considerably less in tolerant cultivar "Swati-55" (42 and 22 x 10<sup>5</sup> c.f.u./g soil, respectively) than in the susceptible cultivar 'Pusa Nav Bahar', where these were 60.3 and 30.8 x 10<sup>5</sup> c.f.u./g soil, respectively. In Pusa Nav Bahar also, the integrated treatments resulted in significantly low inoculum densities of the 2 root-rot pathogens as compared to control. The lower population densities of these two guar root -rot pathogens as observed in the pot experiment was further confirmed in micro plot testing. Though the effects of the treatments were consistent in both, tolerant and susceptible cultivars, their effects were better realized in tolerant cultivar. This shows the effectivity of the selected strains of the BCAs. The integration of fungal and bacterial BCAs as seed treatment proved highly effective than fungicide (carbendazim) seed treatment plus drench, and the individual BCAs were almost at par with it. Integration of BCAs with oil based neem formulation was also quite effective.

**Keywords:** Guar, Root rot, *Fusarium solani*, *Rhizoctonia solani*, Biocontrol, Integrated disease management, Neem formulation, *Trichoderma harzianum*, *Bacillus subtilis*

Guar [*Cyamopsis tetragonoloba* (Linn.) Taub.] is an economically important drought tolerant annual leguminous crop in India, where three forth of the global guar cultivation is carried out. Rajasthan, having 4255000 hectares of area under guar cultivation and producing 2415000 tones at 567 kg ha<sup>-1</sup> productivity level, is the largest guar producing state in India (Anonymous, 2014).

Guar is attacked by many fungal pathogens, causing foliar diseases and root rot diseases. Preliminary surveys in guar cultivation areas of Rajasthan state revealed that both *R. solani* and *F. solani* are involved together in causing root rot, and a control strategy to suppress both the pathogens is required. The popular cultivar 'Pusa Nav Bahar' is susceptible to this disease. Application of fungicides is not

very effective. When applied as seed treatment, these may not last longer enough in effective concentration to suppress the pathogen, while the crop remains susceptible to the disease throughout the growing season. Soil application of fungicides is un-economical, hazardous and may also harm non-target (beneficial) flora in the soil. This problem can, however be tackled through use of botanicals or biocontrol agents and their integration with fungicides.

For developing an effective biological control and its integration with fungicides and/or other control strategies, it is imperative to select effective antagonist(s) and understand their behaviour in the rhizosphere and soil. Similarly, botanicals, particularly neem (*Azadirachta indica*), have also been found effective in management of crop diseases and there is a need to study their efficiency and explore the possibility of their integration with biocontrol agents for developing effective management package for this disease. Keeping in view the above facts, the present investigations were undertaken with the objective to explore possibilities of integrating effective biocontrol agents, neem formulation and/or fungicides to enhance the efficiency of disease control.

## MATERIALS AND METHODS

**Pot experiment:** *Trichoderma harzianum* Gn1, *Bacillus subtilis* Ch-kp-b-1, oil based neem formulation and fungicide Carbendazim found effective in the suppression of guar root-rot were evaluated in pot experiment in different combinations, as seed and seed + soil treatments for ecofriendly management of guar root-rot. Culture of both *F. solani* and *R. solani* was multiplied on corn-meal sand (1:1) medium and added in the pot soil as described in previous pot experiment.

For soil application, *T. harzianum* Gn1 and *B. subtilis* Ch-kp-b-1 were used. *T. harzianum* Gn1 was grown on autoclaved shelled maize cobs - wood saw dust (1:1) in conical flasks at  $25 \pm 1^\circ\text{C}$  for 15 days (Meena, 1995). It was then air dried and used for soil treatment @ 10g / pot. The culture of *B. subtilis* Ch-kp-b-1 was grown on King's B medium for 5 days and then used for soil treatment @ 10ml / pot by thorough mixing of pot soil.

For seed treatment, culture of *T. harzianum* Gn1 was grown on 2 per cent malt extract liquid medium for 10 days. The mycelial mats along with the spores so developed were separated by filtering through filter paper and dried overnight at  $25 \pm 1^\circ\text{C}$ . Dried culture was gently powdered and mixed with equal amount of sterilized fine clay and equal volume of sterilized water to make a slurry. This mixture was used for seed coating. The coated seeds were kept

overnight in moist chamber so as to enable the antagonist to establish on seeds. For seed treatment with *B. subtilis* Ch-kp-b-1, guar seeds were soaked in the bacterial suspension for an hour and were kept overnight in moist chamber. In case of multiple seed treatments with both, fungus and bacterium, the seeds were first soaked in bacterial suspension and then coated with fungal slurry.

Seeds were soaked in carbendazim (0.1%) and oil based neem formulation (0.2%) solutions for an hour for individual seed treatments. While in different combined treatments the dose of both carbendazim and oil based neem formulation was reduced to 0.05 and 0.1 per cent, respectively. In case of multiple seed treatments with both, oil based neem formulation / carbendazim and *T. harzianum* Gn1 / *B. subtilis* Ch-kp-b-1, the seeds were first treated with oil based neem formulation / carbendazim and then with *T. harzianum* Gn1 / *B. subtilis* Ch-kp-b-1. In case of individual seed treatment with neem formulations and fungicides, soil drenching was also done at 15, 30 and 45 days after sowing @ 50ml / pot.

Treated seeds were sown in pots @ 10 seeds pot<sup>-1</sup> keeping 4 replications for each treatment. Samples of 5 seeds were randomly drawn to determine inoculum density of the individual biocontrol agent in each treatment. Just before sowing, soil samples were taken from each pot at the depth of 2 inches to determine initial population densities of the two pathogens.

Observations on total number of germinated seedlings was recorded after 10 days of sowing. Total number of plants and root-rot infected plants were recorded after 45 and 60 days of sowing. Dry biomass weight of guar plants were recorded after harvesting and oven drying at 60 days of sowing. Observations on root-rot incidence were recorded at 45 and 60 days after sowing. To determine the population of biocontrol agents and their possible effect on *F. solani* and *R. solani* soil samples from guar rhizosphere and around from both, diseased and healthy plants were collected after 60 days of sowing. Samples were collected from each pot of each treatment carefully by uprooting the plants and lightly shaking these to remove extra soil. The rhizosphere soil was collected by lightly scrapping with a hard brush. Samples of all the four replications of each treatment were pooled and placed in polythene bags, labeled and brought to the laboratory. Sub samples from these pooled samples were used to determine population of biocontrol agents and the pathogens as per the method described earlier.

## II. Microplot experiment

In order to evolve an effective and eco-friendly approach for the management of guar root-rot complex, an experiment

in microplots was conducted in randomized block design (RBD) by integrating the host plant resistance, biological control agents, chemical fungicide and Neem formulation. Promising biocontrol agents- fungus *T. harzianum* Gn1 and bacterium *B. subtilis* Ch-kp-b-1, effective oil based neem formulation and effective fungicide carbendazim were integrated in different combinations with guar root-rot tolerant cultivar 'Swati-55' and also with the susceptible cultivar Pusa Nav Bahar.

Culture of *F. solani* and *R. solani* was multiplied on maize-meal sand (1:1) mixture at  $25 \pm 1^\circ \text{C}$  for 10 days. These 2 cultures were finally mixed with equal proportion and added in the equal amount of sterilized soil. This mixture of soil was added in the soil of micro plots (1.5 x 1.5m) @ 300g plot<sup>-1</sup>. In each set, 3 micro plots as 3 replications were maintained. All the plots were individually lightly irrigated with a hose pipe taking care that the irrigation water does not mix in the neighbouring plots. These plots were used for sowing 20 days after inoculation.

For seed treatments, cultures of *T. harzianum* Gn1 was grown on 2 percent malt extract agar (MEA). The spores and colonies of *T. harzianum* Gn1 so developed were harvested by suspending in 20ml water in each petri dish and mixed with sterilized fine clay (10g) to make slurry. *B. subtilis* Ch-kp-b-1, culture was grown on King's 'B' medium. Guar seeds were soaked in the bacterial suspension for an hour and were kept overnight in moist chamber. In case of multiple seed treatments with both, fungus and bacterium, the seeds were first soaked in bacterial suspension and then coated with fungal slurry.

Seeds were soaked in carbendazim (0.1%) and Oil based neem formulation (0.2%) solutions for an hour for individual seed treatments. In case of multiple seed treatments with both, Oil based neem formulation/carbendazim and *T. harzianum* Gn1 / *B. subtilis* Ch-kp-b-1, the seeds were first treated with Oil based neem formulation/carbendazim and then with *T. harzianum* Gn1 / *B. subtilis* Ch-kp-b-1. Drenching of each oil based neem formulation @ 0.2 per cent and carbendazim @ 0.1 per cent was done at 15 days interval up to harvesting, by irrigating 250ml suspension around the plants in each plot.

Observations on total number of germinated seedlings was recorded after 10 days of sowing. Total number of plants and root-rot infected plants were recorded after 30, 45 and 70 days of sowing. Green pod Yield was recorded up to 70 days of sowing. Dry biomass of guar plants was also estimated at the time of harvesting. Observations on root-rot incidence were recorded at 45 and 60 days after sowing. To determine the population of biocontrol agents and their

possible effect on *F. solani* and *R. solani* soil samples from guar rhizosphere and around from both, diseased and healthy plants were collected after 70 days of sowing. Samples were collected from each plot of each treatment carefully by uprooting the plants and lightly shaking these to remove extra soil. The rhizosphere soil was collected by lightly scrapping with a hard brush. Samples of all the four replications of each treatment were pooled and placed in polythene bags, labeled and brought to the laboratory. Sub samples from these pooled samples were used to determine population of biocontrol agents and the pathogens as per the method described earlier.

The data were subjected to analysis of variance and least significant difference (critical deviation) determined at 5 per cent probability. Treatment means were compared using C.D. (critical difference) to determine efficacy of the different treatments. All the experiments were repeated once and pooled data were used for analysis.

## RESULTS AND DISCUSSION

The pot experiment results presented in Table 1 showed that seed treatment with combination of *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1 was resulted in the highest (85 per cent) germination and lowest root-rot (2.0 and 3.5 per cent) at 45 and 60 days, respectively. It also showed highest dry biomass weight (10.1g), as compared to 37.5 per cent germination and 74.4 and 86.2 per cent root-rot and 0.65g dry biomass in the untreated control.

The integrated treatments were significantly ( $p=0.05$ ) superior over the individual ones. Combination of *T. harzianum* Gn1 + oil based neem formulation, *B. subtilis* Ch-Kp-b-1 + carbendazim, *B. subtilis* Ch-Kp-b-1 + oil based neem formulation and *T. harzianum* Gn1 + carbendazim followed in order, showing germination ranging from 83.7-80.0 per cent, and root-rot of 2.2-7.1 per cent at 45 days after sowing and 4.7-12.2 per cent at 60 days after sowing. The integration of soil plus seed treatments of *T. harzianum* Gn1 and carbendazim also showed good disease suppression resulting in 80 per cent germination, 5.2 and 8.5 per cent root-rot and 9.4g dry weight of plants. This was followed by combination of *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 as both seed and soil treatment. The latter showed less disease 11.2 per cent at 60 days also and significantly higher dry biomass weight (8.0g).

The over all disease incidence was lower and dry weight of biomass was higher in the treatments, specially the BCAs which were applied as seed treatments compared to their soil treatments.

The data on population density of biocontrol agents

and pathogens in rhizosphere soil (Table 2) showed that all the treatments significantly suppressed the inoculum density of *F. solani* and *R. solani* over the untreated control. In the latter, the population density at 60 days were 92.3 and 40.1 c.f.u./g soil. In seed treatment with *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1, the population were 2.0 and  $0.4 \times 10^5$  c.f.u./g soil, which were significantly lower than their individual treatment as well as control. Good pathogen suppression was also observed in combination of *T. harzianum* Gn1 + oil based neem formulation and *B. subtilis* Ch-Kp-b-1 and Carbendazim seed treatment. But other treatments were not effective against *F. solani* and its population reduced to  $18-29.7 \times 10^5$  c.f.u./g soil. Soil

application of *T. harzianum* Gn1 was better effective in pathogen suppression as compared to *B. subtilis* Ch-Kp-b-1. In these, suppression of *R. solani* was more than of *F. solani*. In various soil+seed treatments, the population of *F. solani* ranged from  $14.0-31.1 \times 10^5$  c.f.u./g soil.

Among soil + seed treatment, combination of soil application of *T. harzianum* Gn1 + carbendazim seed treatment was the most effective in suppression of the two pathogens, where  $14.0 \times 10^5$  c.f.u./g soil of *F. solani* and  $1.7 \times 10^5$  c.f.u./g soil of *R. solani* were recorded.

