RNI No. UPENGO3865/24/1/2013-TC

ISSN (Print) : 2347-7377
ISSN (Online) : 2455-7560

Current Horticulture

(a journal dedicated for the advancement of Horticultural science)

Vol. 13 No. 1, January–March 2025

www.currenthorticulture.com

(www.currenthorticulture.com)

Current Horticulture

(a journal dedicated for the advancement of Horticultural science)

- The *Current Horticulture* is a research journal published under the aegis of Society for Horticultural Research and Development (SHRD), Ghaziabad, Uttar Pradesh, India. Corporate Office: SD-70, Shastri Nagar, Ghaziabad 201002 (Uttar Pradesh), India.
- The prime objective of the *Current Horticulture* is for the advancement of basic and fundamental research in Horticultural science among horticulturists - researchers, scientists, students, educators and other stakeholders - to promote scientific exchange and interaction among them in a mission-mode approach.

CURRENT HORTICULTURE

Vol 13, No. 1, January-March 2025

Contents

Research Review Article

Current Horticulture **13**(1): 03–13, January–March 2025

DOI: 10.5958/2455-7560.2025.00001.8

Received: 03 January 2024; Accepted: 04 August 2024

Novel green management strategies for fruit flies (Tephritidae: Diptera) infesting horticultural crops in India: a critical review

M A Rashmi[1] K J David[2] and Abraham Verghese[2*]

[1] *Rashvee-International Phytosanitary Research and Services, Bengaluru, Karnataka, India*

Abstract

Fruit flies, in the family Tephritidae, are major pests of horticultural crops and of quarantine concern in India and globally due to their concealed feeding habits and invasive nature. In India, most problematic species belong to the genera *Bactrocera, Dacus*, and *Zeugodacus* within the subfamily Dacinae, and *Carpomya* within the subfamily Trypetinae. The economic impact of these pests extends beyond yield losses and increased management costs. They can also lead to the loss of export markets and increased expenses for the construction and maintenance of fruit treatment and management facilities. Approximately 40 species of Tephritidae have been intentionally or unintentionally introduced outside their natural ranges by humans. Notable examples include *Bactrocera dorsalis* (Hendel), *B. carambolae* Drew and Hancock, *B. latifrons* (Hendel), *Zeugodacus cucurbitae* (Coquillett), and *B. zonata* (Saunders), which have spread from the Oriental region to other parts of the world. Conversely, *B. oleae* (Rossi) was introduced from the Mediterranean region to India. Beyond their role as pests, some fruit flies are significant as biological control agents for invasive weeds. Over 20 species, primarily from the subfamily Tephritinae, have been used to manage invasive Asteraceae species.

Key words: Fruit flies, Horticultural crops, Tephritidae: Diptera, Diagnosis, Host plants, Biocontrol

Several species of *Urophora* were introduced to North America to control thistles and knapweeds (White and Elson-Harris, 1992). In India, introduction of *Cecidochares connexa* Macquart on Siam weed (*Chromolaena odorata*) and *Procedidochares utilis* Stone on *Eupatorium adenophorum* has been significant for biological control, causing stem galls (Bhumannavar *et al.*, 2004; 2007; Ramani, 2004).The Tephritidae family, a significant group within the order Diptera (true flies), encompasses over 5,000 described species. These species are distributed across six subfamilies, 500 genera, and 40 tribes and subtribes (Korneyev, 1999; Norrbom *et al.*, 1999; Freidberg, 2006).

In India, approximately 300 species from 84 genera and five subfamilies—Dacinae, Phytalmiinae, Tachiniscinae, Tephritinae, and Trypetinae—have been documented (Agarwal and Sueyoshi, 2005; David and Ramani, 2011; David *et al.*, 2013; David and Hancock, 2013; David *et al.*, 2014; David *et al.*, 2017; David and Ramani, 2019; David *et al.*, 2020, 2021, 2022, 2024).Tephritid fruit flies are distinguished by several morphological features. They possess well-developed frontal plates and frontal setae that are significantly longer than the surrounding setulae. A notable characteristic is the presence of a costal break before the apex of the subcostal vein, which is protected by two or three spines. The Sc vein is bent and joins the costa at nearly a right angle. The wing cell cup has an acute extension and may be either patterned or hyaline (Hardy, 1973; White and Elson-Harris, 1992; Korneyev, 1999b).These characteristics not only aid in the identification of tephritid flies but also highlight their ecological and economic importance, particularly in agriculture where many species are considered pests.

***Corresponding author :** abraham.avergis@gmail.com

[2]ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru

The Tephritidae family, encompassing over 5,000 species, is found in a variety of environments ranging from open savannahs to dense rainforests. These flies are widely distributed across tropical, subtropical, and temperate regions, with the notable exceptions of the Arctic and Antarctic (Kapoor *et al.*, 1980; Norrbom *et al.*, 1999; Agarwal and Sueyoshi, 2005).In India, fruit flies are prevalent across all geographic regions. The tribe Dacini, which includes the genera *Bactrocera*, *Zeugodacus*, and *Dacus*, is particularly widespread throughout the country. These genera are known for their significant impact on horticultural crops, making them a major concern for agricultural practices.

Additionally, introduction of certain Tephritidae species to non-native regions has further expanded their distribution. For example, *Bactrocera dorsalis* and *B. zonata* have been introduced from the Oriental region to other parts of the world, while *B. oleae* was brought from the Mediterranean region to India (Norrbom *et al.*, 1999). In India, the subfamily Dacinae is the most prevalent, comprising nearly 42% of the country's Tephritidae fauna with 119 described species. The subfamily Tephritinae follows with 69 species, and Trypetinae with 65 species. The tribe Acanthonevrini, within the subfamily Phytalmiinae, includes 18 species from 10 genera.

Only a single species from the subfamily Tachiniscinae has been reported in India (David and Hancock, 2013).The high diversity in the Oriental region, particularly in India, can be attributed to the varied climatic conditions and habitats that support a wide range of Tephritidae species. This diversity is crucial for understanding the ecological roles and economic impacts of these species, especially those that are pests of horticultural crops.

Biology and nature of damage

While fruit flies are commonly known as fruit feeders, only species within the subfamilies Dacinae (particularly the tribe Dacini) and Trypetinae are frugivorous. Other taxa within the Tephritidae family exhibit a diverse range of feeding habits, including bamboo shoot feeders, flower feeders, leaf miners, and gall makers. Female fruit flies possess an extendable ovipositor, which they use to deposit eggs between parts of the host flower, intact fruit, stem, or leaves. The life cycle includes three larval instars and a puparial stage.Larvae of fruit flies develop in seed-bearing plants, with approximately 35% of species attacking soft fruits. In addition to infesting soft fruits, around 40% of fruit fly larvae develop in Asteraceae flowers, while others are associated with flowers from various plant families or mine the leaves, stems, or root tissues (White and Elson-Harris, 1992). Some species also induce gall formation.

Fruit flies are synovigenic, meaning that female flies require a protein-rich diet to mature their eggs and commence oviposition after emergence. Most pestiferous species are multivoltine, producing 10–12 generations per year, with the exception of *Bactrocera minax*, which is univoltine. The damage caused by fruit flies is multifaceted. They not only directly damage the host plants but also facilitate the entry of secondary pathogens, exacerbating the economic losses.

Host plant associations of Tephritidae

Fruit flies exhibit a high degree of host specificity, with the exception of saprophytic and polyphagous taxa. Polyphagous species such as *Zeugodacus cucurbitae*, *Z. tau*, and various *Dacus* species are primarily associated with host plants in the family Cucurbitaceae. Among the pestiferous species, *Bactrocera minax* is highly host-specific to the Rutaceae family. In contrast, several monophagous species of *Dacus* are associated with the Asclepiadaceae family.Within the subfamily Dacinae, only the tribe Gastrozonini has adapted to bamboo as a host. Gastrozonini is considered a monophyletic tribe (Wang and Chen, 2002; Kovac *et al.*, 2006; De Meyer, 2006; Dohm *et al.*, 2014), with larvae primarily feeding on the shoot meristem or other soft tissues of living or dead bamboo shoots.Species in the subfamily Phytalmiinae are generally saprophagous. However, Hardy (1986) and Permkam and Hancock (1995) reported that species in the genera *Clusiosomina*, *Clusiosoma*, *Cheesmanomyia*, and *Rabaulia* infest fruits of *Ficus* species. Larvae of genera such as *Austronevra*, *Dacopsis*, *Diarrhegma*, *Diarrhegmoides*, *Lumirioxa*, and *Phytalmia* develop in decomposing tree trunks or rotting parts of trees (Hardy, 1986; Permkam and Hancock, 1995). Some species of *Afrocneros* and *Ocnerioxa* have been found under the bark of living trees (Munro, 1967), and *Termitorioxa termitoxena* (Bezzi) breeds in termite galleries within tree trunks (Hill, 1921).

The subfamily Trypetinae exhibits the most varied larval feeding habits. The tribe Adramini is primarily found in the Old World, with two species of *Euphranta* present in North America (Hardy, 1986; White and Elson-Harris, 1992; Hancock and Drew, 1994). One species, *E. toxoneura* (Loew), feeds on sawfly larvae within galls (Kopelke, 1984). According to White and Elson-Harris (1992), the tribe Carpomyini reproduces exclusively in fruits, with most species being highly host-specific.

FRUIT FLY PESTS IN INDIA

One of the problems faced by tephritiditologists in India and Asian countries is the proper identification of fruit fly species (Diptera: Tephritidae). Among the fruit flies, the genus *Bactrocera* and *Zeugodacus* are commonly encountered in parapheromone (methyl eugenol or cue lure) traps. Madhura and Verghese, 2004 present a key that would enable one to easily identify species that usually come into traps. This has quarantine implications also, as it helps to work out the spread or introduction of fruit flies to new areas.

Elucidation of genetic variation in geographical populations can be an important aspect to study the pest populations and their management. Within an ecosystem, the extent of genetic variation between geographical populations depends on several factors, including gene flow between populations, host range and time since separation.

Fruit fly systematics is one of the important fields of applied entomology. Despite the importance of the family, the higher classification of the Tephritidae is still in a fluid state. Years of work by many taxonomists using morphological characters had not yielded adequate resolution of higher classification within the family Tephritidae because of homoplasy of several morphological characters and difficulty involved in identification of immature stages. The first and foremost important step in pest management system is correct identification of the pest. *Bactrocera dorsalis* is a complex with high variability in morphology and behaviour with several cryptic species, yet undetermined by classical taxonomy.

Within an ecosystem, the extent of genetic variation between geographical populations depends on several factors, including gene flow between populations, host range, climatic factors, etc. The genomic DNA was extracted from male flies of *Bactrocera dorsalis* (Hendel) collected from different agro-ecological regions of Karnataka. The percent polymorphism varied from 33.33% to 100% with an average of 71.66%. The Jaccard's similarity coefficients ranged from zero to 0.91. UPGMA dendrogram generated by RAPD data indicated the segregation of populations into three clusters. Genetic diversity plays an important role in the survival and adaptability of a species; therefore, *B. dorsalis* populations of different agro-ecological regions have undergone changes probably to survive or the changes are consequent to interplay (Rashmi *et al.*, 2016).

Oriental fruit fly: *Bactrocera (Bactrocera) dorsalis* Hendel

Diagnosis: Adult: Face yellowish with two separate black spots. Medium sized flies with yellow lateral vittae on black/ reddish brown scutum. Wing with continuous costal band confluent with vein R_{2+3}. All femora yellow without any fuscous/black markings. Abdomen orange red with a prominent T shaped mark (White and Elson-Harris, 1992; Ramani, 1997).

Attractant: Methyl Eugenol

Host plants

Aegle marmelos (L.) Corr. (Bael), *Anacardium occidentale* L. (Cashew), *Artocarpus altilis* (Park.) (Bread fruit), *A.heterophyllus* Lamk.(Jack fruit), *Capsicum fruitescens* L.(Red pepper), *Carissa carandas* L. (Karanda), *Cerbera manghas* L.(Honde fruit), *Chrysophyllum cainitto* L.(Star apple), *Citrus aurantium* L.(Sour orange), *C. grandis* Osbeck. (Pomelo), *C. medica* L.(Citron), *C. nobilis* Lours (Orange), *C.reticulata* Blanco (Mandarin), *Coffea arabica* L. (Arabian coffee), *C. canephora* Pierre ex Froehner (Robusta coffee), *Cydonia oblonga* Mill.(Quince), *Diospyros* sp. (Persimmon), *Eriobotrya japonica* (Thunb.) (Loquat), *Ficus carica* L. (Fig), *F. mysorensis* Heyne, *Litchi chinensis* (Gaertn.) Sonn. (Litchi), *Malus pumila* Mill. (Apple), *Mangifera indica* L. (Mango), *Manilkara achras* (Mill.) (Sapodilla), *Mimusops elengi* L. (Spanish cherry), *Morus australis* Poir. (Common mulberry), *Musa paridisiaca* L. (Banana), *Persea americana* Mill. (Avocado), *Physalis peruviana* L.(Cape gooseberry), *Prunus armeniaca* L. (Apricot), *P avium* L. (Sweet cherry), *P. domestica* L. (Plum) , *P. persica* (L.) (Peach), *Psidium guajava* L. (Guava), *Punica granatum* L. (Pomegranate), *Pyrus communis* L.(Pear), *Rubus fruiticossus* L. (Black berry), *Santalum album* L. (White Sandalwood), *Solanum erianthum* D.Don., *Solanum indicum* L. (Indian night shade), *S. melongena* L. (Egg plant) , *S. torvum* Swartz, *Syzigium cumini* (L.) Skeels (Jamun), *Terminalia catappa* L. (Indian almond), *Zizyphus mauritiana* Lamk. (Jujube/ Ber) (White and Elson-Harris,1992; Kapoor, 1993; Ramani, 1997)

Distribution: Assam, Bihar, Delhi, Himachal Pradesh, Jammu & Kashmir, Kerala, Karnataka Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal (Bhat, 1989; Agarwal & Sueyoshi, 2005).

Biology and Ecology

The life cycle of *B. dorsalis* range from 21 to 26 days with an average of 23.5 days. Eggs are laid in clusters of 2 to 9 in half to overripe fruits by making punctures using telescopic ovipositor. Incubation period of eggs range from 24-48 hours with an average of 36 hours. Three larval instars are there, which take 2.16, 4.83 and 5.25 days respectively. Fully matured maggot drop to soil and pupation takes place in soil at a depth of two to ten centimeters with an average of 5.4 cm under field conditions (Belavadi, 1979).