Application of combination of biocontrol agents was found better effective than their individual treatments. This

Table 1. Evaluation of biocontrol agents in combination with effective neem formulation and fungicide for suppression of guar root-rot

Treatment	Per cent seed germination*	Per cent disease incidence*		Dry biomass of plants pot <sup>-1</sup> * (g)
		45 DAS	60 DAS	
Seed Treatment				
<i>Trichoderma harzianum</i> Gn1	75.0 (60.0)	8.9 (17.3)	14.5 (22.3)	6.400
<i>Bacillus subtilis</i> Ch-Kp-b-1	47.5 (43.5)	19.8 (26.4)	25.0 (29.9)	3.475
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1	85.0 (67.4)	2.0 (8.0)	3.5 (10.7)	10.075
<i>Trichoderma harzianum</i> Gn1 + Oil based neem formulation (0.1%)	83.7 (66.3)	2.2 (7.3)	4.7 (12.5)	9.950
<i>Trichoderma harzianum</i> Gn1 + Carbendazim (0.05%)	80.0 (63.7)	7.1 (15.4)	12.2 (20.4)	7.600
<i>Bacillus subtilis</i> Ch-Kp-b-1 + Oil based neem formulation (0.1%)	80.0 (66.8)	5.7 (13.7)	10.3 (18.7)	9.025
<i>Bacillus subtilis</i> Ch-Kp-b-1 + Carbendazim (0.05%)	82.5 (65.4)	3.9 (11.3)	6.9 (15.1)	9.600
Oil based neem formulation (0.2%)	75.0 (60.0)	10.4 (18.8)	15.2 (22.9)	6.400
Carbendazim (0.1%)	70.0 (56.9)	11.7 (19.9)	20.8 (27.1)	5.375
Carbendazim (0.1%) + Oil based neem formulation (0.2%)	55.0 (47.8)	15.7 (23.3)	22.3 (28.1)	4.850
Soil + Seed Treatment				
<i>Trichoderma harzianum</i> Gn1 [both soil + seed treat.]	52.5 (46.4)	15.9 (23.4)	25.0 (29.9)	4.375
<i>Bacillus subtilis</i> Ch-Kp-b-1 [both soil + seed treat.]	55.0 (47.9)	13.8 (21.7)	22.1 (27.9)	5.050
<i>Trichoderma harzianum</i> Gn1 soil treat.+ Carbendazim (0.05%) seed treat.	80.0 (64.1)	5.2 (13.1)	8.5 (16.9)	9.450
<i>Trichoderma harzianum</i> Gn1 soil treat.+ Oil based neem formulation (0.1%) seed treat	77.5 (65.2)	8.6 (17.0)	12.5 (20.6)	6.900
<i>Bacillus subtilis</i> Ch-Kp-b-1 soil treat. + Carbendazim (0.05%) seed treat.	70.0 (57.0)	12.9 (21.0)	20.8 (27.1)	5.150
<i>Bacillus subtilis</i> Ch-Kp-b-1 soil treat.+ Oil based neem formulation (0.1%) seed treat.	77.5 (62.1)	8.9 (17.3)	13.7 (21.7)	6.800
[ <i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1] soil treat + Carbendazim (0.05%) seed treat.	75.0 (60.6)	9.8 (18.2)	16.4 (23.8)	6.050
[ <i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1] soil treat. + Oil based neem formulation (0.1%) seed treat.	70.0 (56.9)	10.1 (18.4)	19.2 (25.9)	6.000
Control (Untreated)	37.5 (37.7)	74.4 (59.7)	86.2 (68.3)	0.650
	SEm±	3.85	0.83	0.61
	LSD ( <i>p</i> = 0.05)	10.90	2.30	1.70
			0.29	0.84

\*Average of four replications DAS = Days After Sowing  
Values in parenthesis are ArcsinÖpercentage

is, because the bio control agents vary in their spectrum and the type and amount of antibiotics they produce (Hawell *et al.* 2000). These two pathogens incited pre-germination rot of the guar. This may be the reason that BCAs seed treatment was more effective than soil treatment, as the BCAs present on the seed have better chances for establishing on the developing hypocotyle and root systems (Mukhopadhyay *et al.* 1992), compared to those applied in the soil.

The tested BCAs establish well in guar rhizosphere and significantly suppressed the inoculum density of the two pathogens over the untreated (inoculated) control. It was observed that with plant development, the inoculum density of the two pathogens also increased. Some effect of oil based neem formulation and Carbendazim alone applied as both, seed treatment and soil drench at 45 days were also effective in reducing the disease and suppressing the pathogens. But in practical disease control, their repeated use is not only un-economical but may also have residue hazards. Therefore, development and use of integrated management strategy involving biocontrol agents and seed treatment with fungicides/ botanicals should be more useful.

The results of the microplot experiment where in promising biocontrol agents *T. harzianum* Gn1 and *B. subtilis* Ch-kp-b-1, oil based neem formulation and carbendazim were integrated in different combinations with Guar root-rot tolerant cultivar 'Swati-55' and also with the susceptible cultivar Pusa Nav Bahar (Table 3). That the inoculation of both the pathogen in soil were effective, as in untreated plots (control), pre-emergence rotting occurred and only 22.7 per cent germination was observed in tolerant cultivar 'Swati-55', and 12.7 per cent in susceptible cultivar 'Pusa Nav Bahar'. All the tested treatments resulted in significantly higher germination over the untreated controls. Highest germination (81.5 per cent) in Swati-55 was recorded with combined application of *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1, followed by carbendazim seed treatment + drench (73.3 per cent). Combination of seed treatment with oil based neem formulation with the two BCAs resulted in almost at par germination with that of carbendazim (67.4 and 67.2 per cent, respectively) with the two BCAs, while *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 alone were not much effective in the micro plots.

Combination of *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 also resulted in lowest disease, which ranged from 4.4- 14.9 per cent during 30-70 days. This was clearly followed by carbendazim 0.1 per cent (seed treatment + drenching) and *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1 + Carbendazim or *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1 + Oil based neem formulation (0.2%). All these

treatments developed around 20 per cent root-rot up to 70 days. The highest yield of green pods and dry biomass of plants was obtained with *T. harzianum* Gn1 plus *B. subtilis* Ch-Kp-b-1 seed treatment (1037.5g and 197.5g, respectively) followed by Carbendazim (seed treatment + soil drench) and *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1 + oil based neem formulation (Table 3). The latter did not differ significantly from combination of Carbendazim with *T. harzianum* Gn1 + *B. subtilis* Ch-Kp-b-1.

The combined treatments were significantly superior in terms of germination, the disease suppression, yield of green pods and dry biomass weight over the individual treatment. Similar trends of efficacy of combined treatments were also recorded with cultivar 'Pusa Nav Bahar'. In this, combined seed treatment of the two BCAs with Neem formulation was also significantly superior in suppressing the disease at 45 and 70 days, and also in yield of green pod and dry biomass weight of plants over control.

The biocontrol agents applied as seed treatment individually or in combination, or in combination with fungicide carbendazim seed treatment or oil based neem formulation, established and multiplied well in the developing guar rhizosphere. The population of the each BCAs was higher in their individual treatment as compared to their combination as well as in further integration with carbendazim or oil based neem formulation. All the treatments resulted in significant suppression of the two pathogens as compared to the untreated control in both the guar cultivars (Table 4). The population density of *F. solani* and *R. solani* was considerably less in tolerant cultivar 'Swati-55' ( $42.0$  and  $22.0 \times 10^5$  c.f.u./g soil, respectively), than that in the susceptible cultivar 'Pusa Nav Bahar', where these were  $60.3$  and  $30.8 \times 10^5$  c.f.u./g soil, respectively. In treatments with two BCAs, the population density of the pathogens was  $15.7$  and  $3.6 \times 10^5$  c.f.u./g soil, while in their further integration with carbendazim, the population density was  $18.0$  and  $4.8 \times 10^5$  c.f.u./g soil and with oil based neem formulation there was  $18.5$  and  $3.9$  c.f.u./g soil, respectively. Application of carbendazim alone as seed + soil drench also resulted in suppression to  $22.0$  and  $8.9 \times 10^5$  c.f.u./g soil, respectively.

In Pusa Nav Bahar also, the integrated treatments resulted in significantly low inoculum densities of the pathogens as compared to the untreated control. In the integration with carbendazim, the population densities were  $18.2$  and  $10.3$  c.f.u./g soil, while with Neem formulation, these were  $15.6$  and  $6.9 \times 10^5$  c.f.u./g soil, respectively.

Diseases caused by soil borne pathogens are difficult

to manage, because these pathogens are natural soil inhabitants and can survive in the soil for prolonged periods in the soil as saprophytes on the decaying crop residues as well as in the form of resistant resting structures like chlamydospores and sclerotia (Bochow 1987). Use of biocontrol agents has advantage as these are good substrate competitors, and also suppress the pathogens by active antagonisms including antibiosis and in case of fungal BCAs by mycoparasitism. The *Trichoderma* spp. have been termed as opportunistic, avirulent plant symbionts (Harman *et al.* 2004). Establishment and multiplication of the introduced biocontrol agents in the rhizosphere is crucial for practical biological control. The efficacy of the biocontrol agents can be increased by – (i) Genetic manipulation of the biocontrol agents, (ii) Modification of soil environment to enhance the

growth and activity of BCAs such as organic or inorganic soil amendments or use of effective food base, or (iii) Use of more than one BCA. In the dry land crop like guar, the latter option seemed more feasible. Therefore, the two biocontrol agents were used in mixture, and further evaluated in combination with fungicide (carbendazim) and botanicals (oil based neem formulation). It was found that the efficacy of the two BCAs in combination was much better than the individual one, and was somewhat reduced when used with carbendazim or oil based neem formulation. The effect of the treatments varied in the two guar cultivars, and were better realized in tolerant cultivar 'Swati-55' as compared to the susceptible cultivar 'Pusa Nav Bahar'. The lower population densities of the two guar root-rot pathogens in rhizosphere of tolerant cultivar as observed in the pot trial were further

Table 2. Population densities of biocontrol agents and pathogens in rhizosphere soil of guar cultivar 'Pusa Nav Bahar'

Treatment	Population of BCAs and pathogens per gram rhizosphere soil after 60 days of sowing			
	<i>T.h. Gn1</i> (c.f.u. x 10 <sup>6</sup> )	<i>B. s.Ch-kp-b-1</i> (c.f.u. x 10 <sup>9</sup> )	<i>F. solani</i> (c.f.u. x 10 <sup>5</sup> )	<i>R. solani</i> (c.f.u. x 10 <sup>5</sup> )
<b>Seed treatment</b>				
<i>Trichoderma harzianum</i> Gn1	4.5	-	13.1	3.6
<i>Bacillus subtilis</i> Ch-Kp-b-1	-	23.0	27.7	4.3
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1	0.2	60.3	2.0	0.4
<i>Trichoderma harzianum</i> Gn1 + Oil based neem formulation (0.1%)	2.6	-	3.0	1.0
<i>Trichoderma harzianum</i> Gn1 + Carbendazim (0.05%)	1.5	-	20.0	2.2
<i>Bacillus subtilis</i> Ch-Kp-b-1 + Oil based neem formulation (0.1%)	-	5.0	18.0	2.0
<i>Bacillus subtilis</i> Ch-Kp-b-1 + Carbendazim (0.05%)	-	5.6	5.0	1.4
Oil based neem formulation (0.2%)	-	-	29.7	4.0
Carbendazim (0.1%)	-	-	28.4	2.4
Carbendazim (0.1%) + Oil based neem formulation 0.2%)	-	-	29.5	2.5
<b>Seed + soil treatment</b>				
<i>Trichoderma harzianum</i> Gn1 [both soil + seed treat.]	0.8	-	21.2	2.9
<i>Bacillus subtilis</i> Ch-Kp-b-1 [both soil + seed treat.]	-	89.2	31.1	4.0
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 [both soil + seed treat.]	0.2	75.8	19.7	2.3
<i>Trichoderma harzianum</i> Gn1 soil treat.+ Carbendazim (0.05%) seed treat.	1.3	-	14.0	1.7
<i>Trichoderma harzianum</i> Gn1 soil treat.+ Oil based neem formulation (0.1%) seed treat	2.2	-	21.0	3.0
<i>Bacillus subtilis</i> Ch-Kp-b-1 soil treat.+ Carbendazim (0.05%) seed treat.	-	16.7	29.0	3.6
<i>Bacillus subtilis</i> Ch-Kp-b-1 soil treat.+ Oil based neem formulation (0.1%) seed treat.	-	6.3	23.0	2.8
[ <i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1] soil treat + Carbendazim (0.05%) seed treat.	1.0	29.0	25.3	2.7
[ <i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1] soil treat. + Oil based neem formulation (0.1%) seed treat.	2.4	68.0	26.4	2.9
Control (Untreated)	-	-	92.3	40.1
Initial population of <i>F.solani</i> at sowing = $1 \times 10^6$				
Initial population of <i>T.harzianum</i> Gn1 on seed: $2.0 \times 10^6$ c.f.u./seed				
Initial population of <i>R.solani</i> at sowing = $4 \times 10^5$				
Initial population of <i>B.subtilis</i> on seed: $17.5 \times 10^9$ c.f.u./seed				

Table 3. Integrated management of guar root-rot in micro plots

Treatment	Seed Germination* (%)	Per cent disease incidence *			Green pod weight (gm)*	Dry biomass of plants plot <sup>-1</sup> (gm)*
		30 DAS	45 DAS	70 DAS		
<b>Variety: Swati-55</b>						
<i>Trichoderma harzianum</i> Gn1 (ST)	65.6 (54.1)	14.6 (22.4)	15.6 (23.2)	21.9 (27.9)	803.5	110.0
<i>Bacillus subtilis</i> Ch-Kp-b-1 (ST)	45.8 (42.6)	22.2 (28.1)	26.6 (31.0)	32.1 (34.5)	397.0	69.9
Oil based neem formulation (0.2%) (ST+Drench)	55.5 (48.2)	15.9 (23.5)	18.5 (25.5)	27.4 (31.5)	555.0	87.1
Carbendazim (0.1 %) (ST+Drench)	73.3 (58.8)	5.2 (13.0)	11.9 (20.1)	17.3 (24.6)	907.0	183.4
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 (ST)	81.5 (64.5)	4.4 (11.9)	8.0 (16.30)	14.9 (22.5)	1037.5	197.5
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1+Carbendazim (0.1%) (ST)	67.2 (55.0)	11.0 (19.3)	14.2 (22.0)	20.7 (27.0)	837.5	114.2
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1+ Oil based neem formulation (0.2%) (ST)	67.4 (55.0)	8.9 (17.3)	13.7 (21.6)	18.3 (25.3)	850.0	118.6
Control (Untreated)	22.7 (28.3)	27.0 (31.3)	33.9 (35.6)	38.8 (38.2)	197.5	46.1
<b>Variety: Pusa Nav Bahar</b>						
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1+ Carbendazim (0.1%) (ST)	37.6 (37.8)	6.5 (14.8)	24.2 (29.4)	31.8 (34.2)	339.3	150.9
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1+ Oil based neem formulation (0.2%) (ST)	44.4 (41.7)	5.6 (13.6)	9.7 (18.1)	17.3 (24.5)	515.3	192.6
Control (Untreated)	12.7 (20.7)	20.1 (26.5)	59.7 (50.6)	76.9 (61.4)	229.0	37.7
SEM ±	1.3	1.0	0.9	1.3	15.9	5.4
LS D ( <i>p</i> = 0.05)	3.9	2.9	2.7	3.8	47.1	6.1

\*Average of three replications

DAS = Days after sowing

Values in parenthesis are Arcsin Öpercentage

Table 4. Population densities of biocontrol agents and pathogens in rhizosphere soil of guar in micro plots

Treatment	Population of BCAs and pathogens per g soil 70 days after sowing			
	<i>T. harzianum</i> Gn1 (x10 <sup>5</sup> )	<i>B. subtilis</i> Ch-Kp-b-1 (x10 <sup>9</sup> )	<i>F. solani</i> (x10 <sup>5</sup> )	<i>R. solani</i> (x10 <sup>5</sup> )
<b>Var. Swati-55</b>				
<i>Trichoderma harzianum</i> Gn1	3.5	-	15.0	3.9
<i>Bacillus subtilis</i> Ch-Kp-b-1	-	28.5	20.8	3.6
Oil based neem formulation (0.2%)	-	-	25.1	6.8
Carbendazim (0.1%)	-	-	28.0	8.9
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1	3.0	26.1	12.7	3.6
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 + Carbendazim (0.1%)	1.6	19.3	18.0	4.8
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 + Oil based neem formulation (0.2%)	2.7	19.0	18.5	3.9
Control (Untreated)	0.0	0.0	42.0	22.0
<b>Var. Pusa Navbahar</b>				
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 + Carbendazim (0.1%)	1.8	21.0	18.0	10.3
<i>Trichoderma harzianum</i> Gn1 + <i>Bacillus subtilis</i> Ch-Kp-b-1 + Oil based neem formulation (0.2%)	1.9	20.0	15.6	6.9
Control (Untreated)	0.0	0.0	60.3	30.8
Initial c.f.u. of <i>T. harzianum</i> Gn1: $2.2 \times 10^6$ per seed	Initial c.f.u. of <i>B. subtilis</i> Ch-Kp-b-1: $17.8 \times 10^9$ per seed			
Initial c.f.u. of <i>F. solani</i> : $10.1 \times 10^5$ per g soil	Initial c.f.u. of <i>R. solani</i> : $4.8 \times 10^5$ per g soil			

confirmed in the microplots also. The consistent effect of the BCAs in tolerant as well as susceptible cultivar also shows the efficacy of the selected strains of BCAs in disease suppression.

Such attempts have been found effective in other studies also. Zhang *et al.* (1996) combined *Gliocladium virens* with *Bacillus subtilis* to effectively suppress wilt and root-rot of cotton caused by *Fusarium oxysporum*. Jeong *et al.* (1993) demonstrated that in cucumber, presence of fluorescent bacteria *Pseudomonas putida* in roots system was beneficial for colonization by *Gliocladium virens* G 872, and the inoculum of the latter in roots apparently lowered the population of *Fusarium oxysporum* in cucumber roots. Kroji and Papavizas (1983) successfully combined host plant resistance, biocontrol agent *T. viride* (T-1-R4) and seed treatment with metalaxyl to control damping-off and root-rot in pea. Chattopadhyay and Sen (1996) used *Aspergillus niger* + *T. viride* + carbendazim seed treatment for control of muskmelon wilt, and could considerably reduce the disease as well as population of the pathogen. In the present studies also combination of *T. harzianum* Gn1 and *B. subtilis* Ch-Kp-b-1 was very effective, and can be used as the major components of integrated management package of guar root-rot complex.

There is an increasing body of evidence to demonstrate that the biocontrol agents not only suppress the pathogen by active antagonism, but also act as biochemical elicitors of disease resistance. Induction of resistance to *Rhizoctonia solani* in cotton roots through elicitation of terpenoid phytoalexin has been reported by Howell *et al.* (2000). Induction of phytoalexin capsidiol and pathogenesis related proteins like chitinase and  $\alpha$ -1, 3 glucanase has also been reported by *Trichoderma* spp. in chilli root-rot caused by *Rhizoctonia solani* (Mathur *et al.* 2004). The possibilities of induction of systemic or local resistance responses due to these BCAs in guar rhizosphere need to be studied. But for practical application, it is desirable to evaluate these BCAs in integrated package under diverse agro-climatic condition in conventional guar producing belt of Rajasthan, followed by their commercial production for use by the farmers.

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# Bio-efficacy of fungicides against late blight disease of potato caused by *Phytophthora infestans* (Mont)

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## Abstract

The present work deals with the bio-efficacy of newer fungicides against sheath blight of potato, the most important disease of potato worldwide. All the fungicidal treatments recorded significantly less PDI in comparison to control. However, amisulbrom 20% SC (Kirari) applied @ 500 ml ha<sup>-1</sup>, recording minimum and significantly less PDI was found the most effective in producing disease free tubers and yielding significantly higher yields ie., 402.77 q ha<sup>-1</sup> in 2013-14 and 380.06 q ha<sup>-1</sup> in 2014-15 than other treatments.

**Key words:** Bio-efficacy, fungieides, potato late flight

Potato (*Solanum tuberosum*), an important staple food in different states of India, is prone to more than a hundred diseases caused either by bacteria, fungi, viruses, phytoplasma, viroids and nematodes, etc. The most common fungal diseases are late blight of potato caused by *Phytophthora infestans* (Mont.) de Bary (Irish famine, 1845), wart disease caused by *Synchytrium endobioticum* (Schilb.) Perch., fusarium dry rot caused by *Fusarium sulphureum* Schlechtendahl, fusarium wilt caused by *F. avenaceum* (Fr.) Sacc., gray mold caused by *Botrytis cinerea* Pers.:Fr., pink rot caused by *Phytophthora drechsleri* Tucker, phoma leaf spot caused by *Phoma andigena* var. *andina* Turkensteen, powdery scab caused by *Spongospora subterranea* (Wallr.) Lagerh, *rhizoctonia* canker and blackscurf caused by *Rhizoctonia solani* Kühn, septoria leaf spot caused by *Septoria lycopersici* Speg and white mold caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. However, late blight or *phytophthora* blight caused by the omycetease fungus, *Phytophthora infestans* (Mont) de Barry is worldwide in distribution (Hardy *et al.*, 1995) and is one of the most important foliage diseases in areas with favourable weather conditions.

The late blight is the most destructive disease of potato in India (Singh, 1996). The disease under conducive weather conditions causes heavy yield losses in susceptible potato cultivars annually in different states of India. Many fungicides, contact and systemic, are recommended to manage the disease and farmers are using them many times to protect their crops. There is a tendency of development of resistant fungal races against use of systemic fungicides (Singh, 1996). Josepovits and Dobrevalszky (1985) reported that the use of fungicides with different modes of action is the best strategy to delay build up of resistance. New

fungicide, amisulbrom 20% SC (Kirari) was therefore evaluated against the late blight disease of potato and the results are presented.

## MATERIALS AND METHODS

A comparative study for the evaluation of different fungicides was carried out at Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. Well sprouted potatoes of Kufari Naveen that were susceptible to late blight infection were planted at 60 cm between row spacing and 9 cm within row spacing in a randomized complete block design with four replications. The fungicides were applied as per treatments mentioned above by foot sprayer fitted with hollow cone nozzle at the initiation of disease incidence and repeated after 10 days. Ten plants were selected randomly in each plot and the data on disease severity were recorded using 0-9 disease rating scale as given below, one day before spray and 10 days after 1<sup>st</sup> spray and 10 & 20 days after 2<sup>nd</sup> spray.

Fungicides with active ingredient and dose formulation

Amisulbrom 20% SC (Kirari)	60	300
Amisulbrom 20% SC (Kirari)	80	400
Amisulbrom 20% SC (Kirari)	100	500
Famoxadone 16.6 % + Cymoxanil 22.1 % (Equation Pro SC)	210	500
Metiram 55 % + Pyraclostrobin 5 % (Cabrio top WG)	1050	1750

The yield of potato tubers for different treatments was recorded at harvest alongwith the percent tuber infection. Percent disease Index (PDI) and percent tuber infection were calculated as per formula given below :

### Rating scale for the assessment of late blight severity on potato leaves (Shutong, *et. al.*, 2007)

Disease severity rating grade	Disease incidence % age	Level of resistance/Susceptibility
0	0.0	No disease
1	10%	Small lesion on the inoculated point with the lesion area less than 10% of the whole leaflet
3	10% and 20%	Lesion area between 10% and 20% of the whole leaflet
5	20% and 30%	Lesion area between 20% and 30% of the whole leaflet
7	30% and 60%	Lesion area between 30% and 60%
9	Over 60%	Lesion area over 60% of the whole leaflet

$$\% \text{ Disease Index (PDI)} = \Sigma \frac{(\text{Disease severity level} \times \text{number of leaflets with same severity level})}{(\text{Total number of leaflets} \times 9)} \times 100$$

$$\text{Tuber infection (\%)} = \frac{\text{Total no. of tuber harvest from the plot} - \text{Total no. infected tuber harvest from the plot}}{\text{Total no. of tuber harvest from the plot}} \times 100$$

The disease severity data was arcsine transformed before analysis of variance (ANOVA). Recorded data were subjected to statistical analysis using ANOVA of SAS statistical data analysis software. Duncan's multiple range tests was used to determine the most significant treatment (Steel, *et. al.*, 1997).

## RESULTS AND DISCUSSION

Table 1: Per cent disease Index (PDI) of late blight (*Phytophthora infestans*) on potato in different treatments before and 10 days after 1<sup>st</sup> spray treatment 2013-14

Fungicide	Dose ha <sup>-1</sup>		PDI before treatment	PDI 10 days after 1 <sup>st</sup> spray treatment	PDI 10 days after 2 <sup>nd</sup> spray treatment	PDI 20 days after 2 <sup>nd</sup> spray treatment
Amisulbrom 20% SC (Kirari)	60	300	2.00 (8.05)	12.40 (20.60)	10.90 (19.20)	15.10 (22.85)
Amisulbrom 20% SC (Kirari)	80	400	1.50 (6.92)	7.90 (16.30)	5.80 (13.90)	7.10 (15.43)
Amisulbrom 20% SC (Kirari)	100	500	1.90 (7.85)	0.50 (3.91)	0.90 (5.34)	0.00 (0.00)
Famoxadone 16.6% + Cymoxanil 22.1% (Equation Pro SC)	210	500	2.10 (8.30)	8.20 (16.60)	7.00 (15.31)	8.20 (16.61)
Metiram 55% + Pyraclostrobin 5% (Cabrio top WG)	1050	1750	2.40 (9.10)	9.80 (18.21)	5.90 (14.03)	7.90 (16.30)
Control	-	-	1.80 (7.67)	50.00 (44.98)	60.80 (51.20)	70.10 (56.86)
SEm±			(0.64)	(1.25)	(1.25)	(1.12)
CD 5%			(NS)	(4.10)	(4.01)	(3.59)

Figures in parenthesis are angular transformed values

## Bio-efficacy

The pre-treatment data on percent disease index (PDI) in different treatments and the control that varied between 1.50 to 2.40 and 8.90 to 11.10 in crop season 2013-14 and 2014-15, respectively, did not differ significantly.