Adults are synovigenic. They were observed to mate after feeding for a few days during evening hours of day. The mating usually starts at dusk and lasted from 35 minutes with an average 1 hour 10 minutes (Belavadi, 1979).

Bactrocera (Bactrocera) carambolae Drew & Hancock

Diagnosis: Face fulvous/ yellow with two oval black spots, scutum predominantly black with broad (>0.15mm) lateral postsutural vittae, fore femur with elongate black spot, mid and hind femur without spots/ markings, wing with costal band overlapping vein R_{2+3} and expanded slightly beyond the apex of $R_{2+3,}$ abdomen orange brown with a prominent T pattern and lateral transverse markings on tergites IV and V.

Attractant: Methyl Eugenol

Host plants: It is known to breed on 75 host plants belonging to 26 families. Ranganath and Veenakumari (1995, 1999) recorded its severe incidence in *Syzygium* spp. in Andamans**;** List of host plants: *Alangium griffithii* (Alangiaceae), *Bouea oppositifolia Mangifera indica* (Anacardiaceae), *Annona montana, Annona muricata, Rollinia pulchrinervis*, *Uvaria grandiflora* (Annonaceae), *Thevetia peruviana* (Apocyanaceae), *Argena pinnata* (Arecaceae), *Garcinia atroviridis, Garcinia cowa,* *Garcinia griffithii, Garcinia mangostana* (Clusiaceae), *Terminalia catappa, Terminalia catappa, Terminalia manii, Terminalia procera* (Combretaceae), *Baccaurea motleyana, Drypetes longifolia* (Euphorbiaceae), *Persea americana* (Lauraceae), *Fagraea ceilanica* (Loganiaceae), *Aglaia dookoo, Lansium domesticum, Sandoricum koetjape* (Meliaceae), *Artocarpus altilis, Artocarpus comeziana, Artocarpus elastia, Artocarpus heterophyllus, Artocarpus integer, Artocarpus lakoocha, Artocarpus odoratissimus, Artocarpus rigidus* var. *asperulus, Ficus grossularioides, Ficus hispida, Pouroma paefolia* (Moraceae), *Knema angustifolia* (Myristaceae), *Eugenia uniflora, Psidium cattleianum, Psidium guajava, Rhodomyrtus tomentosa, Syzygium aqueum, Syzygium grande, Syzygium jambos, Syzygium malaccense, Syzygium samarangense* (Myrtaceae), *Ochanostachys amentosa* (Olacaceae), *Averrhoa bilimbi, Averrhoa carambola* (Oxalidaceae), *Xanthophyllum amoenum* (Polygalaceae), *Punica grandum* (Punicaceae), *Ziziphus jujuba* (Rhamnaceae), *Pellacalyx saccardianus, Rhizophora* sp. (Rhizophoraceae), *Citrofortunella mitis, Citrus aurantifolia, Citrus limon, Citrus madurensis, Citrus paradisi, Citrus reticulata, Fortunella margarita, Fortunella polyandia, Paramignya andamanica, Tetractomia majus, Triphasia trifoloia* (Rutaceae), *Lepisanthes alata* (Sapindaceae), *Chrysophyllum cainito, Manilkara littoralis, Manilkara zapota, Mimusops elengi, Planchonella longipetiolatum, Pouteria campechiana* (Sapotaceae), *Irvingia malayana* (Simaroubaceae), *Capsicum annum, Lycopersicon esculentum, Solanum ferox* (Solanaceae), *Symplocos cochinchinensis* (Symplocaceae) (Allwood *et al.*, 1999)

Distribution: Peninsular Malaysia, Malaysia, Indonesia, Singapore, Thailand, Borneo, India (Andaman Islands); French Guiana, Surinam, Vietnam (Drew & Hancock, 1994; Drew and Romig, 2016), Bangladesh (Leblanc *et al.*, 2019). It was originally described from Malaysia in 1994 by Drew and Hancock. Ranganath and Veenakumari (1995, 1999) reported the occurrence of *B. carambolae* in Andaman Islands, India. Hence this pest cannot be considered as an invasive species to India, as it has been already reported from Andaman Islands. Even though it has been recorded from Andaman Islands, so far, no *B. carambolae* were encountered in mainland India.

Guava fruit fly: *Bactrocera (Bactrocera) correcta* (Bezzi)

Diagnosis: Adults are medium-sized with scutum black in colour with broad lateral vittae (>0.15 mm). Wing with a costal band discontinuous beyond vein R_1, sometimes faint with a narrow apical spot. Abdomen reddish brown with a prominent T shaped mark. This species is characterized by the presence of facial spots coalescing to form a transverse line (White and Elson-Harris, 1992, Ramani, 1997).

Attractant: Methyl Eugenol

Host plants

Carrisa carandas L.,*Casimiroa edulis* Llave & Lex, *Eugenia uniflora* L., *Mangifera indica* L , *Malphigia glabra* L., *Prunus armeniaca* L. *Santalum album* L., *Vitis vinifera* L., *Zizyphus mauritiana* Lam. (Kapoor,1993; Ramani, 1997).

Distribution: Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu (Bhat, 1989; Agarwal & Sueyoshi, 2005).

Peach fruit fly: *Bactrocera (Bactrocera) zonata* (Saunders)

Diagnosis: Pale orange brown to red species with lateral postsutural yellow vittae on scutum, circular to oval facial spots, anterior supra-alar setae, prescutellar setae, 2 scutellar setae present. Wing with discontinuous costal band to form a spot apically. Abdomen reddish brown with pecten on third tergum of males (Ramani, 1997; White and Elson-Harris, 1992)

Attractant: Methyl Eugenol

Host plants: *Aegle marmelos* (L.) Corr. Serr., *Anona squamosa* L.,*Careya arborea* Roxb., *Casimiroa edulis* Llave & Lex, *Citrus aurantium* L., *C.grandis* Osbeck., *C.limon* (L.) Burman f., *C.medica* L., *C.nobilis* Lours, *C.reticulata* Blanco., *C.sinensis* (L.), *Cucumis melo* L., *Diospyros blancoi* A.DC, *Ficus carica* L., *Lagenaria siceraria* (Mol.) Standl., *Luffa acutangula*L(Roxb.), *Luffa aegyptica* Mill., *Lycopersicum esculentum*(L.) Karst., *Malphigia glabra* L., *Mangifera indica* L. , *Prunus persica* (L.) Batsch., *Psidium guajava* L., *Punica granatum* L. , *Pyrus communis* L., *Solanum melongena* L., *Syzigium cumini* (L.) Skeels., *S. jambos* (L.) Alston., *Terminalia catappa* L., *Zizyphus mauritiana* Lamk.(Kapoor, 1993; Ramani, 1997).

Distribution: Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Punjab, Karnataka, Kerala, Madhya Pradesh, Maharashtra , Tamil Nadu, Uttaranchal, Uttar Pradesh, West Bengal (Agarwal & Sueyoshi, 2005).

Zeugodacus (Hemigymnodacus) diversus Coquillett

Morphology: Adult: Small to medium sized fly, with greenish black body with both lateral and medial vittae on the thorax. Wings with costal band confluent with R_{2+3}. Males lack pecten on 3rd abdominal tergite. Sexual dimorphism is seen in this species. Face of male entirely yellow, without facial spots, face of female with a transverse black line above the mouth opening (Ramani, 1997; White and Elson-Harris, 1992).

Attractant: Methyl Eugenol

Host plants: *Benincasa hispida* (Thunb.) Cogn., *Luffa aegyptica* Mill. , *Citrus aurantium* L., *C.grandis* Osbeck., *Coccinia grandis* L. Voigt., *Cucurbita maxima* Duch. , *Cucurbita pepo* L.,*Lageneria siceraria*(Mol.) Standl.,*Musa paradisica* L., *Psidium guajava* L., *Syzygium cumini*(L.) Skeels.,*S.malaccense* (L.) Merr. & Perr., *Solanum erianthum* D.Don., *Mangifera indica* L., *Myristica beddomei* King, *M.fragrans* Houtt., *Citrus aurantium* L. (Kapoor,1993)

Distribution: Andhra Pradesh, Bihar, Himachal Pradesh, Karnataka Maharashtra, Meghalaya, Punjab,Tamil Nadu, Uttaranchal, Uttar Pradesh, West Bengal (Bhat, 1989; Agarwal & Sueyoshi, 2005).

Nature of damage: The female flies lay eggs at the base of the flower and flower buds, nearer to the ovary. In opened flowers, the flies may lay eggs directly into the ovary. The larvae on hatching feed on the reproductive organs of flower. The affected flowers become unfit for pollination or fruit setting and subsequently drop off and rot (Gavigowda, 1976).

Melon fly: *Zeugodacus (Zeugodacus) cucurbitae* (Coquillett)

Diagnosis: A predominantly orange-brown species with separate black spots on fulvous face. Scutum with yellow medial and lateral postsutural vittae, wing is characterized by the presence of broad costal band expanded into an apical spot, with radial medial band and subapical band.

Attractant: Cuelure

Host plants

It is a highly polyphagous pest with wide host range. *Benincasa hispida* (Thunb.) Cogn., *Capsicum fruitescens* L., *Careya arborea* Roxb., *Coccinia grandis* L. Voigt,*Cucumis melo* L., *C. sativus* L., *Momordica charantia* L.,*Momordica dioica* Roxb.ex Wild, *Mukia maderaspatana* (L.) M. Roem., *Trichosanthes cucumerina* L., *T.dioica* (L.), *Luffa* spp, *Citrus* spp, *Psidium guajava* L., *Carica papaya* L. (Kapoor,1993; Ramani, 1997) are list of few host plants infested by *Z. cucurbitae*.

Distribution: Widespread in India (Agarwal & Sueyoshi, 2005).

Biology and ecology

The adult female inserts their eggs singly or in clusters of 4-10 beneath the skin of suitable hosts, especially in tender vegetables. Incubation period ranges from 27-28 hours during August and 31-38 hours during May (Back & Pemberton, 1914). Narayanan and Batra (1960) reported 24 hours and 6-9 days as duration of eggs in summer and winter, respectively. There are three larval instars, which span for 1.2, 1.58 and 2.25 days respectively and the total larval duration is 5-6 days at mean temperature of 25.72^{0}C. However, the larval duration varies with the host plant and season. Puparium is formed out of the third larval skin; pupation takes place in soil and the pupal period ranges from 8 to 10 days. Adult life may vary based upon the nutrition, if given water only, life is prolonged to 3 days, with sucrose, the flies survived for 17 days, with sucrose and water, up to 32 days (Gavigowda, 1976).

***Dacus* (*Didacus*) *ciliatus* Loew**

Integrated pest management

Fruit flies, specifically *Bactrocera* spp and *Zeugodacus cucurbitae*, pose significant threats to various fruit crops such as mango, guava, custard apple, dragon fruit, sapota, and others. *Zeugodacus cucurbitae* is particularly problematic for cucurbitaceous crops and tomatoes. Effective management strategies for fruit flies, particularly *Bactrocera* spp. and *Zeugodacus cucurbitae*, involve an integrated approach combining several methods. Key strategies include field sanitation to remove infested fruits and reduce breeding sites, and the use of protein bait sprays and pheromone traps (e.g., methyl eugenol for *Bactrocera* spp. and cue-lure for *Z. cucurbitae*) to attract and kill adult flies (Sivinski *et al.*, 2018). Additionally, bagging fruits can physically prevent oviposition, while early harvesting can reduce the window of vulnerability.

Verghese and Rashmi 2022 Evaluated the potential of Plant Health Clinics (PHCs) as a model for disseminating biocontrol products to farmers. The study finds that PHCs can effectively bridge the gap between research and practice, facilitating the adoption of biocontrol methods and enhancing pest management in horticultural crops.

Plant Health Clinics (PHCs) are pivotal in the implementation of Integrated Pest Management (IPM) strategies, especially in horticultural crops. Here's how they contribute:

- **Diagnosis and advisory services**: PHCs provide accurate diagnosis of pest and disease problems in crops. By identifying the specific pests or pathogens affecting the plants, they can recommend targeted and effective IPM strategies. This helps in reducing the indiscriminate use of pesticides and promotes the use of environmentally friendly control methods.

- **Promotion of biocontrol products**: PHCs play a crucial role in promoting the use of biocontrol agents and products. They educate farmers about the benefits of using natural predators, parasitoids, and microbial pesticides, which are integral components of IPM. This not only helps in managing pest populations sustainably but also reduces the reliance on chemical pesticides.
- **Training and capacity building**: PHCs conduct regular training programs and workshops for farmers, extension workers, and other stakeholders. These programs focus on the principles and practices of IPM, including the use of cultural, biological, and mechanical control methods. By building the capacity of farmers, PHCs ensure that IPM practices are effectively implemented at the field level.
- **Monitoring and surveillance**: PHCs are involved in the regular monitoring and surveillance of pest populations. They collect data on pest incidence and severity, which helps in predicting pest outbreaks and implementing timely control measures. This proactive approach is essential for the success of IPM programs.
- **Extension and Outreach**: PHCs serve as a bridge between research institutions and farmers. They disseminate the latest research findings and IPM technologies to the farming community. This ensures that farmers have access to up-to-date information and can adopt the best practices for pest management.
- **Customized Solutions**: PHCs provide customized pest management solutions based on the specific needs and conditions of individual farms. This personalized approach ensures that IPM strategies are tailored to the local agro-ecological conditions, making them more effective and sustainable (Verghese *et al*., 2021).

In summary, Plant Health Clinics are instrumental in promoting sustainable pest management practices through the implementation of IPM. They provide essential services that help farmers manage pests effectively while minimizing the environmental impact and ensuring food safety (Verghese and Rashmi, 2022).

Integrated Pest Management Strategies

Integrated Pest Management (IPM) strategies are crucial for managing fruit flies, particularly *Bactrocera* spp. and *Zeugodacus cucurbitae*. These strategies include cultural practices such as field sanitation, which involves removing infested fruits to reduce breeding sites. Protein bait sprays and pheromone traps, such as methyl eugenol for *Bactrocera* spp. and cue-lure for *Z. cucurbitae*, are effective in attracting and killing adult flies (Vargas *et al*., 2015). Additionally, bagging fruits and early harvesting can prevent oviposition and reduce the window of vulnerability (Dhillon *et al*., 2005).

Biological control

Biological control agents play a significant role in managing fruit fly populations. Parasitoids and entomopathogenic fungi are commonly used to target various life stages of the flies. For instance, augmentative releases of parasitoids like *Fopius arisanus* have shown promising results in controlling *Bactrocera* spp. (Sivinski *et al*., 2018). The use of entomopathogenic fungi, such as *Metarhizium anisopliae*, has also been effective in reducing fruit fly populations (Nair *et al*., 2022).