After 10 days of 1<sup>st</sup> spray treatment (before 2<sup>nd</sup> spray treatment), the PDI ranged from 0.50 to 12.40 percent in different treatments and 50 percent in control and all the treatments recorded significantly less PDI in comparison to control in crop season 2013-14. However, the PDI ranged from 5.4 to 12.10 percent in different treatments and 45.40 percent in control and all the treatments recorded significantly less PDI in comparison to control in crop season 2014-15. Amisulbrom 20 percent SC (Kirari) @ 500 ml ha<sup>-1</sup> recorded minimum PDI (0.50%) and was found significantly more effective in comparison to other fungicides. Famoxadone 16.6 percent + Cymoxanil 22.1 percent (Equation Pro SC) @ 500 ml ha<sup>-1</sup>, Metiram 55 percent + Pyraclostrobin 5 percent (Cabrio top WG) @ 1750 ml ha<sup>-1</sup> and Amisulbrom 20 percent SC (Kirari) @ 400 ml ha<sup>-1</sup> were next effective fungicides and all treatments were at par with each other in both crop season 2013-14 and 2014-15 (Table 1 & 2).

Ten and 20 days after 2<sup>nd</sup> spray treatment, all the fungicidal treatments recorded significantly less PDI in comparison to control. However, amongst the treatments, amisulbrom 20 percent SC (Kirari) @ 500 ml ha<sup>-1</sup> recorded minimum and significantly less PDI in comparison to the remaining treatments. Famoxadone 16.6 percent + Cymoxanil 22.1 percent (Equation Pro SC) @ 500 ml ha<sup>-1</sup>, Metiram 55 percent + Pyraclostrobin 5 percent (Cabrio top

Table 2: Per cent disease Index (PDI) of late blight (*Phytophthora infestans*) on potato in different treatments before and 10 days after 1<sup>st</sup> spray treatment 2014-15

Fungicide	Dose (ha <sup>-1</sup> )		PDI before treatment	PDI 10 days after 1 <sup>st</sup> spray treatment	PDI 10 days after 2 <sup>nd</sup> spray treatment	PDI 20 days after 2 <sup>nd</sup> spray treatment
Amisulbrom 20% SC (Kirari)	60	300	10.20 (18.57)	12.10 (20.33)	9.90 (18.32)	10.15 (18.55)
Amisulbrom 20% SC (Kirari)	80	400	9.50 (17.82)	8.20 (16.61)	7.80 (16.30)	9.70 (18.10)
Amisulbrom 20% SC (Kirari)	100	500	8.90 (17.33)	5.40 (13.31)	1.20 (6.27)	0.90 (5.44)
Famoxadone 16.6% + Cymoxanil 22.1% (Equation Pro SC)	210	500	11.10 (19.44)	10.60 (18.40)	8.15 (16.55)	9.90 (18.30)
Metiram 55% + Pyraclostrobin 5% (Cabrio top WG)	1050	1750	10.00 (18.37)	8.60 (17.03)	7.90 (16.29)	10.10 (18.49)
Control	-	-	9.80 (18.16)	45.40 (42.34)	58.00 (49.58)	60.80 (51.21)
SEm±			(0.86)	(0.60)	(0.50)	(0.51)
CD 5%			(NS)	(1.83)	(1.52)	(1.55)

Figures in parenthesis are angular transformed values

WG) @ 1750 ml ha<sup>-1</sup> and Amisulbrom 20 percent SC (Kirari) @ 400 ml ha<sup>-1</sup> were the next effective fungicides and all were at par with each other in both crop season 2013-14 and 2014-15 (Table 1 & 2).

In all the treatments, infested tubers by the disease were found to be significantly less in comparison to control. However, amongst the treatments, amisulbrom 20 percent SC (Kirari) applied @ 500 ml ha<sup>-1</sup> was most effective, as all the tubers were free from disease infection. Famoxadone 16.6 percent + Cymoxanil 22.1 percent (Equation Pro SC) @ 500

ml ha<sup>-1</sup>, Metiram 55 percent + Pyraclostrobin 5 percent (Cabrio top WG) @ 1750 ml ha<sup>-1</sup> and Amisulbrom 20 percent SC (Kirari) @ 400 ml ha<sup>-1</sup> were next effective fungicides recording only 2.50 to 2.90 percent of infected tubers as against 35 percent and this same fungicides were effective ranged between 1.10 to 5.40 percent of infected tubers as against 32.10 percent in control in both crop season of 2013-14 and 2014-15 respectively (Table 3).

#### Yield of potato tubers

All fungicidal treatments recorded significantly more

Table 3: Per cent infested tubers by late blight (*Phytophthora infestans*) and yield of potato in different treatments during 2013-14 and 2014-15

Fungicides	Dose (ha <sup>-1</sup> )	Dose (ha <sup>-1</sup> )	Per cent infested tuber at harvest		Yield (q ha <sup>-1</sup> )	
	a.i. (g)	Formulation (g ml <sup>-1</sup> )	2013-14	2014-15	2013-14	2014-15
Amisulbrom 20% SC (Kirari)	60	300	3.50 (10.72)	5.40 (13.41)	260.80	210.40
Amisulbrom 20% SC (Kirari)	80	400	2.50 (9.06)	3.10 (10.08)	360.40	292.10
Amisulbrom 20% SC (Kirari)	100	500	0.00 (0.00)	1.10 (6.01)	402.77	380.60
Famoxadone 16.6% + Cymoxanil 22.1% (Equation Pro SC)	210	500	2.90 (9.77)	2.55 (9.11)	370.50	310.50
(Metiram 55% + Pyraclostrobin 5% (Cabrio top WG)	1050	1750	2.80 (9.62)	2.60 (9.25)	375.50	293.75
Control	-	-	35.00 (36.25)	32.10 (34.49)	190.40	180.40
SEm±			(0.49)	(0.34)	8.43	20.38
CD 5%			(1.58)	(1.04)	26.92	59.13

Figures in parenthesis are angular transformed value

tuber yield in comparison to control. Amongst the treatments, amisulbrom 20 percent SC (Kirari) @ 500 ml ha<sup>-1</sup> recorded significantly higher yield of 402.77 q ha<sup>-1</sup> in 2013-14 and 380.06 q ha<sup>-1</sup> in 2014-15 in comparison to the remaining treatments. Famoxadone 16.6 percent + cymoxanil 22.1 percent (equation pro SC) @ 500 ml ha<sup>-1</sup>, was also found effective against tuber infection and produced good tuber yield 375.50 q ha<sup>-1</sup> in 2013-14 and 293.75 q ha<sup>-1</sup> in 2014-15. Another tested fungicide metiram 55 percent + pyraclostrobin 5 percent (Cabrio top WG) @ 1750 ml ha<sup>-1</sup> and amisulbrom 20 percent SC (Kirari) @ 400 ml ha<sup>-1</sup> recorded significantly more yield 375.50 q ha<sup>-1</sup> and 293.75 q ha<sup>-1</sup> than amisulbrom 20 percent SC (Kirari) @ 300 ml ha<sup>-1</sup> 260.80 q ha<sup>-1</sup> and 210.40 q ha<sup>-1</sup> in crops season 2013-14 and 2014-15. The lowest yield of potato tuber was obtained from plot of control it was weighted 190.40 q ha<sup>-1</sup> and 180.40 q ha<sup>-1</sup> in both crops season of 2013-14 and in 2014-15 (Table 3).

Varied range of chemical fungicides are available in the market for controlling *Phytophthora infestans* and so is the extent of disease inhibition with them. Therefore, by selecting appropriate chemical fungicides, farmers can save their crops in best possible way. The study may be helpful to the farmers for selection of effective fungicides for control of late blight of potato and also in obtaining better yield.

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# Evaluation of different substrates on growth period and yield of oyster mushroom (*Pleurotus ostreatus*) (Jacq. Fr.) P. Kumm

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## Abstract

Mushroom cultivation is the most suitable technology for creating wealth and health out of waste from plants, animal and industries which are abundantly available on earth in India. There are agricultural waste are available in huge quantity but maximum part of these agricultural waste are burnt after harvesting. This poor management of agricultural waste are increasing environmental pollution. The investigations carried out on the comparison of different substrates on growth period and yield of oyster mushroom (*Pleurotus ostreatus*) revealed minimum spawn run period on wheat straw (20.67 days) against maximum of 25 days on paddy straw. Similar pattern in the cropping period, registering lowest of 54 days on wheat straw and maximum of 60 days on paddy straw was recorded. The highest yield (878 g bed<sup>-1</sup>) was obtained from mushroom bed of wheat straw + paddy straw + weeds. Wheat straw substrate also gave a good yield (821.33 g bed<sup>-1</sup>) while the lowest (598.34 g bed<sup>-1</sup>) from mushroom bed of paddy straw.

**Key words:** Agri wastes, growth, yield and *Pleurotus ostreatus*

Oyster mushroom (*Pleurotus ostreatus*), commonly called as *Dhingri* in India because of its oyster like shape, belongs to family *Pleurotaceae*. It has about 40 well recognized species, out of which 12 species are cultivated in different parts of country. *Pleurotus* is an efficient lignin-degrading mushroom and can grow well on different type of lingo cellulosic material under variable temperature conditions and hence are ideally suited for cultivation throughout the year in various regions of tropical country like India. Among all cultivated mushroom genera, *Pleurotus* comprises the largest number of species and varieties. Most of them grow best at temperature below 20°C and while others prefer temperatures between 24°C and 30°C. So oyster mushrooms cultivation of varied shape, colour, texture and aroma can be achieved round the year.

Oyster mushroom growers have wide range of substrate containing lignin and cellulase together as its carbon source required for production of oyster mushroom. These are sunflower seed hulls, rice/wheat/straw, bean, sugarcane bagasse, rubber tree, sawdust groundnut shells, cotton waste, cottonseed hulls, coco lumber saw dust, coffee pulp, corncobs, paper, water hyacinth, water lily, cocoa shell waste and coir pith.

Huge quantities of lingo-celluloid crop residues and other organic wastes are generated annually through the activities of agricultural, forest and food processing industries. It is estimated that India is generating 600 million tons of agricultural waste besides, fruit and vegetable residue, coir dust, husk, dried leaves, pruning, coffee husk, tea waste which when burnt create problems of air soil and water

pollution affecting human, animal and plant vegetation adversely. Burning of agricultural wastes also increase problem of global warming and raise in temperature. But milky mushroom production is one of the potent ways to be recycled as substrate. If even one per cent of these crop residues are used to produce mushroom, India will become a major mushroom producing country in the world (Tewari and Pandey, 2002). Therefore, the present study was based on the yield performance of oyster mushroom (*Pleurotus ostreatus*) when grown on different agro based substrates.

## MATERIALS AND METHODS

The fresh fruit body of oyster mushroom (*Pleurotus ostreatus*) (Jacq. Fr.) P. Kumm collected from growing room of mushroom spawn laboratory, BHU was used for preparation of mushroom culture. It was sub-cultured and maintained on PDA medium at 26°C temperature in BOD incubator for further investigation. Wheat straw (*Triticum aestivum*), paddy straw (*Oryza sativa*), weed (*Echinochloa colonum*), mango leaf (*Mangifera indica*), collected from Agricultural Farm, Institute of Agricultural Sciences, B.H.U. were used as substrates for mushroom cultivation.

Wheat straw, paddy straw, mixture of paddy straw, wheat straw and weed straw (1:1:1), mixture of wheat straw, weed straw and mango leaf litter (3:2:1), mixture of wheat and paddy straw (1:1).

The substrates were chopped, dried, freed from diseases, rottings and other inert matters and soaked in water for 15 hr. in large plastic buckets. After soaking, excess water

was drained out. The moist substrates, filled in gunny bags, were sterilized (at 121°C, 15 psi for 1 hr.) in autoclave, cooled and later spread on clean floor. Spawn of *Pleurotus ostreatus* were mixed separately in different substrates @4 kg quintal<sup>-1</sup> dry substrates and filled in separate polythene bags. Each bag contained 2 kg moist substrate. Later size 6-8 small holes (1 mm) were made around the bags.

The mushroom bags were kept vertically in a dark room, where temperature and relative humidity, ranging between 24-28°C and 80-85 per cent, respectively was maintained for the spawn run. After completion of the spawn run, the polythene bags were torn off from the sides without disturbing the beds, the mushroom removed and kept on wooden racks. To provide adequate moisture, water on mushroom beds was sprayed daily.

Oyster mushrooms were harvested before spraying water. The right stage for picking can be judged by the shape and size of fruiting bodies. In young mushrooms, the edge of the cap is thick and the cap margin is enrolled, while the cap of mature mushrooms becomes flat and inward curling starts. It is advisable to harvest all the mushrooms at one time from a bag so that the next crop of mushrooms starts early. Usually 5-6 days after opening the bags, mushroom primordial began to form. Fruiting bodies were harvested in about 4-5 days after their appearance. Harvesting was done by grasping the stalk and gently pulling or twisting the mushroom from substrates level. Mushroom fruiting was continued after harvesting first, second and so on. After harvesting, lower parts of the stalks/stipes with adhering debris should be cut using a knife. Fresh mushroom was harvested three times at appropriate intervals.

The data on growth periods, various growth parameters and the yield potential were recorded and analysed statistically.

## RESULTS AND DISCUSSION

The data pertaining to growth period (spawn run period, initiation of pin head, harvesting of 1<sup>st</sup> flush, 2<sup>nd</sup>

flush and harvesting of 3<sup>rd</sup> flush) of *Pleurotus ostreatus* on five substrates is given in table 1.

The mushroom bed of wheat straw was colonized very fast by mushroom mycelium (20.67 days) followed by mixed substrate of wheat straw+weed+mango leaf litter (23 days). The maximum spawn run period of 25 days was recorded from mushroom bed of paddy straw. Other growth period like initiation of fruiting bodies, harvesting of 1<sup>st</sup> flush, harvesting of 2<sup>nd</sup> flush and harvesting 3<sup>rd</sup> flush were also recorded. The mushroom pin heads were first initiated (25.67 days) from mushroom bed of wheat straw followed by mixture of wheat and paddy straw (26.33 days) and wheat straw+weed+mango leaf (27 days). Maximum period of pin head initiation (28.33 days) was recorded from paddy straw followed by 28.0 days on paddy straw+wheat straw+weed and minimum of 26.33 days on wheat straw. The mushroom bed of wheat straw was also first for each harvesting of first (31 days), second (41 days) and third flushes (53.6 days). The minimum total cropping period of 53.6 days from mushroom bed of wheat straw and maximum of 60 days from mushroom bed of paddy straw was recorded.

Our results are in accordance with Ahmed (1998) who reported the spawn run period of *P. ostreatus* to be completed within 17–20 days on different substrates. Khan *et al.*, 2001 studied the cultivation of oyster mushroom on different substrates and reported that after spawn running, pinhead formation took 7-8 days and sporocarps formed after 10-12 days. Cotton waste gave the highest yield. Formations of fruiting bodies per bag were also more in the cotton waste. Shah *et al.* (2004) found that pin-heads appeared in about 6 days.

The data on effect of different substrates on growth parameters on *P. ostreatus*, presented in table 2, showed highest number of fruiting bodies on wheat straw (30.67) and minimum on wheat + paddy straw (23.87). Maximum weight of fruiting body was observed on wheat + paddy + weed straw (31.44 gm) and minimum on wheat + paddy straw (24.33 gm). Maximum stalk length (9.53 cm) was

Table 1. Effect of different substrates on growth period of *Pleurotus ostreatus*

Substrates	Growth period (days)					
	Spawn run period	Pin head initiation	1 <sup>st</sup> Harvesting	2 <sup>nd</sup> Harvesting	3 <sup>rd</sup> Harvesting	Total crop period
Wheat straw	20.67	25.67	31	41	53.6	53.6
Paddy straw	25	28.33	36.3	49	60	60
Paddy straw + Wheat straw + Weed (1:1:1)	23.3	28	34.33	44.3	55.3	55.3
Wheat straw + Weed + Mango leaf (3:2:1)	23	27	33	45	57.33	57.33
Paddy straw + Wheat straw (1:1)	23.67	26.33	37.67	47.67	56.6	56.6
SeM	0.89	0.95	1.54	1.74	1.34	
CD at 5%	2.81	3	4.88	5.49	4.25	
CV	6.69	6.13	7.78	6.65	4.13	

Table 2. Effect of different substrates on growth parameters of *Pleurotus ostreatus*

Substrate	Total no. of fruiting bodies	Max. wt. of fruiting body (g)	Min. wt. of fruiting body (g)	Max. length of stalk (cm)	Min. length of stalk (cm)	Total length of fruiting body (cm)	Max dia. of cap (cm)	Min. dia. of cap (cm)
Wheat straw	30.67	25.98	9.84	5.93	4	9.85	8.33	5.04
Paddy straw	28.33	31.44	10.44	6.19	3.57	10.47	11.38	4.77
Paddy+Wheat+ Weed straw	29	29.65	11.67	9.53	6.40	12.20	9.29	4.57
Wheat+Weed+Mango leaf	24	28.23	12.32	7.93	4.62	10.42	10.90	5.16
Paddy+Wheat straw	23.87	24.33	10	5.57	4.43	8.67	10.43	5.63
SEM	1.23	1.29	0.94	0.38	0.34	0.36	0.55	0.31
CD at 5% level	3.90	4.06	2.98	1.21	1.08	1.13	1.74	0.98
CV	7.90	8.00	15.13	9.50	12.88	6.04	9.53	10.76

observed on wheat + paddy + weed straw against minimum (5.57 cm) on wheat + paddy straw. Maximum total length of fruiting body was observed on wheat + weed + paddy straw (12.20 cm) against minimum on wheat + paddy straw (8.67 cm). Maximum diameter of cap was observed on paddy straw (11.38cm) whereas minimum (8.33 cm) was observed on wheat straw.

### Yield potential

The comparative evaluation of five different substrates on yield potential of 1<sup>st</sup> flush, yield of 2<sup>nd</sup> flush and 3<sup>rd</sup> flush and the total yield of *Pleurotus ostreatus*, presented in table 3, showed the highest yield (878 g bed<sup>-1</sup>) from mushroom bed of wheat straw + paddy straw + weed (1:1:1). The wheat straw substrate has also gave good yield (821.33 g bed<sup>-1</sup>). The lowest yield (598.34 g bed<sup>-1</sup>) was obtained from mushroom bed of paddy straw. The above result was confirmative with finding of Das and Mukherjee (2007) who found that when weed plants were mixed with rice straw in the 1:1 ratio, there is increase in the yield than when used individually. Kumari and Varennyam 2008 reported highest yield of *P. ostreatus* on wheat straw (29.27 g fresh weight kg<sup>-1</sup> substrate) followed by the combination of paddy and wheat straw (27.96 g fresh weight kg<sup>-1</sup> substrate). Jadhav *et al.* (1996) studied the effects of different substrates on the yield of oyster mushroom, which was cultivated on wheat straw, paddy straw, stalks and leaves of maize and cotton, jowar, soybean straw, groundnut creepers plus wheat straw. Cotton stalks and leaves gave the best results as compared to the other substrates. It may thus be concluded that mushroom bed prepared from mixture of three agriculture residues like paddy straw, wheat straw and weed straw was superior compared to other substrates in increasing. The growth and yield potential of oyster mushroom (*Pleurotus ostreatus*).

Table 3. Effect of different substrates on yield potential of *Pleurotus ostreatus*

Substrates	Yield potential (g bed <sup>-1</sup> )			
	1 <sup>st</sup> Flush	2 <sup>nd</sup> Flush	3 <sup>rd</sup> Flush	Total
Wheat straw	308	277.33	236	821.33
Paddy straw	213.67	216	168.67	598.34
Paddy + Wheat + Weed straw	326.33	306.67	245	878
Wheat + Weed + Mango leaf	290	268.33	216.67	775
Paddy + Wheat straw	263	254	193.33	710.33
SeM	12.36	7.50	6.12	
CD at 5% level	38.64	23.63	19.30	
CV	7.57	4.91	4.99	

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# Raid screening of antityrosinase compounds from fungi

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## Abstract

Tyrosinase inhibitors are involved in controlling the undesired browning in fruits, vegetables and marine foods and also they used as whitening agents. The research in finding tyrosinase inhibitors drawn attention as there is a need in finding new inhibitors because the present tyrosinase inhibitors are having side effects such as carcinogenic properties. The screening of different fungies done through plate assay technique using dual assay technique on enriched PDA and inhibitory studies done by using spectrophotometric assay, where partially purified tyrosinase from *Acremonium rutilum* was used, revealed that *A.niger-1* and *A.ornatus* showed 98.3 and 98.1 per cent inhibition, which were highest as compared to other screened fungi. Plate assay method appears to be the best and rapid method for tyrosinase inhibitors, as all isolates screened by plate assay has shown inhibition to partially purified enzyme which were used for plate assay. *A.ornatus* showed a strong positive reaction with FeCl<sub>3</sub> test indicating that the compound is kojic acid which was separated by TLC with a standard kojic acid and the separated compound again showed 98.5 per cent tyrosinase inhibition. Kojic acid was identified as a potent fungal tyrosinase inhibitor from *A.ornatus*. *A.niger-1* didn't show any of the compounds tested and require a detail study. When the percent inhibition of synthetic kojic acid was compared with naturally screened and identified kojic acid, the percent inhibition was 91 per cent with synthetic IC<sub>50</sub> 1mM, where as it was 98.5 per cent inhibition which is appreciable with natural kojic acid irrespective of the concentration.

**Keywords:** *Aspergillus ornatus*, kojic acid, tyrosinase inhibitory activity

Tyrosinase catalyzes the oxidation of phenolic compounds to the corresponding quinones and is responsible for the enzymatic browning of fruits and vegetables. It is an important enzyme in controlling the quality and economics of fruits and vegetables in food industry<sup>(1)</sup>. In addition to the undesirable color and flavor, the quinone compounds produced in the browning reaction may irreversibly react with the amino and sulfhydryl groups of proteins. The quinone-protein reaction decreases the digestibility of the protein and bioavailability of essential amino acids, including lysine and cysteine. The unfavourable darkening from enzymatic oxidation generally results in a loss of nutritional value in mushrooms, sea foods and has been of great concern<sup>(1,2)</sup>.

Tyrosinase plays an important role in the developmental and defensive functions of insects. Tyrosinase is involved in melanogenesis, wound healing, parasite encapsulation and sclerotization in insects<sup>(3)</sup>. The development of tyrosinase inhibitors have become an active alternative approach in controlling insect pests. In addition, tyrosinase inhibitors have become increasingly important in cosmetic<sup>(4)</sup> and medicinal products in relation to hyper pigmentation. Melanin plays an important role in protecting human skin from the harmful effects of UV radiation from the sun, also determines phenotypic appearance. Various dermatological disorders such as hyper pigmented lentigenes include melasma, age spots and sites of actinic damage result in the accumulation of an excessive level of

epidermal pigmentation<sup>(5)</sup>. Great interest has shown in involvement of melanin in malignant melanoma, the most life-threatening skin tumors. Therefore, development of high-performance tyrosinase inhibitors is necessary for the applications in agricultural, cosmetic, pharmaceutical and food industries. Since most of the research was done on both synthetic and natural inhibitors especially plant origin, our study was mainly focused on rapid screening, production and purification of fungal metabolites as antityrosinase compounds where no reports are existing in this area. Hence screening of tyrosinase producing fungus *Acremonium rutilum* were isolated and tyrosinase was purified. *A.rutilum* was used as indicator organism and the antityrosinase compounds were screened both by plate assay and spectrometric inhibitory assay.

## MATERIALS AND METHODS

### Plate assay technique

Sterile enriched czapek dox agar and broth were amended with synthetic inhibitors- benzoic acid, kojic acid, EDTA, L-cysteine, L-ascorbic acid, PVP resorcinol and L-phenylalanine were inoculated with *A.rutilum* and were incubated for 5-8 days at 30°C.

### Inhibitory assay using tyrosinase enzyme

Purification of tyrosinase from *A.rutilum* was done as per Krishnaveni et al. (2015). Ascorbic acid, Benzoic acid, kojic acid and EDTA with different concentrations (0.025, 0.1, 0.5,

1mM) were added to the standard reaction mixture containing 8mM L-dopa, 0.1M sodium acetate buffer (pH 5.5) and 0.5 ml purified tyrosinase and rate of inhibition was checked at 475nm using UV-Vis spectrophotometer. The % inhibition of the tyrosinase activity was calculated by the equation:  $\{[(A-B)-(C-D) / (A-B)]\} \times 100$ .

#### Screening of tyrosine inhibitors from fungus by rapid plate assay method

Based on the previous experiments with synthetic inhibitors, fungal inhibitors were screened. Isolation of fungi was done by collecting soil samples in Gulbarga region. The tyrosinase producing *A.rutilum* was used as indicator and was inoculated on ECA. The isolated colonies were inoculated near to the indicator at 48hrs and again incubated for 4 days at 30°C.

#### Screening of tyrosine inhibitors from fungus by inhibiting purified Cytosolic tyrosinase from *A.rutilum*

Twenty five ml of sterile potato broth media amended with 0.2% L-Tyrosine, 2% starch, 1% glucose, 1% sucrose, 0.5% yeast extract, and 0.5% peptone was inoculated with a loopful of the selected fungi by plate assay. The flasks were incubated for 8 days on orbital shaker incubator at 180rpm, 30 °C. 0.5 ml of samples were tested against 0.5 ml purified cytosolic tyrosinase catalysed L-DOPA oxidation at 475nm. The % inhibition of the tyrosinase activity was calculated by the equation:  $\{[(A-B)-(C-D) / (A-B)]\} \times 100$ .

#### Identification of compound

*A.niger* -1 and *A.ornatus* were grown in 100ml of the broth and the samples were checked for the presence of L-DOPA [9], alkaloids [10], flavonoids [11], kojic acid [12], citric acid, ascorbic acid and oligosaccharides by qualitative analysis and TLC experiments.