Chemical control

Chemical control methods, including the use of selective insecticides, are often integrated with other management strategies to enhance effectiveness. Reduced-risk insecticides, such as Spinosad and neem-based products, are preferred due to their lower environmental impact and safety for non-target organisms (Dhillon *et al*., 2005). These insecticides can be used in bait sprays or as part of a broader IPM program to manage fruit fly populations effectively (Verghese *et al*., 2002).

Host plant resistance

The development and use of resistant cultivars is another important strategy in managing fruit flies. Resistant cultivars can significantly reduce the incidence of fruit fly infestations. Research has shown that certain cultivars of cucurbits exhibit resistance to *Z. cucurbitae*, thereby reducing the need for chemical interventions (Nair *et al*., 2022). This approach not only helps in managing fruit fly populations but also promotes sustainable agricultural practices.

Phytophagous insects use chemical cues emanating from plants to orient to their food hosts while plants ward off herbivory again through use of chemicals. This interplay between chemicals is an interesting area of chemical ecology. Secondary metabolites that occur constituently in plants act as chemical barriers to insects and many protect plants against attack by a wide range of potential pests (Verghese *et al*., 2012)

The changing cycles of tannin according to varieties and time is an index of infestation of fruits. The defensive mechanism exhibited by the tannins in resistant varieties is evident from the results and confirmed through regression. The signal start by Langra and EC 95862 via., tannins may therefore deter females from ovipositing. If commercial varieties like Alphonso and Banganpalli have to be made resistant to fruit flies the peels need to be augmented with tannins with modern breeding tools or gene transfers. From the knowledge of the present studies, semiochemical lures, attractants and repellents can be developed for tephritids and future research should not only continue the mix of basic and applied research on fruit flies but also explore multimodal communication systems such as sound, vision and gustation in order to improve the application of chemical ecology to solve real-world pest problems (Rashmi *et al*., 2020).

A push-pull strategy for the management of the Oriental fruit fly, *Bactrocera dorsalis (*Hendel) in mango explores the effectiveness of a push-pull strategy in managing *Bactrocera dorsalis*. The study shows that combining repellent plants (push) with attractant-baited traps (pull) significantly reduces fruit fly infestations in mango orchards, offering an environmentally friendly and sustainable pest management approach (Verghese *et al*., 2020).

The effectiveness of a push-pull strategy to manage the Oriental fruit fly, *Bactrocera dorsalis*, in mango orchards. The push component involves the application of azadirachtin, a neem-based pesticide, on mango trees during the fruiting stage to repel female fruit flies. The pull component uses methyl eugenol traps to attract and capture male fruit flies. The combined approach significantly reduces fruit fly infestations, offering an environmentally friendly and sustainable pest management solution (Verghese *et al*., 2020).

Sterile Insect Technique (SIT)

The Sterile Insect Technique (SIT) is a widely used method in wide-area management programs. This technique involves the mass-rearing and sterilization of male fruit flies, which are then released into the wild. When these sterile males mate with wild females, no offspring are produced, leading to a gradual reduction in the fruit fly population. The SIT has been successfully implemented in various regions, including Hawaii and the Mediterranean, to control *Bactrocera* spp. populations (Vargas *et al*., 2015; Dhillon *et al*., 2005). The Sterile Insect Technique (SIT) is an effective, species specific and environment friendly approach to achieve area-wide management of insect pests and has been successfully applied against several species of fruit flies like *Ceratitis capitata* Wied, *Anastrepha ludens* Loew and *Bactrocera* spp. in different countries. It involves releasing a large number of specially reared and sterilized male insects into the target area where they mate with wild females of same species resulting in failure of off-spring production thus gradually bringing down the pest population.

The SIT was conceived by Knipling in 1955 and was used to successfully eradicate the NewWorld Screwworm, *Cochliomyia hominivorax* Coquerel, a cattle pest, from North and Central America. This can be used in a wide range of situations either for prevention of establishment of new pests or to suppress or eradicate the existing pests. Use of SIT resulted in an enormous growth in the export of fresh fruits and vegetables in Mexico, Chile, South Africa, USA etc. (Rami Reddy and Rashmi, 2016).

Area-Wide Integrated Pest Management (AW-IPM)

Area-Wide Integrated Pest Management (AW-IPM) programs combine multiple control strategies over large geographic areas to manage fruit fly populations effectively. These programs often include the use of SIT, biological control agents, bait sprays, and cultural practices. For example, the Hawaii Area-Wide IPM program (HAWPM) integrated these methods over a 10-year period, significantly reducing fruit fly populations and damage (Vargas *et al*., 2015). Similarly, the Regional Fruit Fly Project in the Pacific targeted *Bactrocera* fruit flies in Pacific Island Countries and Territories, demonstrating the effectiveness of AW-IPM strategies (Vargas *et al*., 2015).

The localized eradication of the mango stone weevil, *Sternochetus mangiferae*, a significant pest in mango production by implementation of targeted control measures, following IPM including the use of strategic pesticide applications, to effectively reduce weevil populations in specific regions. The results demonstrated that these localized interventions significantly mitigated weevil infestations, thereby protecting mango yields and improving fruit quality. The findings underscored the importance of adopting precise and region-specific pest management strategies to enhance the sustainability and productivity of mango orchards in India (Verghese *et al.,* 2023).

Use of entomopathogenic fungi

Entomopathogenic fungi, such as *Metarhizium anisopliae* and *Beauveria bassiana*, have been explored as biological control agents in wide-area management programs. These fungi infect and kill fruit flies, providing a natural and environmentally friendly control method. Studies have shown that these fungi can be effectively integrated into AW-IPM programs to suppress fruit fly populations (Gutiérrez, 2010).

Geographical Information Systems (GIS)

Geographical Information Systems (GIS) are increasingly being used in wide-area management programs to monitor and manage fruit fly populations. GIS technology allows for the mapping and analysis of fruit fly distribution and population dynamics, enabling more targeted and efficient control measures. This technology has been particularly useful in large-scale eradication programs, such as those implemented in Australia and the United States (Dhillon *et al.*, 2005).

Previously, the Indian Institute of Horticultural Research (IIHR) in Bangalore developed cost-effective integrated pest management (IPM) strategies (Verghese *et al.*, 2002). However, there is now an urgent need to phase out traps using insecticide-laced plywood or other substrates due to concerns about high residuals, environmental pollution, and impacts on non-target organisms, especially ants. The strategy of male annihilation for fruit flies is no longer effective in most fruit ecosystems, debunking the myth that "more flies in traps mean more control." This approach remains somewhat valid in vegetable ecosystems where fruit fly densities are typically low. Parapheromone lures should be reserved for fruit fly surveillance and diversity assessment, as sticky traps are unsuitable for identification in diversity studies. Young males do not respond well to Methyl eugenol (ME) combined with insecticides, making male annihilation unsatisfactory. Frank Milburn Howlett (1877-1920): Discoverer of the pied piper's lure for the fruit flies (Tephritidae: Diptera)" by Verghese *et al.* (2013) provides a historical account of Frank Milburn Howlett's groundbreaking discovery of methyl eugenol as an attractant for male tephritid fruit flies.

The IPM of fruit flies has been significantly improved by Rashvee International Phytosanitary and Research Services (RIPRS), recognized by the Government of India and DPPQ. Under a BIRAC, DBT program, an insecticide-free liquid lure fruit fly trap, ovipositional deterrence spray, and phagostimulant baits were developed. These innovations align with updated export protocols and Good Agricultural Practices. The key components of Integrated Fruit Fly Management are as follows:

Sanitation: Collect fallen fruits into small manure pits (3ft x 3ft x 3ft), wet them, and close the pits after harvest. This practice, recommended at one pit per tree, attracts older females and prevents pupation and subsequent adult emergence by collecting infested fruits with maggots.

Non-insecticidal liquid lure: Introduce a climate-resilient, anti-evaporant liquid lure (Rashvee fruit fly liquid lure) instead of plywood or other substrate traps. Use 5ml of the lure per 100ml of water in disposable water bottles. These traps, designed to withstand high wind, rainfall, and temperature, should be used at a minimum of 8-10 traps per acre for mango and 15 traps per acre for cucurbits. For fruit crops, use the Rashvee fruit fly liquid ME lure. Fasten traps on lower branches, between 2 meters in height, at least marble-sized fruits, or 30 days prior to harvest.

Trap superiority: The liquid traps have been found superior to commercial traps in attracting diverse species of fruit flies, as studied by ICAR-NBAIR.

Placement geometry: Follow the RIPRS placement geometry for optimal results.

Female fruit fly deterrence: Based on trap surveillance data, further control can be achieved by applying 2-3 pre-harvest sprays of 1ml Azadirachtin 10000 ppm synergized with 1ml Rashvee Herbal Liquid Soap as an adjuvant, 30 days prior to harvest, to deter oviposition.

High trap catches: If trap catches are high (15 per day), a single spray of 0.37 ml/litre Spinosad 20 days prior to harvest is recommended.

Phagostimulant Bait: Rashvee Phagostimulant Bait, splashed at the base of the tree, attracts and kills both male and female fruit flies.

Bait preparation: Prepare the bait by mixing 20 litres of water with 1 kg of phagostimulant bait, leaving it overnight covered. The next day, add 40 ml of Decamethrin, stir well, and splash it at the base of the tree using an old brush. This can be done 10 days before harvest and repeated 5 days before harvest.

Post-harvest technology encompasses a range of techniques and practices aimed at preserving the quality and extending the shelf life of agricultural products from the moment of harvest until they reach the consumer. It plays a crucial role in reducing food loss, ensuring food security, and enhancing the economic value of crops by maintaining their quality and safety.

Key methods include Hot Water Treatment (HWT), where mangoes are immersed in hot water to kill pests without damaging the fruit, and Vapor Heat Treatment (VHT), which uses hot, humid air to achieve similar results. Cold Treatment involves storing mangoes at low temperatures to control pests and extend shelf life. Irradiation exposes mangoes to ionizing radiation to sterilize pests, ensuring the fruit meets international quarantine standards. Edible Coatings, such as chitosan or aloe vera, form a protective barrier on the fruit, reducing moisture loss and delaying ripening. Modified Atmosphere Packaging (MAP) alters the atmospheric composition around the fruit to slow down respiration and ripening processes. These technologies are crucial for maintaining the quality, safety, and marketability of mangoes, ensuring they meet both domestic and international standards (Verghese & Rashmi, 2014).

References

Agarwal, M. L. and M. Sueyoshi (2005). Catalogue of Indian fruit flies (Diptera: Tephritidae). *Oriental Insects* **39**: 371–433.

Allwood, A. J., Chinajariyawong, A., Drew, R. A. I., Hamacek, E. L., Hancock, D. L., Hengasawad, C., Jipanin, J. C., Jirasurat, M., Kong Krong, C., Kritsaneepaaiboon, S., Leong, C. T. S. and Vijaysegaran, S., 1999, Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *Raffles Bulletin of Zoology Supplement* **7**: 1–92.

Back, E. A. and Pemberton, C.E (1914). Life history of the melon fly. *Journal of Agricultural Research* **3**: 269-74.

Bhat, G.U (1989). Faunistic and some ecological studies on Fruit flies (Diptera: Tephritidae) of Bangalore and Kodagu districts. M.Sc Thesis, University of Agricultural Sciences, Bangalore, pp. 117.

Bhumannavar, B. S., S. Ramani., S. K. Rajeswari., *et al* (2007). Field release and impact of *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) on *Chromolaena odorata*. *Journal of Biological Control* **21**(1): 59–64.

Bhumannavar, B.S., S. Ramani., S. K. Rajeswari., *et al* (2004). Host specificity and biology of Cecidochares connexa (Macquart) (Diptera: Tephritidae) introduced into India for the biological suppression of *Chromolaena odorata* (Linnaeus) King & Robinson. *Journal of Biological Control* **18**(2): 111-20.

David, K. J. and D. L. Hancock (2013). The first record of *Ortalotrypeta isshikii* (Matsumura) and subfamily Tachiniscinae (Diptera: Tephritidae) from India, with re-description of the species. *Australian Entomologist*, 40 (3): 131–35.

David, K. J. and S. Ramani (2011). An illustrated key to fruit flies (Diptera: Tephritidae) from Peninsular India and the Andaman and Nicobar Islands. *Zootaxa*, 3021: 1–31.

David, K. J., D. L. Hancock. and S. Ramani (2014). Two new species of *Acroceratitis* Hendel (Diptera: Tephritidae) and an updated key for the species from India. *Zootaxa*, **3895** (3): 411–18.

David, K. J., D. L. Hancock., S. K. Singh., *et al* (2017). New species, new records and updated subgeneric key of *Bactrocera* Macquart (Diptera: Tephritidae: Dacinae: Dacini) from India. *Zootaxa*, **4272** (3): 386–400.

David, K.J (2005). Diversity and abundance of fruit flies (Diptera: Tephritidae: Dacinae) in Kerala with special reference to Western Ghats, *M Sc. Agri Thesis* submitted to University of Agricultural Sciences, Bangalore.

David, K.J. and Hancock, D.L (2013). The first record of *Ortalotrypeta isshikii* (Matsumara) and sub family Tachinscinae (Diptera: Tephritidae) from India, with redescription of the species. *Australian Entomologist* **40** (3): 131-35.

David, K.J. and Hancock, D.L (2017). A new species of *Gastrozona* Bezzi (Diptera: Tephritidae: Dacinae: Gastrozonini) with an updated key to species from India. *Zootaxa*, **4216** (1)**:** 55–64.

David, K.J., Hancock, D.L., Singh, S.K., Ramani, S., Behere, G. & Salini, S (2017). New species, new records and updated subgeneric key of *Bactrocera* Macquart (Diptera: Tephritidae: Dacinae: Dacini) from India. *Zootaxa*, **4272** (3): 386–400.

De, Meyer, M (2006). Systematic revision of the fruit fly genus *Carpophthoromyia* Austen (Diptera, Tephritidae). *Zootaxa*, **1235**: 1–48.

Dohm, P., D. Kovac., A. Freidberg., *et al* (2014). Basic biology and host use patterns of Tephritid flies (Phytalmiinae: Acanthonevrini, Dacinae: Gastrozonini) breeding in Bamboo (Poaceae: Bambusoidea). *Annals of Entomological Society of America* **107**(1): 184–203.