#### Absorption spectrum of kojic acid by *A.ornatus*.

The UV spectrum of the 0.5ml broth sample in 0.1M sodium acetate buffer (pH 5.5) was determined by double beam UV- Vis spectrophotometer.

## RESULTS AND DISCUSSION

No brown pigmentation on 5<sup>th</sup> and 8<sup>th</sup> day with EDTA and resorcinol indicated that they are strong inhibitors of both laccase and tyrosinases. No brown pigmentation on 5<sup>th</sup> day and appearance of brown pigmentation on 8<sup>th</sup> day indicates only tyrosinase inhibition but not laccase. With cysteine and phenylalanine no brown pigmentation at the earlier stage but turned to reddish pigmentation and reddish purple at the later stages indicates formation of pheomelanins. With kojic acid, ascorbic and benzoic acid

light brown pigmentation and slight tyrosine hydrolysis was seen indicating they are strong inhibitors of monophenolase activity of tyrosinase (Fig.1.1&2). The same observations were shown in the broth samples with all the inhibitors. Synthetic inhibitors selected for inhibitory studies were Ascorbic acid, Benzoic acid, Kojic acid and EDTA. Benzoic acid has shown 100% inhibition with IC 50 value of 1mM. Next to it was EDTA with 98% inhibition whereas Ascorbic acid and kojic acid have shown 96 and 91 % at the same concentration. However, EDTA with 0.5mM, 99% of inhibition was observed. As per the experimental data it is proved that benzoic acid and EDTA are good inhibitors of tyrosinase of *A.rutilum* (Table-1.1).



Fig.1.1 Effect of PVP, Resorcinol, EDTA, Phenylalanine and cysteine on Melanin Pigmentation of *A.rutilum* on 5<sup>th</sup> day at 30°C



Fig.1.2 Effect of PVP, Resorcinol, EDTA, Phenylalanine on Melanin pigmentation of *A.rutilum* on 8<sup>th</sup> day at 30°C

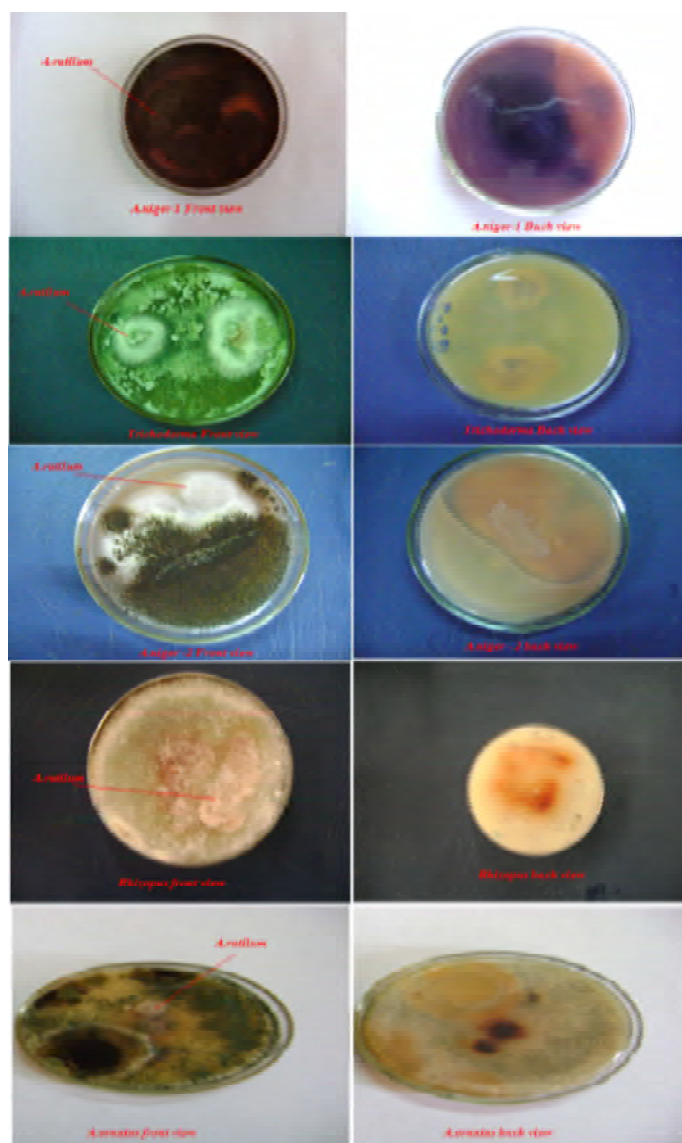
Table 1.1. Effect of inhibitors on partially purified Cyt tyr

Inhibitor	Concentration (mM)	%inhibition
Ascorbic acid	0.025mM	72
	0.1mM	88.1
	0.5mM	96
	1mM	96
Benzoic acid	0.025mM	79.8
	0.1mM	94
	0.5mM	96
	1mM	100
Kojic acid	0.025mM	70.3
	0.1mM	96
	0.5mM	92
	1mM	91
EDTA	0.025mM	51
	0.1mM	90.5
	0.5mM	99
	1mM	98

The results of screening of antityrosinase compounds from fungi by plate assay method with *A.rutilum* as indicator were tabulated (Table-1.2 and Fig 1.3). According to the results, 2 factors are observed. 1) The appearance of tyrosine hydrolysis, reddish brown pigmentation, simultaneous disappearance of brown pigmentation indicates diphenolase reaction gets inhibited 2) no tyrosine hydrolysis, and absence of brown/reddish pink pigmentation of the media indicates inhibition of monophenolase activity. The fungus which will show the above characteristics may be considered as inhibitor producers. According to the results of screening of antityrosinase compounds producing fungus by inhibiting

Table 1.2 Screening of antityrosinase compounds- Plate assay method

Fungus	Pigmentation of the media	Pigmentation of the fungus	L-Tyrosine hydrolysis
<i>A.niger</i> -1	Dark reddish pink	brown pigment absent	++++
<i>A.niger</i> -2	Light pink	-do-	++++
<i>Aspergillus spp.</i> (Light brown)	Yellowish	Brown at backside	++
<i>A.flavus</i>	colorless	brown pigment absent	+++
<i>Aspergillus.spp</i> (peacock green)	colorless	-do-	++
<i>A. terreus</i>	-	-do-	++
<i>Trichoderma spp.</i>	Florescent greenish yellow	-do-	-ve
<i>Rhizopus spp.</i>	Reddish	-do-	-ve
<i>A.clavatus</i>	colorless	-do-	+++
<i>A.niger</i> -4	colorless	-do-	+++
Unidentified	Magenta	-do-	+ve (very less)
<i>A.ornatus</i>	colorless	-do-	+ve (very less)
<i>A.niger</i> -3	Yellowish	-do-	++


Fig.1.3 Effect of Fungal Inhibitors of a) *A.niger*-1, b) *Trichoderma*, c) *A.niger*-2, d) *Rhizopus* and e) *A. ornatus* by Plate Assay

the purified cytosolic tyrosinase from *A.rutilum*, *A.niger*-1 and *A.ornatus* showed 98.4 and 98.3 % inhibition which was highest as compared to other fungi (Table- 1.3). Plate assay method appears to be the best and rapid method for tyrosinase inhibitors, as all isolates screened by plate assay have shown inhibition to partially purified enzyme.

*A.ornatus* showed a strong positive reaction with  $\text{FeCl}_3$  test indicating that the compound is kojic acid which was separated by TLC with a standard kojic acid and the separated compound again showed 98.5% tyrosinases inhibition (Fig.1.4 & 1.5). When the percent inhibition of

Table 1.3. Screening of antityrosinase compounds - by inhibiting the partially purified cyt Tyr from *Arutifum*

Sl.No.	Fungus	Color of the broth	O.D at 475 nm (8mML-DOPA)	Percent inhibition (A-B/A*100)
1	<i>A.niger</i> -1	Straw	0.007	98.3
2	<i>A.ornatus</i>	Yellow	0.008	98.1
3	<i>A.flavus</i>	yellow	0.022	94.7
4	<i>Rhizopus spp</i>	Straw	0.025	94.9
5	<i>A.clavatus</i>	Light orange	0.029	93.1
6	<i>Aspergillus spp</i> (Light brown)	Dark yellow	0.102	75.7
7	<i>Trichoderma spp.</i>	Dark flourescent yellow	0.108	74.3
8	<i>A.niger</i> -3	Pale yellow	0.117	72.1
9	<i>Aspergillus spp</i> (peacock green )	Dark flourescent yellow	0.137	67.4
10	<i>A.niger</i> -2	Pale yellow	0.148	64.8
11	Control (without inhibitor)		233.8	

synthetic kojic acid was compared with naturally screened and identified kojic acid, the percent inhibition was 91% with synthetic  $I_c 50$  1mM, where as it was 98.5% inhibition which is appreciable with natural kojic acid irrespective of the concentration. The absorption spectrum from 200-800nm of *A.ornatus* sample showed a sharp peak with absorbance of 0.219-0.524 at 280-290 nm which states that the proteins with tryptophan residues are more than tyrosine residues. At 300nm the O.D was 0.55 which was highest. Again at 423 nm sharp peak with O.D 0.188 was seen which may be due to some other metabolites. According to the literature kojic

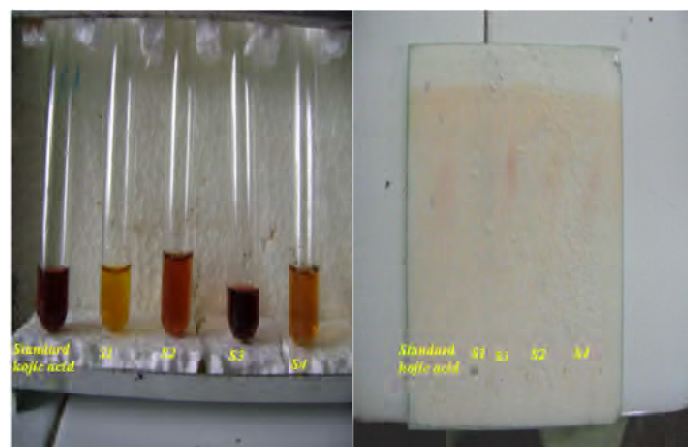


Figure 1.4. a) *A.niger*-1 (S1) (-ve for kojic acid), *A.flavus* (S2), *A.ornatus* (S3) (blood red +ve for kojic acid) and *A.terrus* (S4) samples were compared with standard for kojic acid test. B) *A.ornatus* (blood red +ve for kojic acid) compared with Standard kojic acid on TLC plate.

acid showed kojic acid in aqueous solutions is colorless with high peak at 217 and lowest peak at 270nm with a  $\epsilon$ -max at 340nm<sup>(12)</sup>.

As per present findings fungal metabolites are strong inhibitors of tyrosinase enzyme. In this study synthetic inhibitors were used in plate assay and base upon the results rapid plate inhibitory assay was designed in order to screen the tyrosinase inhibitors from microorganisms. Rapid plate inhibitory assay results are correlating with inhibitory assay using purified tyrosinase. Duckworth and Coleman (1970) reported that benzoic acid inhibited diphenolase activity of tyrosinase and this inhibition was competitive with catechol and irreversible and bound to Cu (I) which was associated with the deoxy form of tyrosinase<sup>(13)</sup>. Mushroom tyrosinase showed 70% inhibition with 100 M benzoic acid [14]. Khan and Andrawis reported an  $I_c 50$  value of 300 M using L-tyrosine as the substrate and detection of dopachrome [15]. Benzoic acid with  $I_c 50$  value of 0.64mM showed a mixed type of inhibition with L-DOPA [16]. EDTA was reported to be a metal chelator and a strong inhibitor of metalloenzymes especially laccase and tyrosinase [19]. Calcium disodium EDTA (21 CFR 172.120) and disodium EDTA (21 CFR 172.135) have been approved for use as food additives by the United States Food and Drug Administration [20]. Cysteine is an effective inhibitor of enzymatic browning. The inhibition of melanosis by cysteine is due to the formation of colourless thiol-conjugated o-quinones.. L-ascorbic acid and its various neutral salts and other derivatives have been the leading GRAS antioxidants for use on fruits and vegetables and in fruit juices, for the prevention of browning and other

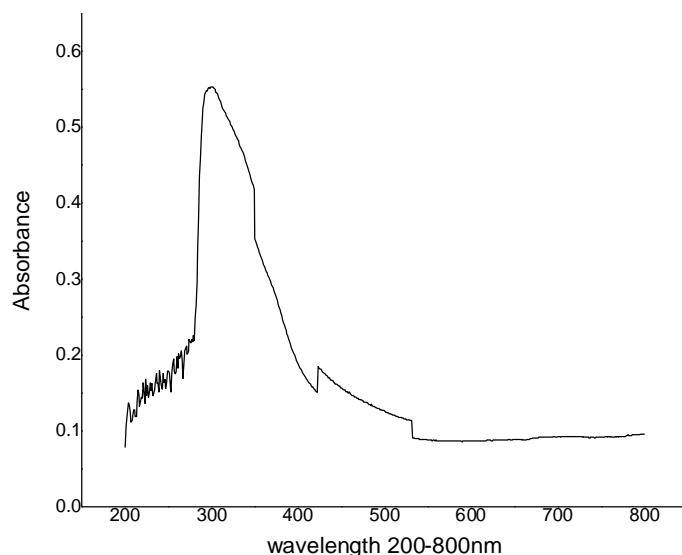


Figure 1.5. Absorption spectrum of the antityrosinase compound from *A.ornatus*

oxidative reactions [26]. Polyphenol oxidase inhibition by ascorbic acid has been attributed to the reduction of enzymatically formed o-quinones to their precursor diphenols [27]. More stable forms of ascorbic acid derivatives, such as erythroic acid, 2- and 3-phosphate derivatives of ascorbic acid, phosphinate esters of ascorbic acid, and ascorbyl-6-fatty acid esters of ascorbic acid, have been developed to overcome these problems [28]. Hulme *et al.* (1964) suggested that PVP inhibits by combining with the catechol oxidase substrate complex by attachment to the phenolic substrate moiety [29]. Harel *et al.*, (1964) observed that PVP and its monomer, N-vinyl-2-pyrrolidone inhibited the enzyme irreversibly and was able to act in the absence of added substrate [30]. Our result correlates with the assumption of Loomis *et al.*, (1966) [31] and Maurice *et al.*, (2005) [19]. Although resorcinol is a poor tyrosinase inhibitor, substitution in the 4-position yields increased inhibitory activity. 4-substituted resorcinol showed a competitive inhibition on mushroom tyrosinase with L-DOPA as a substrate.