Doorenweerd, C., L. Leblanc., A. L. Norrbom., *et al* (2018). A global checklist of the 932 fruit fly species in the tribe Dacini (Diptera: Tephritidae). *Zookeys* **730**: 17–54.

Freidberg, A (2006). Biotaxonomy of Tephritoidea. Israel *Journal of Entomology* **35**–36: 1–597.

Gavigowda (1976). Studies on fruit flies infesting cucurbits with special reference to bionomics of *Dacus cucurbitae* Coquillett (Diptera: Tephritidae) and possibility of utilizing susceptible musk melon in protecting cucurbits from its attack, *M Sc. Agri Thesis* submitted to University of Agricultural Sciences, Bangalore.

Hancock, D. L. and R. A. I. Drew (1994). New species and records of Asian Trypetinae (Diptera: Tephritidae). *Raffles Bulletin of Zoology* **42**: 555–91.

Hardy, D. E (1973). The fruit flies (Tephritidae: Diptera) of Thailand and bordering countries. *Pacific Insects Monograph* **31**: 1–353.

Hardy, D. E (1974). The fruit flies of the Philippines (Diptera-Tephritidae). *Pacific Insects Monograph* **32**: 1–266.

Hardy, D. E (1986). Fruit flies of the subtribe Acanthonevrina of Indonesia, New Guinea and the Bismarck and Solomon Islands (Diptera: Tephritidae: Trypetinae: Acanthronevrini). *Pacific Insects Monograph*, **42**: 1–42.

Hardy, D. E. and R. A. I. Drew (1996). Revision of the Australian Tephritini (Diptera: Tephritidae). *Invertebrate Taxonomy* **10**: 213–405.

Hill, G. F (1921). Notes on some Diptera found in association with termites. *Proceedings of Linnaean Society of New South Wales* **46**: 216–20.

Kapoor, V. C., D. E. Hardy., M. L. Agarwal., *et al* (1980). Fruit fly (Diptera: Tephritidae) Systematics of the Indian Subcontinent. Jalandhar, India: Export India Publications.

Kapoor, V.C (1993) Indian Fruit Flies (Insecta: Diptera: Tephritidae). International Science Publisher, New York, pp. 228.

Kopelke, J. P (1984). Der erste Nachweis eines Brutparasiten unter den Bohrfliegen. *Nat. Mus. Frankfurt* **114**: 1–28.

Korneyev, V. A (1999). Phylogenetic relationships among higher groups of Tephritidae. In Fruit flies (Tephritidae): Phylogeny and Evolution of Behavior. M. Aluja and A. L. Norrbom (Eds), pp. 73–113. Boca Raton, FL: CRC Press.

Kovac, D., P. Dohm., A. Freidberg., *et al* (2006). Catalog and revised classification of the Gastrozonini (Diptera: Tephritidae: Dacinae). *In-Biotaxonomy of Tephritoidea*. A. Freidberg (Ed), Jerusalem, Israel: Entomological Society of Israel, pp. 163–196.

Leblanc, L., Hossain, M. A., Doorenweerd, C., Khan, S. A., Momen, M., San Jose, M. and Rubinoff, D. 2019. Six years of fruit fly surveys in Bangladesh: a new species, 33 new country records and discovery of the highly invasive Bactrocera carambolae (Diptera: Tephroitidae). *Zookeys* **876**: 87–109.

Madhura, H. S., and Verghese, A. (2004). A guide to identification of some common fruit flies (Bactrocera spp.) (Diptera: Tephritidae: Dacinae). *Pest Management in Horticultural* Ecosystems **10**(1).

Munro, H. K (1967). Fruit flies allied to species of Afrocneros and Ocnerioxa that infest Cussonia, the umbrella tree or kiepersol (Araliaceae) (Diptera: Trypetidae). *Annals of the Natal Museum* **18**: 571–94.

Narayanan, E.S. and Batra, H.N (1960). *Fruit flies and their control- A monograph,* I.C.A.R. New Delhi, pp. 66.

Norrbom A. L., L. E. Carroll., F. C. Thompson., *et al* (1999). Systematic database of names. In Fruit Fly Expert Identification System and Systematic Information Database, ed. F. C. Thompson, Leiden, the Netherlands: Backhuys publishers, pp. 65–251.

Norrbom, A. L (2004). Fruit fly (Diptera: Tephritidae) classification & diversity. Fruit fly taxonomy pages. http:// www. sel.barc.usda.gov/diptera/tephriti/TephClas.htm (Accessed January 2010.)

Norrbom, A. L. and Condon, M. A (1999). Phylogeny of the Subfamily Blepharoneurinae Pp 135-154, In Aluja, M. and Norrbom, A.L. (eds), Fruit flies (Tephritidae): Phylogeny and evolution of behavior. CRC Press, Boca Raton, pp. xviii+ 944.

Norrbom, A.L., Carroll, L.E., Thompson, F.C., White, I.M. and Freidberg, A (1999). Systematic Database of Names. In: Thompson FC (Ed.) Fruit fly expert identification system and systematic information database. Myia, 9: 65–251.

Permkam, S. and D. L. Hancock (1995). Australian Trypetinae (Diptera: Tephritidae). *Invertebrate Taxonomy* **9**: 1047–1209.

Ramani, S (1997). Biosystematic studies on fruit flies (Diptera: Tephritidae) with special reference to the fauna of Karnataka and Andaman and Nicobar. *Ph.D. Thesis*, University of Agricultural Sciences, Bangalore.

Ramani, S (2004). Classical biological control attempts in India. In Quarantine Procedures and Facilities for Biological Control Agents, eds. S. Ramani, B. S. Bhumannavar, and R. J. Rabindra, Bangalore, India: Project Directorate of Biological Control, pp. 17–22.

Ranganath, H. R. and Veenakumari, K. 1995. Notes on the dacine fruit flies (Diptera: Tephritidae) of Andaman and Nicobar islands. *Raffles Bulletin of Zoology* **43**(1): 235–38.

Ranganath, H. R. and Veenakumari, K. 1999. Notes on the dacine fruit flies (Diptera: Tephritidae) of Andaman and Nicobar islands-II. *Raffles Bulletin of Zoology* **47**(1): 221–24.

Rashmi M. A., Abraham Verghese, Shivashankar S., Rami Reddy, P. V. and Subhash Kandakoor (2020). Chemical defense and herbivory: A case study of phenolics versus Bactrocera dorsalis (Hendel) infestation in mango. *Pest Management in Horticultural Ecosystems* **26**: 121-28.

Rashmi M. A**,** Abraham Verghese, P.D. Kamala Jayanthi, A.K. Chakravarthy, Arathi Kirubha And Subhash B. Kandakoor, 2020. Effect of climate change on biology of oriental fruit fly, *Bactrocera dorsalis* hendel (Diptera: Tephritidae). *Journal of Entomology and Zoology Studies* **8**(3): 935-40.

Rashmi M. A., Abraham Verghese, P. D. Kamala Jayanthi, A. K. Chakravarthy, Arathi Kirubha, and Subhash B. Kandakoor (2016). Molecular diversity of Oriental fruit fly, Bactrocera dorsalis Hendel (Diptera: Tephritidae) in Karnataka. *Pest Management in Horticultural Ecosystems* **22**: 12-19.

Rami Reddy P. V. and Rashmi M. A**,** 2016. Sterile Insect Technique (SIT) as a component of area-wide integrated management of fruit flies: Status and scope, *Pest Management in Horticultural Ecosystems,* **22** 1-11.

Stonehouse, J. M., Verghese, A., Mumford, J. D., Thomas, J., Jiji, T., Faleiro, R. & Sardana, H. R (2005). Research conclusions and recommendations for the on–farm IPM of Tephritid fruit flies in India. *Pest Management in Horticultural Ecosystems* **11**(2): 172-80.

Vasuki, V. Belavadi (1979). Bionomics of the Oriental Fruit Fly, *Dacus dorsalis* Hendel (Diptera: Tephritidae) on guava (*Psidium guajava* L.) and its control by male annihilation, *M Sc. Agri. Thesis* submitted to University of Agricultural Sciences, Bangalore.

Verghese, A Rakshitha Mouly, T. N. Shivananda, C. B. Soumya and M.A. Rashmi., 2020. A push-pull strategy for the management of the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) in mango. *Pest Management in Horticultural Ecosystems* **26**(2):269-71.

Verghese, A., Madhura, H. S., Jayanthi, P. D. K and Stonehouse, J. M. 2002. Fruit flies of economic significance in India, with special reference to *Bactrocera dorsalis* (Hendel). *Proceedings of 6th International Fruit fly Symposium* held between 6 – 10 May 2002, Stellenbosch, South Africa. pp. 317 – 324.

Verghese, A., Sreedevi, K. and Nagaraju, D. K (2006). Pre and post harvest IPM for the mango fruit fly, *Bactrocera dorsalis* (Hendel). In: Proceedings of the 7th International Symposium on Fruit Flies of Economic Importance 10-15 September 2006, Salvador, Brazil, Pp.179-182.

Verghese, A., and Rashmi, M. A. 2014. Insect Disinfection and Quarantine, *In: Managing Post harvest Quality and Losses in Horticultural Crops* (Editors: K.L. Chadha, R.K. Pal), Daya Publishing House, Astral International Pvt. Ltd., pp.211 -30.

Verghese, A., Shivananda, T. S., Kamala Jayanthi, P. D., & Sreedevi, K. (2013). Frank Milburn Howlett (1877-1920): Discoverer of the pied piper's lure for the fruit flies (Tephritidae: Diptera). *Current Science* **105**(2), 260-262.

Verghese., A, Rashmi, M. A Nagaraj DK, and JP Singh, Localized eradication of mango stone weevil *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae) in India, *Current Science* **125**, NO. 7, 10 OCTOBER 2023.

Verghese.,A, Rashmi, M. A and Rakshitha Mouly, 2021 Customizing IPM in Horticulture (mango) for Food Security and Safety. Compendium of international conference on global perspectives in crop protection for food security (GPCP -2021) December 8-10, 2021.

Verghese.,A,, Rakshitha Mouly, T. N. Shivananda, C. B. Soumya, and M. A. Rashmi (2020). A push-pull strategy for the management of the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) in mango. *Pest Management in Horticultural Ecosystems* **26**(2): 269-71.

Verghese.,A, and M. A. Rashmi (2022). Plant Health Clinic (PHC) startups as a viable extension model for transfer of biocontrol products in horticultural crops. *Pest Management in Horticultural Ecosystems* **28**(2): 115-118.

Verghese, A., Soumya, C.B, Shivashankar, S. Manivannan, S. and Krishnamurthy S. V. 2012. Phenolics as chemical barriers to female fruit fly (*Bactrocera dorsalis)* in mango. *Current Science* **103**(5):563-66.

Wang, X.-J. and X.-L. Chen (2002). A revision of the genus *Gastrozona* Bezzi from China (Diptera: Tephritidae). *Acta Entomologica Sinica* **45**(4): 507–15.

Weems, H. V., Heppner, J. B. and Fasulo, T. R (2001). Melon fly, *Bactrocera cucurbitae* Coquillett (Insecta: Diptera: Tephritidae). Florida department of agriculture and consumer services division of plant industry, University of Florida Publication, EENY, Florida, pp. 199.

White, I. M. and Elson–Harris, M. M (1992). Fruit flies of economic significance: their identification and bionomics. CAB International, Wallingford, UK, pp. 601.

Current Horticulture **13**(1): 14–19, January–March 2025
DOI: 10.5958/2455-7560.2025.00002.4
Received: 09 June 2024; Accepted: 03 December 2024

Cost-effective and high-impact sustainable vegetable farming utilizing low tunnel technology: a review

Hare Krishna[1], S.K. Singh[1], Swati Sharma[1], Manjunatha T. Gowda[1], Rajeev Kumar[1], Shreya Panwar[1], Govind Pal[1], Anant Bahadur[1], Shubham K. Tiwari[1], Kuldeep Srivastava[1], V. Karuppaiah[2], A.K. Singh[3] and S.K. Maheshwari[4]

[1]*ICAR-Indian Institute of Vegetable Research, Shahanshahpur, Varanasi- 221305, Uttar Pradesh, India*

Abstract

The practice of low tunnel vegetable cultivation has emerged as a promising solution to address market fluctuations and enhance farmers' income by enabling off-season vegetable production. This method involves the use of miniature structures that mimic greenhouse conditions, providing protection and creating a favorable microclimate for vegetable crops. Low tunnels are constructed using locally available materials such as bamboo, wood, or metal bars covered with thin plastic sheets or nylon screens. These structures help conserve warmth, stimulate germination, and protect plants from adverse weather conditions, ultimately improving crop quality and yield. Plastic low tunnel technology, in particular, has proven to be a cost-effective method for cultivating various vegetable crops, including cucurbits, melons, and cole crops, in winter season. By advancing the cropping season by 30-60 days and facilitating early market entry of the produce, low tunnels offer significant advantages to farmers, enabling them to capitalize on off-season demand and command higher prices for their produce. Additionally, low tunnel cultivation minimizes pest incidences and reduces pesticide consumption, making it an environmentally sustainable option for vegetable production. Studies have demonstrated the versatility of low tunnel construction techniques and materials, with various covering materials and support structures tailored to specific crop requirements and environmental conditions. The economic viability of low tunnel vegetable cultivation is further supported by high net returns and favorable benefit: cost ratios recorded in comparative evaluations. Overall, low tunnel vegetable cultivation represents a promising technology for enhancing agricultural productivity, optimizing resource utilization, and improving farmer livelihoods, particularly in regions with extreme temperature regimes and fluctuating market conditions.

KEY WORDS: Off season, Farmers'-friendly, Mulching, Microclimate, Irrigation, Low tunnels, Vegetable pest incidences

Quite often, market witnesses glut of vegetables in the season, which leads to poor return to the growers (Pagaria and Swami, 2023). On the other hand, consumers are willing to pay high prices for vegetables in off-season. Vegetables can be cultivated in off-season, with the introduction of greenhouses technologies (Dodiya *et al.,* 2021), wherein temperature and humidity are modulated for desirable growth of vegetables (Singh *et al.*, 2007; Singh *et al.*, 2021). The production of vegetables round the year facilitates the growers to make the maximum use the resources and augment income from vegetable growing as compared to other agricultural crops (Singh and Kumarnag, 2023). One such cost-effective, farmers-friendly technology is 'low tunnel'.

***Corresponding author :** kishun@rediffmail.com

[2]ICAR-Directorate of Onion and Garlic Research, Pune 410 505 (Maharasthra)

[3]Central Horticultural Experiment Station (ICAR-CIAH), Godhra-Vadodara Highway, Vejalpur-389 340, Panchmahals (Gujarat)

[4]ICAR-Central Institute for Arid Horticulture, Beechwal, Bikaner-334 006 (Rajasthan)

Low tunnels are miniature structures producing greenhouse like effect. This type of structures cover rows of plants; therefore, they are also known as 'row cover' (Jayasurya *et al.*, 2021). Low tunnels are constructed with locally available material such as bamboo (Bhatt *et al.*, 2016) and wood or with GI wires, plastic or metal bars to form semi-circular frames, which are covered with thin plastic sheet (PE or PVC 30-50 μ) or with nylon screen (Kang *et al.*, 2013). The sides are secured down by placing them in soil or by side-to-side crisscrossing nylon rope anchored to the base of each pole; however, in the growing season, the sides are opened by lifting them up for improving ventilation or plastic is slit as the temperature increase within the tunnels (Jayasurya *et al.*, 2021).

Such structures are erected to provide temporary protection to crops and usually no higher than 1 m in height. In general, the height of the tunnel is kept at 45-60 cm with 45-60 cm width. Low tunnels are used to conserve warmth to stimulate germination and early growth of seedlings in winters, to protect the plants from frost injury, to improve the quality of the crops (Singh *et al.*, 2007), to provide protection from wind and rain damage in melon cultivation and in winter production (forcing production) of vegetables (Kang *et al.*, 2013). Further, low tunnel production of vegetables offers other advantages such as enhanced nutrients uptake and increased photosynthetic activities of plants owing to favourable micro-climate inside tunnel, crop diversification and making cultivation of vegetables possible in areas where it can't be grown in open field conditions (like high altitudes) (Yadav *et al.*, 2017). Low tunnels are extensively used for off-season production of muskmelon, summer squash, bottle gourd and bitter gourd for advancing cropping season by 30-60 days ahead to their normal season of cultivation.

These tunnels enable the entrapment of carbon dioxide; thereby, improving the photosynthetic activity of the plants, which ultimately leads to yield enhancement (Lodhi *et al.*, 2015). Apart from being inexpensive, they are easy to assemble, dismantle and reassembled for their use in subsequent seasons. This technology enables the growers to capture the market in the early season for getting good return from the sold produce. This technology is quite promising and profitable for the farmers of northern plains of India (Jayasurya *et al.*, 2021)

Material in low tunnels

Plastic low tunnel technology proves to be a straightforward and lucrative method for cultivating cucurbits during the winter season in the northern plains of our country. This technique enables the growth of crops such as summer squash as a complete off-season crop, while other cucurbits like muskmelon, round melon, bottle gourd, cucumber, bitter gourd, and watermelon can be advanced by 30-40 days compared to their normal growing season. Plastic low tunnels consist of flexible transparent coverings that are installed over single or multiple rows of vegetables. They serve to enhance plant growth by warming the air around the plants in open fields during the winter season when temperatures drop below 8°C. Supported by hoops made of GI wire, these low tunnels are covered with clear or transparent plastic measuring 20-30 microns, which is stretched over the hoops and secured at the sides by burying them in the soil.

During the growing season, the plastic is vented or slit open to regulate the temperature within the tunnels as it increases. Farmers can take advantage of this technology to cultivate various varieties of summer squash (both round and long-fruited types), which are emerging crops, alongside the cultivation of netted muskmelon varieties in place of traditional ones. Bitter gourd and round melon are two other crops with increasing demand that usually fetch high prices during the off-season, and they can be successfully grown using plastic low tunnel technology. This approach is highly suitable and profitable for farmers residing in the northern plains of India.

For making plastic low tunnel for bottle gourd cultivation, 60 cm width, 50 cm high and 50-micron transparent plastic were used by Kumar *et al.* (2018). Earlier, Bhatt *et al.* (2016) also employed bamboo sticks for constructing the low tunnels for summer squash production. Saleem *et al.* (2014) used locally and abundantly available willow sticks of 1.5 to 2 cm diameter for making the supporting structure of low tunnel under Kargil conditions. The tunnel was covered with ordinary transparent polythene (2.4 m wide). The low tunnels were constructed by applying the covering material over metal hoops. Clear perforated polythene (0.051 mm) was used to cover the melons, while spun-bound polyster was used on the pepper and tomatoes (Waterer, 2003). Verma *et al.* (2019) used two types of covering material i.e. biodegradable plastic sheet (25 micron) and non-woven cloth (25 gsm) for low tunnel production of long melon; however, polythene covering was found better in terms of yield and fruiting duration. Kapanen *et al.* (2008) assessed the performance of biodegradable starch-based low tunnel films, which had the lifetime of 6 months.

The radiometric properties of the biodegradable films influenced positively the microclimate: air temperature under the biodegradable low tunnel films was 2 ^{0}C higher than under the low-density polyethylene films, resulting in an up to 20% higher yield. The use of a low tunnel covered with organza fabric allowed greater commercial yield of the Kale cv. Hi-crop. Although it is not an agricultural material, the organza fabric resulted in higher productivity with greater production of total and commercial leaves during the rainy season (da Silva Ponce *et al.*, 2021). These studies demonstrate the versatility and adaptability of low tunnel construction techniques and materials, each tailored to specific crop requirements and environmental conditions, aiming to optimize yield and productivity.

Production technologies for low tunnel vegetable cultivation

Low tunnel vegetable cultivation is an effective method for extending the growing season, protecting crops from adverse weather conditions, and improving yield and quality. Indeed, mulching and low tunnels have proven to be one of the highly effective techniques in promoting early production, particularly in warm-season vegetable crops that are susceptible to low temperatures. By creating a microclimate that is warmer and more conducive to plant growth, both mulching and low tunnels provide protection from cold weather, thereby extending the growing season and accelerating plant development. These techniques not only enhance the yield and quality of crops but also contribute to more sustainable agricultural practices by reducing the need for chemical inputs and conserving water. Overall, the utilization of mulching and low tunnels represents valuable strategies for maximizing productivity and resilience in vegetable cultivation, especially in regions where temperature fluctuations pose challenges to crop production. Adamović *et al.* (2021) conducted a study focusing on the impact of mulching and low tunnels on the yield, yield components, and dry matter content of watermelon hybrids: 'New Fantasy F1', 'Celine F1', and 'Top Gun F1'.

Their findings revealed that the use of black PE mulch led to significantly higher yields across all three hybrids, with an average increase of 34.6% compared to the control treatment of bare soil. Moreover, the combination of mulching and low tunnels resulted in the highest average number of fruits per plant (4.7), which was notably greater than mulching alone (3.7) and the control without mulching (3.0). Interestingly, the control treatment without mulching exhibited the highest fruit weight, surpassing both mulching and low tunnel methods. Regarding dry matter content, the hybrid 'Top Gun F1' with mulching demonstrated the highest content at 11.5%, while the hybrid 'Celine F1' with mulching in a low tunnel displayed the lowest dry matter content at 9.6%. These results underscore the effectiveness of both mulching and low tunnels, particularly in enhancing early production and yield of warm-season vegetables like watermelon.

Niaz *et al.* (2009) cultivated three vegetables (tomato, cucumber, and bell pepper) in plastic tunnels as off-season crops to assess their comparative water use efficiency. Irrigation was administered using both drip and furrow irrigation systems. All three crops exhibited lower water consumption under drip irrigation compared to the furrow irrigation system. Drip irrigation yielded the highest water use efficiency for tomato (2.37), followed by cucumber (1.85) and bell pepper (1.22), contrasting with the performance under furrow irrigation. Additionally, apart from achieving high water use efficiency, the drip irrigation system also resulted in greater production compared to the furrow system across all vegetable crops. These findings suggest that vegetable crops require less irrigation water when utilizing the drip system compared to the furrow system, while also achieving higher water use efficiency and crop yields.

Therefore, the drip irrigation method emerges as the most economical choice for vegetable production in rainfed areas. In their study, Lodhi *et al.* (2024) explored the effects of low tunnel heights and various irrigation regimes on the growth parameters of Capsicum. They found that across the crop season, plant height, leaf area index, and dry matter accumulation were consistently highest in the 75 cm tunnel height treatment, followed by 90 cm and 60 cm tunnel heights. Regarding irrigation treatments, drip irrigation with a 0.90 Irrigation Water to Crop Pan Evaporation (IW/CPE) ratio resulted in the greatest plant height and leaf area index compared to other irrigation methods. Conversely, drip irrigation with a 0.75 IW/CPE ratio yielded the highest dry matter accumulation compared to alternative irrigation regimes.

Hastening of harvest season and net return

Plastic low tunnel force early flowering in off season (Kumar *et al.*, 2009). Under low tunnel cultivation, different cucurbits can be transplanted from first week of December to first week of February and can be advanced 30-60 days over their normal season of cultivation. Generally, cucurbits are harvested from 15 February onward (Kumar *et al.*, 2018). This is economical for growing off season vegetables in peri-urban area of the northern plains of the country. City dwellers are willing to purchase these high-priced vegetables; therefore, this technology is promising for improving the socio-economic status of farmers (Kumar *et al.*, 2009).

Among different dates of sowing, the maximum yield of 4.25 quintal per hectare was recorded when bottle gourd was sown on 30th December under low tunnel condition (Kumar *et al.*, 2018). Likewise, for bitter gourd as well 30th December was found to be the best date of sowing for raising crops under low tunnels (Kumar *et al.*, 2017). However, for muskmelon, the highest return per hectare was observed in low poly tunnel when crop was sown on 15th December under Bihar conditions. The prevalent time of sowing at farmer's field was 15th February (Ranjan *et al.*, 2019). Thereby, low tunnel cultivation advanced the growing of crop by around two months.

The success of low tunnel technology is not limited to the cultivation of off-season cucurbits in northern plains. Its potential has been realized for fetching early crops in regions with extremes of temperature regimes such as temperate and arid conditions. Saleem *et al.* (2014) reported that the low tunnel technology hastened the production of marketable seedling of cabbage as well as attainment of marketable heads from 53 to 45.6 days and 85.3 to 75.3 days, respectively under temperate conditions (Kargil, J&K). Higher net returns per unit area were realized under low tunnel cultivation of cabbage than open cultivation due to early maturity, early market entry of produce and evading market glut. Likewise, Verma *et al.* (2019) recorded an advancement of 24-50 days in long melons harvest, when sown on 20th December, as compared to normal season under western Rajasthan conditions. In similar study conducted by Ibarra *et al.* (2001), they observed that muskmelon crop grown under plastic cover flowered 24 days earlier than uncovered plants. The early growth of the crops under low tunnel could be attributed to microclimate created by low tunnels. Ogden and van Iersel (2009) have indicated that low tunnels modify climatic conditions, promoting earlier flowering and fruit ripening as well as fruit precocity production. Temperature within the structure can be regulated for optimum growth of plants. Similarly, higher relative humidity built inside reduces evaporation loss from plants, which lead to optimum utilization of nutrients. It also maintains turgidity of cells, which is useful in enzyme activity leading to a higher yield. Singh *et al.* (2009) investigated the off-season cultivation of five summer squash cultivars (Australian Green, Pusa Alankar, Goldy, C-135, and Adlika) under low plastic tunnels. Australian Green exhibited the shortest time to first harvesting (58.0 days) and the highest average fruit yield (5.80 kg per plant or 696.0 quintal/ha).

Later, Khan and Khan (2020) studied eighty-four farmers engaged in cultivating off-season vegetables using tunnel farming, as well as seasonal vegetables without the use of tunnels. A comparison was made between their respective productivities. The results indicated that the yield per acre was significantly greater when utilizing tunnels compared to traditional methods. Among the three vegetables examined—tomato, cucumber, and bottle gourd—all demonstrated increased revenue, with tomato yielding the highest returns. However, it's important to note that employing tunnel farming entails higher expenses due to the installation of structures and input costs.

Net income and cost benefit ratio is significantly influenced by off season flowering and fruiting induced by low tunnel technology. Kumar *et al.* (2018) noted the highest net income and cost benefit ratio when sowing was done on 30th December under tunnel, which was ascribed to high market value in off-season. Off-season muskmelon cultivation was found economically feasible due to additions of yield (17%), gross income (122%), profit (161%) and market price (90%) in comparison to normal season crop (Latif *et al.* 2018). Rani *et al.* (2022) examined the economics of off-season vegetable cultivation under low tunnel technology and the study findings indicate that the primary cost was attributed to human labor, closely trailed by expenses related to transportation and seed procurement.

Notably, cultivating high-quality produce during the off-season proves advantageous for farmers, enabling them to command better prices in the market. Furthermore, the Benefit-to-Cost (B:C) ratio for the selected cucurbit crops ranged from 1:2.05 to 1:3.35, underscoring the economic viability and profitability of employing low tunnel technology in cultivation. The performance of cole crops in low tunnels has emerged as a successful technological intervention in the Ladakh region, proving to be a boon for farmers of all kinds (Spaldon *et al.,* 2021). This innovation offers a cost-effective, portable, and straightforward installation method. Notably, the yields recorded in cabbage (780 quintals per hectare) and cauliflower (720 quintals per hectare) are significantly higher within low tunnels compared to open-field conditions, where cabbage yields reach only 266.6 quintals per hectare and cauliflower yields are at 500 quintals per hectare.

Moreover, these increased yields translate to higher net returns for farmers, highlighting the efficacy and profitability of adopting low tunnel technology in cole crop cultivation (Spaldon *et al.,* 2021). Subsequently, Spaldon *et al.* (2022) documented the yields of two broccoli hybrids. They observed that the Lucky hybrid exhibited a yield of 400 quintals per hectare (q/ha), whereas the Fiesta hybrid yielded 350 qtl/ha. Notably, the Lucky hybrid demonstrated a high economic return of INR 1,086,200 per hectare, accompanied by an impressive benefit-cost ratio of 1:9. Following closely, the Fiesta hybrid also showed a favorable benefit-cost ratio of 1:75. The comparative evaluation conducted by Kumari *et al.* (2021) between low poly tunnel technology and traditional growing methods of bottle gourd revealed compelling results.

The average yield of bottle gourd demonstrations using low tunnels was significantly higher at 298 quintals per hectare (q/ha), compared to 245 q/ha for the local crop grown conventionally. Moreover, the economic indicators demonstrated the superiority of bottle gourd cultivation under low tunnels. Gross returns were recorded at Rs. 238,400 per hectare, while net returns stood at Rs. 138,200 per hectare, both of which were the highest among all methods evaluated. Additionally, the Benefit-to-Cost Ratio (BCR) was notably higher at 2.38 for bottle gourd grown under low tunnels compared to the local check. One of the key advantages observed was the early market availability of the produce grown under low tunnels, which helped prevent market glut and ensured higher total yields and net profits per unit area. These findings underscore the effectiveness and profitability of adopting low poly tunnel technology for bottle gourd cultivation, offering valuable insights for farmers seeking improved yield and economic returns.