Besides higher plants, some compounds from fungal sources have also been identified and reported for their inhibitory activity on tyrosinase [33]. Azelaic acid is a naturally occurring straight-chain, saturated dicarboxylic acid which is produced by yeast, *Pityrosporum ovale*, has a definite cytotoxic effect on malignant melanocytes of primary cutaneous melanoma, though normal melanocytes appeared not to be affected [34]. Azelaic acid acts as a weak competitive inhibitor of tyrosinase in vitro, which may be a major cause of its melanocytotoxicity. Kojic acid a fungal metabolite produced by many species of *Aspergillus* and *Penicillium* [12], are good chelators of transition metal ions and good scavengers of free radicals [22]. Recently, hemolymph serum tyrosinase from larvae of the noctuid moth *Spodoptera littoralis* was shown to be effectively inhibited by kojic acid when L-DOPA was used as the substrate [35]. Moreover, kojic acid effectively inhibited the formation of pigmented products and oxygen uptake when DL-DOPA, nor epinephrine and dopamine were oxidized by tyrosinase, which means that kojic acid is able to reduce o-quinone to o-diphenol to prevent the final pigment forming and be oxidized to a yellow product by chemical interaction with o-quinone [36]. The Rzepecki and Waite assay procedure has also been used by Kobayashi *et al.*, (1996) who investigated the inhibition of tyrosinase by kojic acid and some of its derivatives and found that derivatives of kojic acid, where an additional group was added via an ester coupling with the hydroxyl group at position 7 of kojic acid were slightly stronger inhibitors than kojic acid ( $IC_{50} = 23 \text{ } \mu\text{M}$ ) [21]. About 70% inhibition was determined with  $100 \text{ } \mu\text{M}$  kojic acid [14]. Kojic acid with  $IC_{50}$  value of 0.014 mM showed a mixed type of inhibition with L-

DOPA [23]. The yeast metallothioneins are ubiquitous cytosolic proteins, usually characterized by selective binding of a large amount of heavy metal ions ( $Zn^{2+}$ ,  $Cu^{2+}$  and  $Cd^{2+}$ ) and high cysteine content [37]. *N. crassa* copper-metallothionein was reported as a metal donor for apotyrasinase [38]. Metallothionein from *A. niger* was also found to be an inhibitor for a commercially purified mushroom tyrosinase, and exhibited a higher inhibitory effect on the oxidation of catechin compared with that of chlorogenic acid [39].

Other fungal extracts such as agaritine and inhibitors (Ia and Ib) from *Agaricus* species were also isolated, purified and characterized. Agaritine, b-N-(g-L (+)-glutamyl)-4-hydroxymethylphenylhydrazine, showed a depigmenting effect that prevented melanin formation. The inhibition was uncompetitive when L-DOPA was used as the substrate and partially competitive when tyrosine was used as the substrate [40]. Taking into account that agaritine is very abundant in *A. bisporus*, it might be suggested that agaritine could play in vivo a role as endogenous regulator of mushroom tyrosinase activity and the extent of o-quinone concentration formed. Moreover, the inhibitory mechanism of two inhibitors, Ia and Ib, isolated from *A. hortensis* was established [41].

From microbial metabolites inhibitors were screened and identified the active molecule, terrein, from *Penicillium spp.* [42] which inhibits melanogenesis in Mel-Ab cells by down regulating microphthalmia-associated transcription factor (Mitf) via extra cellular signal-regulated kinase (ERK) activation leading to the inhibition of tyrosinase production [43]. The majority of aspo-chalasin (Aspo-chalasin I), have been isolated from the species of *Aspergillus* and inhibits tyrosinases [44].

Kojic acid (5-hydroxy-2-hydroxymethyl-4H-pyran-4-one) is biologically synthesized in the oxygen conditions by various microorganisms from the wide range of carbon sources i.e. glucose, disaccharides and polysaccharides. Kojic acid from *A. flavus*, *A. terreus*, *A. oryzae*, *A. albus* was reported [45, 46]. There are no reports on kojic acid from fungus *A. ornatus*. Since there is existence of kojic acid in most of the genus *Aspergillus*, its important to test how much potent *A. ornatus* as kojic acid producer. It is a good chelator of transition metal ions such as Fe (III) and Cu (II) and is degradable in the environment. Its biological activity results from lipophilic and hydrophilic properties, ability to create chelate compounds with metal ions and inhibitory activity towards tyrosinase. It is extensively used in medicine as the anti-inflammatory and analgesic drug. In the food industry, kojic acid is used as flavor enhancer and as food antioxidant improving i.e. stability of edible fats and oils. Because of its inhibitory effect on tyrosinase, kojic acid is commonly used

in cosmetic industry as whitening agent and as effective compound of creams protecting the skin against UV radiation. Besides, kojic acid and its derivatives tend to have antifungal, insecticidal, anticancer and bacteriostatic properties, its application in the above industries is significantly spreading.

A mixture of ascorbic acid and kojic acid has been patented for use as an anti-browning agent in foods [47]. Kojic acid has potential applicability in the prevention of melanosis in both plant and seafood products. Saruno *et al.*, (1979) demonstrated that kojic acid from *Aspergillus albus* inhibited mushroom PPO activity [45]. Chen *et al.*, (1991) determined that kojic acid was a competitive inhibitor of the oxidation of chlorogenic acid and catechol by apple polyphenol oxidase [48]. Kojic acid inhibits the rate of formation of pigmented products, as well as the rate of oxygen uptake, when various o-dihydroxy- and trihydroxy phenols are oxidized by tyrosinase [36]. Tyrosinase inhibition by kojic acid was thought to be due to its ability of kojic acid to bind copper at the active site of the enzyme. Although kojic acid is a good inhibitor of polyphenol oxidase, its toxicity is of concern. Wei *et al.* (1991) reported weak mutagenic activity of kojic acid in a *Salmonella typhimurium* assay [49]. However, because of the hazardous side-effects of whitening agents, the use of hydroquinone in cosmetics has been banned by the European Committee [50]. Kojic acid was also restricted because of the carcinogenic potential [51]. Thus, attention has recently been focused on the novel products in cosmetics [52].

It was concluded that use of natural products in cosmetics from microbial sources play a significant role as they can be produced in an economical way with no side effects. Advanced studies have shown kojic acid derivatives to be stronger tyrosinase inhibitors. Hence, further work in this direction is needed.

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# Morphological traits in indigenous ivy gourd (*Coccinia grandis*) genotypes of N.E. region of India

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## Abstract

An experiment was carried out at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat to study the morphological traits in ivy gourd (*Coccinia grandis*) genotypes collected from different parts of Assam and other North Eastern States (Arunachal Pradesh, Tripura and Nagaland) during the summer season. The experiment was laid out in randomized block design with three replications. The qualitative traits were recorded through visual observation as per NBPGR descriptor. Morphological characterization of 22 genotypes revealed significant variation among the genotypes.

**Key words:** Ivy gourd, genotypes, distinct

Ivy gourd, *Coccinia grandis* (L.) Voigt. [Syn. *C. indica* Wight and Arn., *C. cordifolia* (L.) Cogn.] belongs to the family Cucurbitaceae and is known by various names like Kundru, tondli, little gourd, scarlet gourd and kunduli. It is a semi-perennial crop of 4-5 years, yielding fruits in summer and rainy season and is indigenous to India. It is reported to possess anti-inflammatory, antioxidant, antimutagenic, antidiabetic, antibacterial, antiprotazoal, antiulcer,

hepatoprotective, expectorants pharmacological properties (Yadav and Mishra, 2010). In recent time, it is gaining the status of an important vegetable crop in Assam because of increasing consumer awareness about its significant nutraceutical value. Ivy gourd is mostly termed as poor man's vegetable (Singh and Singh, 2014). Landless poors in Bihar grow Ivy gourd on the roof of their huts.

Table 1. Observations on morphological traits (as per NBPGR descriptor)

Genotype	Stem pubescence	Stem shape	Tendrils	Tendrils branching	Leaf margin	Fruit shape	Fruit skin colour	Flesh colour
IG-1	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-2	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Green	White
IG-3	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Green	White
IG-4	Smooth	Rounded	Present	Unbranched	Slightly dentate	Cylindrical	Green	White
IG-5	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-6	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Dark green	White
IG-7	Smooth	Rounded	Present	Unbranched	Slightly dentate	Cylindrical	Green	White
IG-8	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Green	White
IG-10	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-11	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-12	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-13	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Dark green	White
IG-14	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Light green	White
IG-15	Smooth	Rounded	Present	Unbranched	Slightly dentate	Cylindrical	Green	White
IG-16	Smooth	Rounded	Present	Unbranched	Slightly dentate	Cylindrical	Green	White
IG-17	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Green	White
IG-18	Smooth	Rounded	Present	Unbranched	Dentate	Globular	Green	White
IG-19	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-20	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Green	White
IG-22	Smooth	Rounded	Present	Unbranched	Dentate	Globular	Green	White
IG-23	Smooth	Rounded	Present	Unbranched	Dentate	Cylindrical	Green	White
IG-25	Smooth	Rounded	Present	Unbranched	Medium dentate	Cylindrical	Dark green	White

The experimental material comprised of 22 ivy gourd [*Coccinia grandis* (L.) Voigt] germplasm collected from farmers of different parts of Assam and other North Eastern states (Arunachal Pradesh, Nagaland and Tripura) including a variety from IIVR, Varanasi. Being dioecious in nature, to evaluate these 22 genotypes, a common male parent was also included as an experimental material. Out of total 25 initial collection, 3 genotypes i.e. IG-9, IG-21 and IG-24 were found to be bitter. Therefore, these genotypes were excluded. Planting was done at a spacing of 2m x 2m. All the recommended package of practices were followed.

The qualitative traits were recorded through visual observation as per NBPGR descriptor. The results are presented in Table 1. The stems of all the genotypes were found to be smooth. From the cross section of all the genotypes, it was observed that the stem shape was rounded. Plate 1 shows all the collected genotypes of ivy gourd.

Variations in leaf margin is presented in Plate 2. The leaves have 3-5 lobes. Leaf margin was found to be slightly dentate, medium dentate and dentate. All the genotypes showed unbranched tendrils (Plate 3).

Two distinct types of fruit shapes, viz., cylindrical and globular were observed in ivy gourd genotypes (Table 1). Two genotypes i.e. IG-18 and IG-22 had globular shaped fruits and rest of the genotypes had cylindrical fruit shape.

Three distinct classes of fruit skin colour at edible stage were observed, i.e. dark green, green and light green (Plate 4). In most of the genotypes, the fruit skin colour was green. The genotype IG-14 had light green skin colour. Fruit skin colour of IG-6, IG-13 and IG-25 was observed to be dark green.

At edible stage, flesh colour of all the genotypes was observed to be white (Plate 5). But, when it over-matures the colour turns to yellowish-red.