Minimization of pest incidences and reduced pesticide consumption

Low tunnels, when covered with spun-bonded fabric (row covers), serve as a valuable tool for extending the growing season of vegetable crops while also acting as a physical barrier against airborne insects and other non-soil pests. In a study by Acharya *et al.* (2020), it was observed that low tunnels significantly reduced insect infestation and leaf injury due to chewing herbivory in Brussels sprouts. Compared to open fields without protection, plants under low tunnels experienced reduced infestations of lepidopteran insects and the harlequin bug, *Murgantia histrionica* (Hemiptera: Pentatomidae). However, it's worth noting that aphid infestations were observed under low tunnels during the fall season. Interestingly, the study found no significant effect of mulch colour (white or black) on insect infestation or chewing injury, and there was no interaction observed between tunnel covering and mulch colour. The findings suggest that low tunnels can serve as an effective management tool for sustainable vegetable production by reducing insect infestations and feeding injury. Despite some challenges such as aphid infestations, the overall benefits of using low tunnels as a protective measure against pests outweigh the drawbacks, contributing to more resilient and sustainable farming practices. Likewise, Nordey *et al.* (2020) suggested using low tunnels as a suitable alternative for reducing pesticide use. da Silva Ponce *et al.* (2021) showed that the use of nonwoven shade mesh reduced the damage from *Plutella xylostella* and *Diabrotica speciosa* on kale plants grown in low tunnel during the rainy season and reduced *Myzus persicae* during the dry season. However, cultivation under the protection of the organza fabric provided more effective protection against *P. xylostella* and *D. speciosa*, resulting in greater production of kale leaves. Kale cultivation in the open field showed lower commercial production, more damaged leaves and greater damage by *Hellula undalis*.

REFERENCES

Acharya TP, Welbaum GE and Arancibia RA. 2020. Low tunnels reduce insect populations, insecticide application, and chewing insect damage on brussels sprouts. *Journal of Economic Entomology* **113**(5): 2553-2557.

Adamović B, Paroški D, Vojnović Đ and Ilin Ž. 2021. The effect of mulching and low tunnel on the yield, yield components and quality of watermelon. *Acta Horticulturae* **1320**: 101-108

Bhatt L, Maurya SK and Singh D. 2016. Economic feasibility of summer squash cultivation using low tunnel and black plastic mulch under *tarai* condition of Uttarakhand. *Journal of Applied and Natural Science* **8** (2): 817 – 821.

da Silva Ponce F, Trento DA, de Lima Toledo CA, Antunes DT, Zanuzo MR, Dallacort R, Oliveira RC and Seabra S. 2021. Low tunnels with shading meshes: An alternative for the management of insect pests in kale cultivation. *Scientia Horticulturae* **288**:110284.

Dodiya VC, Vala GS and Senjaliya HJ. 2021. Effect of different shade net on performance of fenugreek (*Trigonella foenum-graecum* L.) in summer season. *Current Horticulture* **9**(1), 63-64.

Ibarraa L, Floresa J, Carlos J and PeÂrezb D. 2001. Growth and yield of muskmelon in response to plastic mulch and row covers. *Scientia Horticulturae* **87**: 139-45

Jayasurya P, Chatterjee S, Biswas A, Viswanath M and Roy A. 2021. Low cost protected structures for off-season vegetable production: a review. *The Pharma Innovation Journal* **10**: 778-783.

Kang Y, Chang YCA, Choi HS and Gu M. 2013. Current and future status of protected cultivation techniques in Asia. *Acta Horticulturae* **987**: 33-40.

Kapanen A, Schettini E, Vox G and Itävaara M. 2008. Performance and environmental impact of biodegradable films in agriculture: a field study on protected cultivation. *Journal of Polymers and the Environment* **16**: 109-122.

Khan MB and Khan J. 2020. An economic analysis of tunnel farming in enhancing productivity of off-season vegetables in district Peshawar. *Sarhad Journal of Agriculture* **36**(1): 153-160.

Kumar D, Kumar A, Singh SS and Bala KS. 2017. Influence of microclimate condition of under low tunnel on productive responses in bitter gourd (*Momordica charantia*). *Bulletin of Environment, Pharmacology and Life Sciences* **6**(3): 46-50.

Kumar D, Kumar A, Singh SS, Prasad RK and Kant S. 2018. Effect of Plastic Low Tunnel on Flowering and Fruiting Behaviour during off Season of Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl]. *International Journal of Current Microbiology and Applied Sciences* **7 (**Special Issue**)**: 4829-4835.

Kumar S, Kant K and Kumar R. 2009. Off season cucurbits farming inside low tunnel—a review. *Progressive Research* **4** (Special Issue): 480-483.

Kumari A, Jat AS and Choudhary M. 2020. Effect of low poly tunnel on the yield and economics of bottle gourd. *Bhartiya Krishi Anusandhan Patrika* **35**(4): 264-66.

Latif MT, Sher FA and Hussain M. 2018. Profitability analysis of normal season and off-season muskmelon cultivation in district Sialkot, Pakistan. *Innovative Agriculture* **1**: 24-27.

Lodhi AS, Kaushal A, Singh KG. 2015. Low Tunnel Technology for Vegetable Crops in India. In: Singh KG, Goyal MR and Rudra RP (Eds). Best Management Practices for Drip Irrigated Crops. 1st Edition. Imprint Apple Academic Press. Pp. 8.

Lodhi AS, Chouhan SS and Bhalawe S. 2024. Impact of Low Tunnel Heights and Irrigation Regimes on Growth Parameters of Capsicum. *Journal of Experimental Agriculture International* **46**(1): 7-16.

Niaz S, Ali, MA, Ali S and Awan S. 2009. Comparative water use efficiency of drip and furrow irrigation systems for off-season vegetables under plastic tunnel in rainfed areas. *Life Sciences: an International Journal* **2**: 952-55.

Nordey T, Ochieng J, Ernest Z, Mlowe N, Mosha I and Fernandes P. 2020. Is vegetable cultivation under low tunnels a profitable alternative to pesticide use? The case of cabbage cultivation in northern Tanzania. *Crop Protection* **134**: 105169.

Ogden AB and MW Van Iersel. 2009. Southern highbush blueberry production in high tunnels: temperatures, development, yield, and fruit quality during the establishment years. *HortScience* **44**: 1850-56.

Pagaria P and Swami P. 2023. Vegetable production potential and income generation in Barmer district. *Current Horticulture* **11**(3): 79-80.

Ranjan A, Kumar A, Prakash S and Pa, AK. 2019. Effect of low poly tunnel and planting time on growth parameters and yield of muskmelon. *International Journal of Current Microbiology and Applied Sciences* **8**(1): 2735-39.

Saleem T, Mehdi M, Hakeem AH, Trumboo MS and Ganai NA. 2014. Comparative study on cultivation of cabbage under low tunnel and open field conditions in cold arid Ladakh region. *Journal of Krishi Vigyan* **2**(2): 19-21.

Singh B and Kumar M. 2009. Evaluation of summer squash varieties under plastic low tunnels during their off-season cultivation. *Indian Journal of Horticulture* **66**(1), 135-36.

Singh B and Kumarnag KM. 2023. Pollination management in horticultural crops under protected conditions: a review. *Current Horticulture* **11**(2): 3-8.

Singh B and Sirohi NPS. 2006. Protected cultivation of vegetables in India: Problems and future prospects. *Acta Horticulturae* **710**: 339-342.

Singh S, Singh DR and Chand S. 2021. Techno-economic feasibility of tomato (*Solanum lycopersicum*) hybrids for year-round cultivation in Andamans, India. *Current Horticulture* **9**(2): 46-51.

Spaldon S, Kanwar MS, Laskit J, Hussain A and Angmo K. 2022. Offseason broccoli (*Brassica oleracea* var *Italica*) cultivation under low tunnel in eastern Ladakh (UT). *The Pharma Innovation Journal* **11**(12): 368-70

Spaldon S, Laskit J, Kanwar MS, Tundup P and Angmo K. 2021. Technological intervention in production of cole crops under low tunnel in cold arid Changthang region in Ladakh (UT). *Indian Journal of Extension Education* **57**(4): 184-186.

Verma AK, Choudhary BR, Samadia DK and Singh D. 2019. Standardization of sowing date and covering material under low tunnels for early harvest of longmelon. *Vegetable Science* **46**(1&2): 28-33.

Waterer D. 2003. Yields and economics of high tunnels for production of warm-season vegetable crops. *HortTechnology* **13**(2): 339-43.

Yadav A, Kumar A, Pradhan R, Gopi R, Kalita H, Lepcha B and Maurya BN. 2017. Intensive Organic Vegetable Production under Low Cost Plastic Tunnels. Extension Folder SKM/EF/2017/10. ICAR-National Organic Farming Research Institute, Tadong, Gangtok, Sikkim.

Current Horticulture **13**(1): 20–34, January–March 2025
DOI: 10.5958/2455-7560.2025.00003.0
Received: 07 February 2024; Accepted 11 November 2024

Garlic (*Allium sativum*) storage in tropical region–a review

PC Tripathi*, V Sankar and KE Lawande

National Research Centre for Onion and Garlic, Rajgurunagar, Pune, Maharashtra, India

Abstract

Garlic (*Allium sativum*) is one of the important spices used worldwide in different cuisines. Garlic is grown in one season but its demand is around the year. Thus A large quantity of garlic is stored to fulfill the demand during off season. The storage losses of garlic in temperate region are lower as compared to tropical region. The storage losses of garlic is higher in tropical region due to higher temperature and humidity during storage period. These losses may be 15 to 40 percent which includes physiological weight loss(PLW), rotting and sprouting. There are several reasons of higher storage losses such as genetic makeup of cultivars, type of manure and fertilizer and their time of application and quality, quantity, method and time of application of water, pre harvest treatments, harvesting time , field curing, drying, store environment, storage structures etc.. There are two distinct temperature regimes where losses are minimum. One is high temperature regime, where storage temperature is 25-30^{0}C and another is low temperature regime, where temperature is augmented maintained 0 to 2^{0}C. Best results under both the temperature regimes are obtained when humidity is maintained at 65 to 70 %. The storage losses in high temperature conditions (25-30^{0}C) are high (30-35%) but storage cost is low. Various research works carried out on assessment of losses and reduction of storage losses through pre and post harvest management and modification of storage environment in the tropical garlic growing regions of the world are summarized in this review article.

Keywords: Garlic, Storage, Tropical region, Physiological loss, Sprouting, Decay, Biochemical Change

Quite often, market witnesses glut of vegetables in the season, which leads to poor return to the growers (Pagaria and Swami, 2023). On the other hand, consumers are willing to pay high prices for vegetables in off-season. Vegetables can be cultivated in off-season, with the introduction of greenhouses technologies (Dodiya *et al.,* 2021), wherein temperature and humidity are modulated for desirable growth of vegetables (Singh *et al.*, 2007; Singh *et al.*, 2021). The production of vegetables round the year facilitates the growers to make the maximum use the resources and augment income from vegetable growing as compared to other agricultural crops (Singh and Kumarnag, 2023).

One such cost-effective, farmers-friendly technology is 'low tunnel'. Low tunnels are miniature structures producing greenhouse like effect. This type of structures cover rows of plants; therefore, they are also known as 'row cover' (Jayasurya *et al.*, 2021). Low tunnels are constructed with locally available material such as bamboo (Bhatt *et al.*, 2016) and wood or with GI wires, plastic or metal bars to form semi-circular frames, which are covered with thin plastic sheet (PE or PVC 30-50 μ) or with nylon screen (Kang *et al.*, 2013). The sides are secured down by placing them in soil or by side-to-side crisscrossing nylon rope anchored to the base of each pole; however, in the growing season, the sides are opened by lifting them up for improving ventilation or plastic is slit as the temperature increase within the tunnels (Jayasurya *et al.*, 2021). Such structures are erected to provide temporary protection to crops and usually no higher than 1 m in height. In general, the height of the tunnel is kept at 45-60 cm with 45-60 cm width.

Low tunnels are used to conserve warmth to stimulate germination and early growth of seedlings in winters, to protect the plants from frost injury, to improve the quality of the crops (Singh *et al.*, 2007), to provide protection from wind and rain damage in melon cultivation and in winter production (forcing production) of vegetables (Kang *et al.*, 2013). Further, low tunnel production of vegetables offers other advantages such as Garlic (*Allium sativum*) is an herb that is grown around the world. It belongs to family Alliaceae and onion, leeks, and chives are other important crops of this family. It is an integral part of most of the cuisines throughout the world. Apart from its use in cuisine, garlic has historically been used to alleviate pains, leprosy, deafness, diarrhoea, constipation, parasitic infection, fever, stomach ache etc. since long (Woodward, 1996; Tattelman 2005; Rana *et al.* 2011; Tripathi *et al.* 2013). Garlic is most commonly used for conditions related to the heart and blood system. The medicinal properties of garlic were mentioned in *Charaka-Samhita*- a well known ancient Indian medical book for management of heart disease and arthritis (Rivlin, 2001). In another ancient medical text, garlic was reported to be used against

***Corresponding author :** prakaashtripathii2000@yahoo.co.in

*Present Address: Principal Scientist, Horticultural Science Division, ICAR, New Delhi

digestive diseases, exhaustion, parasites, and leprosy (Woodward, 1996).

Garlic is one of the oldest cultivated crops which were brought under cultivation almost 5000 year ago in Central Asia, China and India. Almost 150 countries of world cultivate garlic. Garlic is cultivated in about 1.65 million hectares with an annual global production of about 28.85 million metric tones. China is the largest producer of garlic in the world and accounts for 74per cent of total garlic production. India ranks second and produces 11per cent of the total production. The average productivity of the garlic in the world is 9.64 tones but the productivity in China is more than 25 tones per hectare. Other produces are Bangladesh, Spain and South Korea. The average productivity of the garlic is 13 tones but the productivity in China more than 25 tones /ha. More than 50 tropical countries produce garlic. India, Bangladesh, Ethiopia, Nigeria, Myanmar, Brazil, Pakistan etc. are major tropical garlic growing countries.