Plate 1. Ivy gourd genotypes

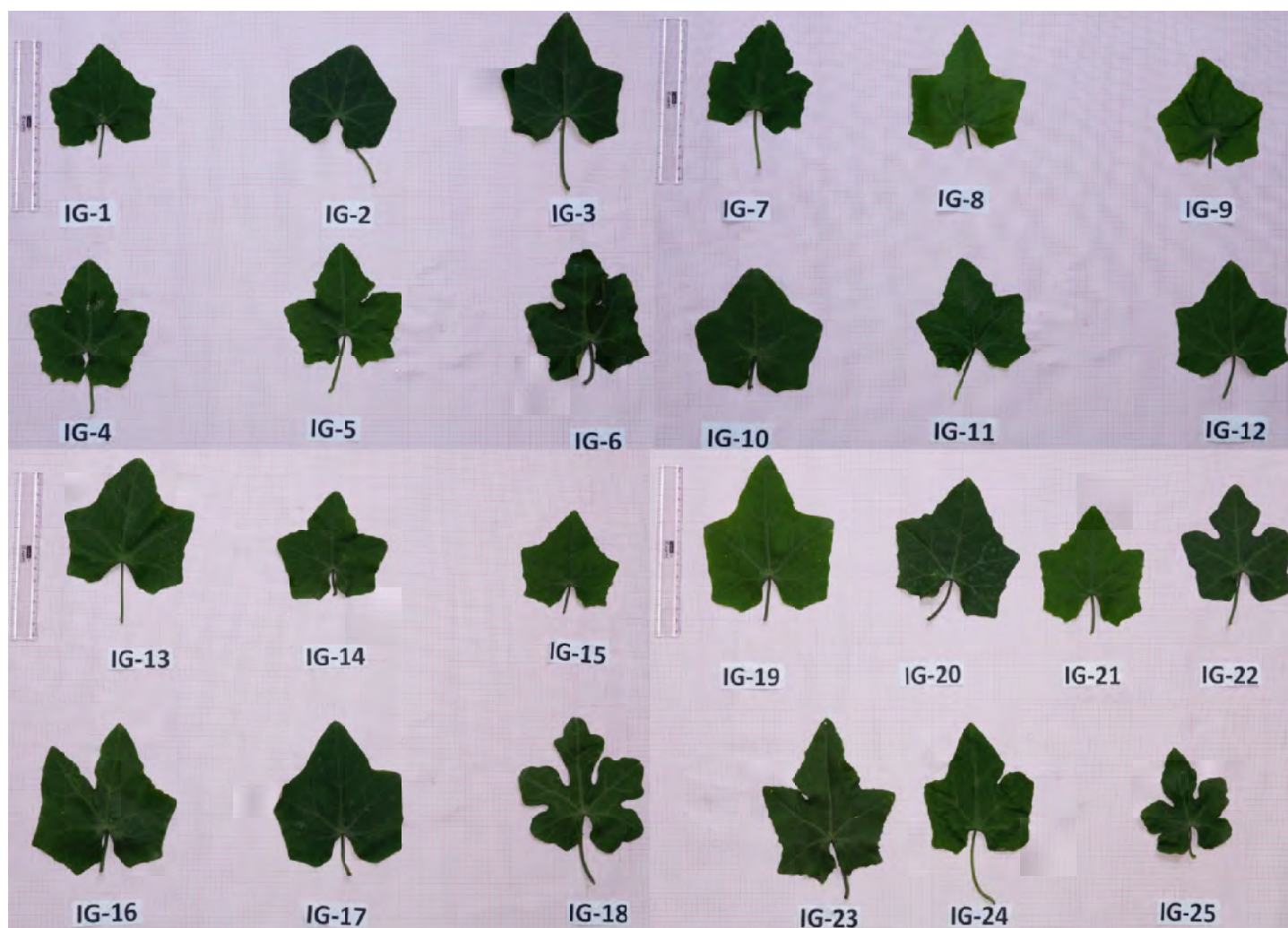


Plate 2. Variations in leaf margin



Plate 3. Un branched tendrils



Dark green      Green      Light green  
Plate 4. Fruit skin colour



Plate 5. Flesh colour

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# Silicon nutrition in Rice

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## Abstract

Silicon (Si) is considered as a beneficial element for crop growth, especially for crops under Poaceae family. Rice is a typical silicon accumulating plant and it benefits from silicon nutrition. Si is absorbed in the form of monosilicic acid and its transportation is governed by three genes i.e. LSi1, LSi2 and LSi6. Silicon is deposited beneath the cuticle as cuticle-silicon double layer in the form of silicic acid. Highly weathered soils are low in available silicon mainly due to leaching loss. Its supply is essential for healthy growth and economic yield of the rice crop. Silicon interacts favourably with other applied nutrients and improves their agronomic performance and efficiency in terms of yield response. Also it improves the tolerance of rice plants to abiotic and biotic stresses. Hence, silicon management is essential for increasing and sustaining rice productivity.

**Keywords:** Silicon, rice, biotic stress, abiotic stress, yield, productivity.

Silicon (Si) is the second most abundant element in the earth's crust. It is not considered as an essential element, but is a beneficial element for crop growth, especially for Poaceae crops. Si concentration of plant shoots varies greatly among plant species, ranging from 0.1 to 10% Si on a dry weight basis. Silica strengthens the plant, protects the plant against pests and diseases, increases crop production and quality, stimulates active immune systems of plants, increases plant nutrition, increase plant salt resistance and neutralizes heavy metal toxicity in acid soils. Si fertilizer has a double effect on the soil-plant system. First, improved plant-silicon nutrition strengthens plant-protective properties against insect pests incidence, and unfavorable climatic conditions. Second, Si optimizes soil fertility through improved water, physico-chemical soil properties and maintenance of nutrients in plant-available forms.

In the soil solution, Si is present as Monosilicic acid and Polysilicic acid as well as complexes with organic and inorganic compounds such as aluminium oxides and hydroxides. While it is the PAS (plant available silicon) that is taken up by the plants and has a direct influence on crop growth. The solubility of Si in the soil is affected by a number of dynamic processes occurring in the soil including the particle size of the silicon fertilizer, the soil acidity (pH), organic complexes, presence of aluminium (Al), iron (Fe) and phosphate ions, dissolution reactions and soil moisture. Si improves physical, chemical and biological properties of soil.

Rice is a high silicon accumulating plant and the plant is benefited from Si nutrition. Rice crop can uptake Si in the

range of 230-470 kg ha<sup>-1</sup>. Si is a beneficial element for plant growth and is agronomically essential for improving and sustaining rice productivity. Besides rice yield increase, Si has many fold advantages of increasing nutrient availability (N, P, K, Ca, Mg, S, Zn), decreases nutrient toxicity (Fe, P, Al) and minimizing biotic and abiotic stress in plants. Hence, the application of Si to soil or plant is practically useful in laterite derived paddy soils, not only to increase yield but also to alleviate the Fe toxicity problems. Si increases the mechanical strength of the culm, thus reducing crop lodging (Savant *et al.*, 1997). In soil, Si is not a much mobile element to plants. Therefore, a continued supply of this element would be required particularly for the healthy and productive development of plant during all growth stages.

## Beneficial effects of silicon in rice

### 1. Decrease lodging

Si in rice shoots enhanced the thickness of the culm wall and the size of the vascular bundles that result in reduction in lodging. Thickening of the cell walls of the sclerenchyma tissue in the culm and/or shortening and thickening of internodes or increase in Si content of the lower internodes provides mechanical strength to enable the plant to resist lodging (Savant *et al.*, 1997).

### 2. Increase crop growth and yield

Si promotes growth, strengthens culms, and favors early panicle formation, increases the number of spikelets per panicle and percentage of matured rice grains and helps to maintain erect leaves which are important for higher rate

of photosynthesis. Si plays an important role in hull formation in rice, and, in turn, seems to influence grain quality (Bhaskaran, 2014). Ahmad *et al.*, (2013) reported that application of Si fertilizers enhanced the growth parameters, increased yield, yield attributes and quality of rice crop.

### 3. Improves availability of applied nutrients

#### i. Nitrogen

Fertilizing with nitrogen tends to make rice leaves droopy, whereas silicon keeps them erect. By adopting proper silicon management, erect leaves can easily account for a 10% increase in the photosynthesis by crop (Yoshida, 1981). Therefore, the maintenance of erect leaves by proper silicon fertilization for higher photosynthetic efficiency becomes more important when rice is grown with liberal applications of nitrogenous fertilizers in lowland rice fields having highly weathered tropical soils. (Yoshida *et al.*, 1969).

#### ii. Phosphorus

The application of calcium silicate to highly weathered soils enhanced upland rice response to applied phosphate. Ma *et al.* (1991) reported that overall beneficial effect of Si may be attributed to a higher P: Mn ratio in the shoot due to the decreased manganese and iron uptake, and thus indirectly improved phosphorus utilization within the rice plants.

#### iii. Potassium

Silicification of cell walls seems to be linked with potassium nutrition. According to Nogushi and Sugawara (1966), potassium deficiency reduces the accumulation of silicon in the epidermal cells of the leaf blades, thus increasing the susceptibility of the plant to rice blast. Therefore, silicon management integrated with potassium may be more important for sustaining rice yields in upland areas than in lowland areas.

### 4. Decrease metal toxicities of Fe and Al

#### i. Iron toxicity

In humid tropical and subtropical area, iron toxicity is one of the major physiological problems in rice growth. Silicon increases the oxidizing power of roots, which converts ferrous iron into ferric iron, thereby preventing a large uptake of iron and limiting its toxicity (Ma *et al.*, 2002). Silicon will regulate Fe uptake from acidic soils through the release of OH<sup>-</sup> by roots (Wallace, 1993).

#### ii. Aluminium toxicity

Si application alleviates aluminium toxicity by creating inert aluminosilicates, stimulating phenolic exudation by

roots or by sequestration in phytoliths (Guntzer *et al.*, 2012).

### 5. Increase abiotic stress tolerance

#### i. Alleviate salt stress

Excessive salinity in cropping soil is a worldwide problem due mainly to rising water tables. Si may alleviate salt stress in higher plants either by improved photosynthetic activity, enhanced K/Na selectivity ratio, increased enzyme activity, and increased concentration of soluble substances in the xylem (Sahebi *et al.*, 2015). Si fertilizer application can also alleviate the adverse effects of salt stress on plants by increasing cell membrane integrity and stability through its ability to stimulate the plant's antioxidant system (Marafon *et al.*, 2013).

#### ii. Alleviate drought stress

The deposition of Si in the culms, leaves, and hulls also decrease transpiration from the cuticle thus increasing resistance to drought stress. Drought stressed plants that were treated with Si fertilizer retained greater stomatal conductance, relative water content, and water potential than untreated plants. Si increased resistance to strong winds generated by typhoons, related to the increased rigidity of the shoots through silicification (Guntzer *et al.*, 2012).

### 6. Increase biotic stress tolerance

#### i. Pest tolerance

Si increases the resistance of plants to many insects in rice like stem borer, leaf folder, brown plant hopper, etc. The deposition of silica on epidermal layers offers a physical barrier to insects by preventing the physical penetration by insects. Sucking and leaf eating caterpillars have a low preference for the silicified tissues than low silica containing succulent parts. Soluble silicic acid (as low as 0.01 mg/ml) in the sap of the rice plant acts as an inhibitor of the sucking activity of the brown planthopper (Yoshihara *et al.*, 1979).

#### ii. Disease tolerance

Si has been found to decrease several diseases in rice like sheath blight, brown spot, grain discoloration, etc. Si might form complexes with the organic compounds of cell walls of epidermal cells, thus increasing their resistance to the enzymes expounded by the pathogen. The antifungal compounds like momilactones were found to accumulate in Si treated rice plants and these acted against blast pathogen.

### Silicon deficiency

Si deficiency makes the rice plants susceptible to pests and diseases. Si deficiency is common in areas with poor

soil fertility, and in highly weathered soils. Its deficiency also seen in organic soils with less Si reserves and also occurs in highly weathered soils. The critical level of Si in soil is 40 mg kg<sup>-1</sup> and the critical level of Si in rice (leaf and straw) is 5%. Si deficiency leads to soft and droopy leaves, reduced photosynthetic activity, reduced grain yields, increased insect pest incidence, reduced number of panicles and filled spikelets per panicle (IRRI, 2016).

### Silicon fertilizers

Calcium silicate, fine silica and sodium silicate, are mostly used silicon fertilizers. Potassium silicate, though expensive, is highly soluble and can be used in hydroponic culture and also applied through foliage. Rice husk, rice husk ash and straw are organic sources of Si. Rice straw hauled away from rice fields are used for various purposes, such as animal feed, biogas production, or mushroom cultivation, may maintain its nutrient value as a source of Si; thus the end products of these uses should be recycled. Si content in rice straw and rice husk ranges from 4-20% and 9-26% respectively. Silicon solubilising bacteria (SSB) is a bio-fertilizer which contains spores of the *Bacillus mucilaginosus*. It is used as an effective soil inoculant. It solubilizes silica and provides the plant with strength to tolerate biotic and abiotic stresses and improves its resistance to pest and disease attack. With the changes occurring in the global environment, the role of Silica will become more and more important for better and sustainable production of the crop. (Chinnasami *et al.*, 1978).

Rice is a silicon accumulator, so adequate attention should be given to silicon nutrition. Highly weathered soils of the tropics and subtropics are low in available silicon. Silicon management agenda includes silicon fertilization and recycling of silicon in rice crop residues. Silicon has manifold advantages. It is essential for healthy growth and productive development of the rice crop. Silicon increases the efficiency of applied nutrients, increases crop yield, increases resistance against lodging, biotic stresses, and abiotic stresses. Silicon management is essential for sustaining rice productivity in temperate, tropical, and subtropical soils.

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