The tropical counties contribute around 39.38 % area and 19.05 percent of total production of garlic in the world. The productivity of temperate countries is 8.43 tons per hectare while the global productivity of garlic is around 9.65 tons/ ha (Table 1, Fig 1, 2&3; FAOSTAT, 2022). Most of these countries produce garlic for their domestic consumption and their contribution to global garlic trade is very less. India is the largest tropical garlic growing country. Madhya Pradesh and Rajasthan are the leading states in India contributing more than 50% in both area and production. The other major garlic growing states are Gujarat, Uttar Pradesh and Maharashtra (Table 2; Anonymous, 2022).

Though garlic was originated in temperate region but it is widely cultivated in tropical regions of the world. Although varieties grown in tropical and subtropical regions have different climatic requirements. The garlic gown in tropical regions has shorter duration, more pungency, and small cloves. Garlic is cultivated in only one season barring few exception. Thus a large quantity of garlic is stored for fulfilling the domestic and international requirements. Though garlic production season the southern hemisphere is different but the area and production in very little the hemisphere.

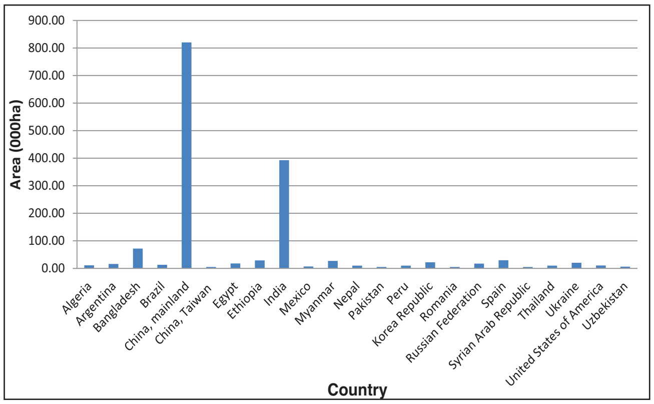

Fig 1. Area under garlic cultivation in major countries of world (2022)

(*Source*: FAOSTAT,2022)

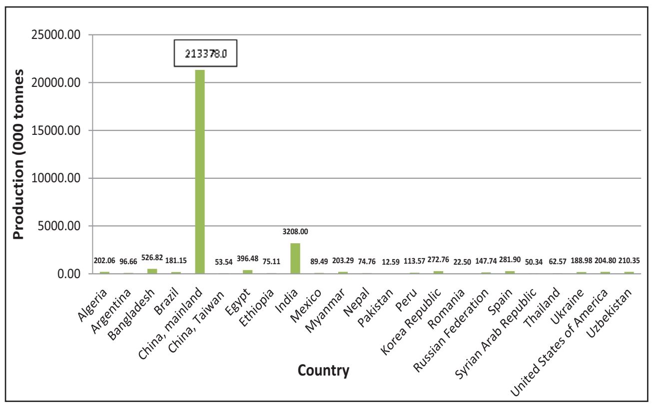

Fig 2. Production of garlic in major countries of world (2022)

(*Source:* FAOSTAT,2022)

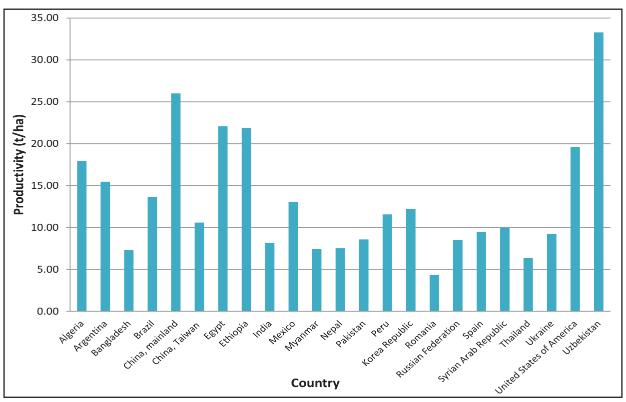

Fig 3. Productivity(ton/ha) of garlic in major countries of world (2022)

(*Source:* FAOSTAT,2022)

Table1. Major tropical garlic producing countries of the world (2022)

Country	**Area ('000 ha)**	**Area (%)**	**Production ('000 tones)**	**Production (%)**	**Productivity (tones/ha)**
Algeria	11.25	0.68	202.06	0.70	17.96
Angola	0.97	0.06	13.08	0.05	13.48
Argentina	16.00	0.97	96.66	0.34	15.47
Bangladesh	72.21	4.36	526.82	1.83	7.30
Bhutan	0.12	0.01	0.30	0.00	2.41
Bolivia	0.55	0.03	2.56	0.01	4.64
Brazil	13.31	0.80	181.15	0.63	13.62
Chile	1.78	0.11	21.65	0.08	12.19
Colombia	0.71	0.04	10.69	0.04	15.12
Cuba	1.71	0.10	10.69	0.04	6.25
Dominican Republic	0.40	0.02	3.02	0.01	7.62
Ecuador	0.84	0.05	1.29	0.00	1.53
Egypt	17.95	1.08	396.48	1.37	22.09
Ethiopia	29.13	1.76	75.11	0.26	21.88
Guatemala	3.39	0.20	29.98	0.10	8.86
India	393.00	23.72	3208.00	11.12	8.16
Indonesia	4.27	0.26	30.58	0.11	7.16
Libya	0.85	0.05	4.84	0.02	5.67
Madagascar	0.40	0.02	2.58	0.01	6.46
Malawi	0.11	0.01	0.74	0.00	6.50
Mali	1.31	0.08	18.10	0.06	13.87
Mauritius	0.01	0.00	0.05	0.00	7.00
Mexico	6.84	0.41	89.49	0.31	13.08
Morocco	2.66	0.16	11.18	0.04	4.21
Myanmar	27.41	1.65	203.29	0.70	7.42
Nepal	9.94	0.60	74.76	0.26	7.52
Niger	0.98	0.06	14.36	0.05	14.71
Nigeria	0.17	0.01	2.25	0.01	13.07
Pakistan	5.21	0.31	12.59	0.04	8.58
Paraguay	0.16	0.01	0.22	0.00	1.39
Peru	9.82	0.59	113.57	0.39	11.56
Sudan	3.25	0.20	28.42	0.10	8.76
Thailand	9.85	0.59	62.57	0.22	6.35
Tunisia	2.28	0.14	25.43	0.09	11.16
Tanzania	1.72	0.10	6.19	0.02	3.59
Uruguay	0.16	0.01	0.88	0.00	5.71
Venezuela	1.63	0.10	14.68	0.05	8.99
Total	**652.46**	**39.38**	**5497.71**	**19.05**	**8.43**

(*Source:* FAO STAT,2022)

Table2. Major garlic producing states in India (2021-22)

State	Area (000ha)	Production (000 tones)	Productivity (t/ha)
Assam	10.81	69.42	6.42
Bihar	1.41	2.21	1.56
Chhattisgarh	1.17	3.02	2.57
Gujarat	26.01	202.83	7.80
Haryana	3.42	39.91	11.69
Himachal Pradesh	6.94	13.58	1.96
Jammu & Kashmir	0.78	0.57	0.73
Karnataka	4.28	24.54	5.73
Kerala	0.19	1.02	5.25
Madhya Pradesh	204.68	2106.63	10.29
Maharashtra	4.05	24.35	6.02
Mizoram	0.02	0.01	0.53
Nagaland	0.28	2.32	8.35
Odisha	11.03	39.51	3.58
Punjab	8.88	97.04	10.93
Rajasthan	98.34	592.52	6.03
Tamil Nadu	1.93	11.18	5.78
Telangana	0.08	1.12	13.86
Uttar Pradesh	40.96	242.24	5.91
Uttarakhand	1.92	11.27	5.86
West Bengal	4.04	38.15	9.45
Total	431.22	3523.44	8.17

(*Source :* MOA&FW,GOI,New Delhi)

Garlic is produced only in one season i.e. winter season in most of the tropical regions. But some higher attitude regions of tropical areas such as high lands of Ethiopia , the Nilgiris hills of India growing garlic during March to September. In, Indian subcontinent, garlic is planted in October –November. It comes from February and continues up to March-April. In Southern hills particularly Nilgiri hills garlic is cultivated in two seasons i.e. March-April to July-August and also in October to March-April. In Northern hills it is cultivated in one season i.e. October to May-June.

More than 95% produce of garlic in tropical regions arrives in market in the months of March to May. But there is constant demand of garlic in the market as it is required daily in small quantity in almost all houses. Further, there is glut in the market during the harvest season. As a result farmers do not get the appropriate prices and they are forced to sale their produce at lower price. Thus it becomes essential to store garlic for regular supply in the market and to stabilize the price. It is estimated that more than one million tones of garlic is stored in tropical region to fulfill the domestic and export demand.

Storage losses

Garlic is less perishable crop as compared to other fresh vegetables. A well cured dried neck and outer skins prolong shelf life, although it will eventually sprout (end of dormancy), its metabolism will increase, and its quality will begin to change, making it more susceptible to attack by microorganisms and diseases (Brewster, 1994).The respiration of garlic during storage is lower than most of the vegetables. Thus the storage losses in garlic are comparatively lower and therefore it can be stored for longer period. The storage losses are directly related to genotypes and storage conditions. In most of the tropical countries, garlic is stored at room temperature and the storage losses are higher at these conditions. These may range between 35 - 40 percent for a period of 6 to 8 months. Tripathi *et al.* (2007) reported that the storage losses for garlic under Indian conditions may be 26-40 percent for 8 months depending on the varieties and storage conditions.

These losses are consisting of physiological loss of weight (20-25%), sprouting (1 -5%) and rotting (5-10 %).

The storage losses of 15 to 40 percent have been reported from other tropical countries. The sprouting losses were higher whenever the garlic was stored at lower temperature or after onset of winter (Bahnasawy and Dabee,2006).Cantwell (2004) pointed out that garlic can be stored at room temperature (20–30 °C) for 1 or 2 months. However, the bulbs eventually loose their firmness and become spongy and discolored due to water loss. Dormancy ends quickly in garlic stored at temperatures between 5 and 18 °C.Volk *et al.* (2004) reported that the quality of garlic bulbs usually deteriorates dramatically by 6 months after harvest.

The bulb size also affects the storage of garlic. It has been reported that the weight loss and diseases are more in small size bulbs while the sprouting and rotting is more in big size bulbs. Therefore it is recommended to use medium size bulbs for storage purpose (Table. 3; Tripathi *et al*, 2007).

Table 3: Effect of different grades on storage losses after 8 months of storage

Size of bulbs	Storage losses (%)				
	Weight loss	Rot	Sprout-ing	Black mould infection	Total
AGB (>35mm)	42.07	18.15	0.7	0.2	61.12
BGB (25-35 mm)	33.25	12.69	0.2	0.2	46.34
CGB (<25mm)	28.66	11.91	0	0.2	40.77

Physiological loss of weight

Garlic is a living product and it respires continuously. The water produced during respiration evaporates slowly but continuously causing continuous loss in weight. This loss is higher at high temperature and low relative humidity conditions. The respiration rate of intact garlic bulbs is 7-13 ml CO_2/kg/hr at 20^{0}C which decreases with decrease in temperature and almost comes to half at 0^{0}C. Since almost 100 per cent garlic is stored under room temperature conditions in India, the weight loss is high and it is more particularly during the month of April to May when outside temperatures are high and relative humidity is low. It has been seen that weight loss during the 5-6 months storage is between 20-25 percent (Tripathi *et al.* ,2007).

Rot/ Decay

There are several diseases which affect garlic during storage. The causal organisms of most of these diseases are carried from field and affect the bulbs during storage. The major diseases of stored garlic are grey mould, blue mould, *Fusarium* basal rot, dry rot and bacterial rot. The most important storage diseases of garlic are grey mould and blue mould caused by *Pencilliumcorymbiferum* and other spp. The affected garlic bulbs may show little external evidence until decay is advanced. The affected bulbs become light in weight and the individual cloves become soft, spongy and powdery dry. In an advanced stage of decay, the cloves break down in a green or grey powdery mass. *Fusarium* basal rot (*Fusarium oxysporumcepae*) infects the stem plate and causes shattering of the cloves is now become major problems in those areas where garlic is repeatedly grown in the same field for years together.

The dry rot (*Botrytis allii*) and bacterial rots (*Erwinia* spp., *Pseudomonas* spp.) are comparatively less prevalent .Among the physiological disorders waxy break down of bulbs is major. It affects garlic during latter stages of growth and is often associated with periods of high temperature near harvest. Early symptoms are associated with development of small, light yellow patches on the clove flesh that darken to yellow or amber with time. Finally the clove becomes translucent, sticky and waxy, but the outer dry skins are not usually affected. Waxy breakdown is commonly found in stored garlic (Tripathi *et al.* ,2007).

Sprouting

Sprouting is not a major problem in garlic. It is very low as compared to onion. The sprouting losses in garlic are more in cold climate than warm tropical climate. Since most of the garlic is stored in India under ambient conditions, the occurrence of sprouting is recorded minimum. The internal sprouting of the cloves is common in garlic when it is stored beyond the month of October in Western Indian conditions. In most of the cases it is not visible but it increases the weight losses and affects the quality of garlic. Higher sprouting problems is noticed when garlic is stores at low temperature (0 $\pm$ 2^{0}C) and again kept at ambient temperature (Tripathi and Lawande, 2006). The losses due to shedding of tunics are very low in garlic as compared to onion. Generally number of tunics in garlic bulbs are restricted to 1-2 and they remain firmly attached to the bulbs.In Mexico, garlic is harvested from February to August and stored at room temperature to meet consumer demand. When the garlic sprouts, its dormancy period and effective shelf life are over, and quality decreases, leading to a decrease in its sale price (Iglesias-Enriquez and Fraga, 1998). Mann and Lewis (1956) have indicated that the dormancy period of garlic depends on temperature and time of storage

Root Growth and other disorders

High relative humidity and insufficient ventilation is the main reason cause of root growth. High Humidity and high temperature conditions, roots grew within a few days. The rooting of bulbs is generally low. The exposure of garlic to direct sun light, nutritional disorders may results in greening, rubberification, shrinkage of cloves.

Biochemical Changes during storage

Apart from the physical changes during storage, the garlic bulbs stored under different temperatures several biochemical changes take place. Storage time is a pivotal functional determinant for the garlic bioactive properties. These are responsible for flavour, taste and firmness etc of the bulbs. Kambiz Mashayekhi *et al* (2016) studied the changes in carbohydrates, enzymes, and pigments were investigated in the red garlic cv. Azarshahr bulbs in storage from harvest to sprouting under Iranian conditions. The garlic cloves were stored under dark condition at to 4 and 21°C, separately.

It was found that starch, lipase, and protease levels declined at the end of storage when clove sprouting started at both 4 and 21°C storage temperature. Starch, glucose, chlorophyll a, b, ab, and carotenoid content during the first 14 days and sucrose at 42 days showed a decreasing trend. Anthocyanin showed an increasing trend 14 and 42 days after harvesting and then decreased up to initiation of sprouting at both 4°C and 21°C storage periods.Vazquez-Barrioset et al. (2006) observed that storage of garlic at 5°C resultedin a 33% reduction in TSS.As far as allicin content is concerned,a sharp increase was observed in allicin content between 45 and 90 days after harvest when it was stored at 18°C but the sulphur (S) status in garlic bulbs was unchanged, which indicated a conversion effect of γ-glutamyl peptides to sulfoxides, a precursor compound for allicin (Nina Kacjan Marsic *et al.* , 2019).

Bahnasawy and Dabee(2006) found that antioxidant capacity of garlic cloves was maximum after 8 weeks of storage at 20 ± 2 °C, whereas for organosulfur compounds and polyphenols, the maximum content was observed between 6 and 8 weeks of storage, followed by a significant decrease after that time period (Fei *et al.*, 2015). The moisture content decreased from 60.33-63.24% before storage to 55.57-58.22% after storage period. Protein changed from 6.26-6.33% before storage to 6.62-7.18% after storage period. Fiber percentage ranged from 2.12-2.15% before storage to 2.16-2.22% after storage period. Carbohydrates increased from 26.30-27.37% before storage to 30.74-33.36% after storage period, depending on storage system, package type and bulb size (Bahnasawy and Dabee, 2006).

Factors effecting storage losses and their Management

There are several factors which are associated with storage losses in garlic. Generally management of storage losses is initiated after the harvest of the crops. There are many pre harvest aspects which affects the storage of garlic. These includes genetic makeup of cultivars, type of manure and fertilizer and their time of application and quality ,quantity, method and time of application of water, pre harvest treatments, harvesting time etc. Post harvest factors include field curing, drying, store environment, storage structures etc.

Genotypes

More than 100 varieties and several hundred landraces of garlic are grown throughout the world. They are broadly classified into soft neck and hard neck (also known as top set) varieties. Hard neck varieties (*Allium sativum* var. *ophioscorodon*) bolt during late spring/early summer, producing a tall, flower stalk or scape. There is considerable variability in the size and number of bulbils produced by hard neck garlic (Table 4). Bulbils may be used as planting stock but require 2 or more years of growth to develop into marketable bulbs.In hard neck garlic, there are a number of subgroups including Porcelain, Rocambole, Purple Stripe, Marbled Purple Stripe, Glazed Purple Stripe, Asiatic, Turban and Creole. Each of these subgroups has general characteristics that make them better suited for certain climates, have favourable growth tendencies, or exhibit unique flavor profiles.

Hard neck garlic may be purple, purple striped, or white and is represented by varieties such as Roja, German Red, Valencia, Continental, and Creole. Soft neck varieties (*A. sativum var. sativum*) do not produces a scape and do not produce bulbils, except in times of stress. A general rule of thumb is that hard neck varieties are more winter hardy, produce larger cloves but have a shorter storage life than soft neck varieties. Most of tropical counties grow soft neck varieties of garlic. The storage conditions prevailing the tropical conditions have much influence on the storage life of the garlic. Taicangbaipi, Ershuizao, Hongqixing, and Single-clove, Ershuizao and Hongqixing are some varieties of garlic in China. Tsedey and Bishoftu Netchare are most common varieties in Ethiopia. In Bogor (Indonesia), a local garlic variety, i.e. Lumbu Kuning is grown which has medium storage life. Two garlic varieties dominate in the US are California White and California Early. Garlic cvs . Cateto Roxo Mineiro 2 and the Cateto Roxo Mineiro 1 are grown in Brazil. Balady and Chinese-Sids40 are the main garlic cultivars grown in Egypt.

In Bangladesh new improved varieties of garlic, are BARI Rashun-1, BARI Rashun-2, BAU Rashun-, and BAU Rashun-2. Three commercial cultivars i.e. Garcua, Gardacho, and Gardos are grown in Turkiye (Nina Kacjan Marsic*et al.*, 2019). The storage life of these cultivars is different. It may ranges from 2 to 6 months. The total solid content, pungency content and chemical composition of the genotype also effected the storage period. Tripathi *et al* (2021) found that the smaller clove varieties having higher solid content perform better than varieties having lower sold content.

Table 4: Comparison of morphological traits of the three forms of garlic(Engeland, 1992)

Trait	***Allium longicuspis***	***Allium sativum var. aphioscorodon***	***Allium sativum var. sativum***
Bolting/ Non bolting	Bolting	Bolting	Non bolting
Anthers	Exserted	Deformed	Non Exserted
Bulb colour	Blotchy or stripped purple	Purple./ porcelain	White
Bulb Layers	1-2	2	4
Clove numbers	8	8	15
Clove colour	Brown	Brown	White
Maturity	Late	Late	Early
Scape	Rocambole: tightly coiled Continental: loose coil	Rocambole: tightly coiled Continental: loose coil	NA
Bulb scales	-	-	Artichoke: Coarse Silver skin: Fine and smooth

The cultivars vary in their storability because of their inherent duration of dormancy. This is measured by the time to sprout either in storage or after planting in the field. It is considered that the purple coloured varieties have better shelf life than white coloured varieties. However, very little information is available on storability of garlic varieties under different tropical regions.

The type and quantity of fertilizers and manures exercise great impact on the storage life of garlic. The recommended dose for garlic is 100 kg Nitrogen, 50 kg phosphorous and 50 kg potassium. The half of the nitrogen and full quantity of potassium and phosphorus should be applied at the time of planting while the remaining amount of nitrogen should be applied in equal quantity at 30 and 60 days after planting. The late application of nitrogen adversely affects the storage life of bulbs. Further the high nitrogen application leads to thick neck bulbs that are more prone to entry of pathogens. The type of fertilizers also have influence the storability of garlic. The ammonium fertilizers have been found better than nitrate fertilizer for storability. The applications of sulphur have been found helpful in shelf life of garlic. The organic fertilizer and green manure also found enhancing the storability of garlic.

The most important active compound in garlic is alliin. Sulfur (S) fertilization was shown to significantly increase the alliin concentration in garlic cloves, while high nitrogen (N) levels had an adverse effect. The effect of graded N and S application on the storage life of garlic has been paid little attention so far. S fertilization increased the alliin concentration by a factor of 2.3 from 11.4 mg/g−1 in the control treatment to 26.6 mg/g−1 dry weight at the highest S level of 45 kg/ha−1 after 83 days of storage. N fertilization decreased by a trend of the alliin content. Fertilizer rates had only a minor influence on water losses from bulbs at short-term storage. After 83 days of storage, water losses were by trend lower at higher S levels, and this relationship proved to be significant when no N was applied. Best quality in terms of high alliin contents and longer storage life was obtained by the application of 30 kg/ ha (Elke Bloem*et al*, 2011). Nitrogen and Sulphur fertilization significantly increased the allicin content of Gardos bulbs (Nina Kacjan Marsic *et al.* , 2019).

Sulphur fertilization significantly increased tyeild and quality of garlic (Choudhary *et al* .,2017). Foliar application of potassium silicate was found effective in increasing storage life in garlic. The highest plant length, number of leaves, fresh, dry weight\plant, neck diameter, bulb diameter and chlorophyll content of garlic were achieved from foliar application of potassium silicate at the 4000ppm after 120 days from planting compared to the control. The weight loss and shrinking percentages of the bulbs after 7 months of the storage were the least with the foliar application of potassium silicate at 8000ppm with chitosan at 200ppm at the room temperature conditions (Shadia Ismail *et al.*, 2019).In an organic cultivation trials, the storage life was found better than the garlic bulb produced with inorganic fertilizer (Tripathi *et al.*,2007).

Water management

The quality of water and time and method of irrigation greatly influence the storability of garlic. It has been noticed that if the water quality is not god the decay problem is enhanced in the storage. The water with high content of contaminants from the cities used for irrigation of garlic particularly during the maturity period increases rotting as compared to the underground water. The time of irrigation also effects storage. The irrigation should not be applied after the crop has reached to maturity. Generally it is recommended that irrigation should be stopped 15 days before harvest of the crop (Tripathi *et al*, 2002).The studies on the methods of irrigation conducted at Rajgurunagar(Pune) in western India revealed that storage losses were lower in the garlic with drip irrigation with 75 % to 100 % PE as compared to surface irrigation.

This was probably due to the optimum quantity of water applied during the maturity of the bulbs. Further the soil remains soft in drip irrigation method which facilitates easy harvesting of the bulbs and reduces the injuries to the bulbs during harvesting. Irrigation before harvest to facilitate easy harvest often enhance rotting losses. Therefore harvesting should be done at proper moisture level (Sankar *et al.*, 2007, Tripathi *et al*. 2017). Field experiments carried out at Navsari (Gujarat, India) during winter season revealed that highest percentage of total weight loss was recorded at 120 days after storage irrespective of different treatments which indicates that garlic bulb can be stored up to 90 days after harvest without much reduction in weight.

The maximum and minimum percentage of total weight loss was recorded under treatment of surface method of irrigation with 1.0 IW/CPE ratio (I3) and mini sprinkler method of irrigation with 0.6 IW/CPE ratio (I1) respectively at all the stages during both the years. Incase of weed management practices the highest percentage of weight loss was recorded with the treatment pendimethalin at 0.75 kg/ha as pre-emergence coupled with one hand wedding at 50 days after sowing (W4) Significantly the lowest percentage of weight loss was observed in treatment of unweeded control (W1) at all the stages during both the years of experimentation (Thanki and Patel, 2010)

Effect of pre-harvest treatments

The pre-harvest application of some chemicals have been found helpful in reducing the storage losses. Application of carbedazim @2g/l one week prior to harvesting has been found effective in reducing the storage losses due to decay. Pre harvest spray of carbendazim was found to reduce field load of disease causing bacteria and fungus before garlic is loaded in the storage structures (NHRDF, 1997). The use of maleic hydrazide (1,2-dihydropyridazine-3,6-dione) [MH] , a plant growth regulator, has been widespread in various garlic growing regions of the world. The sprouting can be prevented by pre harvest application of growth regulator like Maleic hydrazide@ 1500 to 3000 ppm before neck fall when the leaves are green (NHRDF,1997; Ratanamarno and Supa,2015)). Maleic hydrazide (MH) had been used for sprout inhibition but at present it is prohibited due to health hazards. Ratanamarno and Supa (2015) reported that pre-harvest treatment using 2500 ppm protocatechuic acid (PCA), 25 ppm abscisic acid (ABA) as spray to leaves three weeks before harvest and storage at ambient gave the longest storage life of 300 days, which was comparable with 2,500 ppm MH.

This result indicates the potential of PCA and ABA as MH substitute. Pre-storage coating treatment of peeled and un-peeled garlic cloves with either garlic and onion oils, potassium sorbate and sodium benzoate maintained a protective effect against black mould infection during storage for four months. The pre-storage application of essential oils indicated a superior inhibitory effect on black mould incidence in garlic cloves when compared with the food preservatives. The study indicated that garlic and onion oils, potassium sorbate and sodium benzoate could be used as antifungal non-hazardous treatments and could be safely used for fresh products in Egypt (El-Mougy *et al.* 2007). Sharma *et al* (2010) study the storage life of garlic cultivar 'GHC 1', including treatments comprised knotting tops one month prior to harvesting (indigenous practice) and general practice of no knotting of tops, followed by application of iron sulphate, borax and maleic hydrazide @ 2000 ppm (check) each 2 weeks prior to harvesting of bulbs.

The indigenous practice of hanging bulbs in storage significantly resulted in minimum loss of weight and incidence of sprouting, rotting and drying of bulbs compared 25% over no chemical application and also recorded low incidence of sprouting, rotting and drying of bulbs. The use of borax could be beneficial for minimizing the storage losses forlarge-scale storage of garlic bulbs, while indigenous practice could be a suitable preposition for small-scale storage compared to no chemical spray by selling the bulbs during storage.

Harvesting time and method

The change of leaf colour is the sign of maturity in garlic. The stage of maturity of cloves at harvest has significant influence on dormancy. As the bulbs reach maturity, the plants cease to produce new leaves and senescence starts. The tops just above the neck of the bulbs weaken and bend down still remaining green. Further, there is development of bulbils in the pseudostem just above the ground. This is also an indication of maturity in tropical type of garlic. Bulbs continue to increase in size and weight for sometime after softening of the neck and falling over.

This increase is due to continued accumulation of dry matter in the bulb. Bulbs harvested after neck fall have been reported to take less time for drying and curing and shown have marked reduction in storage rot. Garlic harvested when the leaves are still green, require more time to sprout than mature cloves harvested when the foliage has dried. It has also been reported that harvesting of garlic bulbs before the tops have fallen over indicating full maturity, results in poor storage whereas delayed harvesting results in splitting of bulbs and re-sprouting of bulbs (NHRDF, 1997, Tripathi and Lawande ,2004).

Harvesting is done manually by uprooting. Some time the hand hoe is used in hard soil for harvesting. Harvesting with hand hoe damages lot of bulbs. These bulbs get disease infection and exhibits more losses in storage. Therefore care should be taken to harvest garlic in a optimum moisture level and optimum stage of ripening to minimize the storage losses. Generally garlic is stored after making bunches of 20-25 bulbs by tying their leaves.

Effect of removal of tops

Garlic should be stored with leaves for better storage. These bulbs are to be hung by their tops or stored in circular heaps. Hanging of garlic bundles along with leaves is a indigenous practice is adopted for garlic storage in most of the garlic growing areas of the world particularly for domestic consumption and seed purpose. However the presence of leaves for marketing and large scale storage is undesirables as it affects the grading, packing marketing of the bulbs. The topping of garlic is done after curing or sometime after on farm storage (NHRDF, 1997, Tripathi and Lawande, 2004). The studies conducted at NRC Onion and garlic revealed that cutting of leaves exhibits higher weight loss and other storage losses as compared to the garlic stored with leaves. The minimum loss (11.52%) in weight was observed in bulbs stored by hanging with tops (Mahajan, *et. al.,* 2005). The only constraint is that the untopped garlic bulbs require larger area as compared to bulbs without leaves.

Field curing and shade drying

After harvesting the bulbs are is left in the field for 3-4 days for removal of excess surface moisture and drying of leaves. This allows the formation of strong outer protective scales and hardening of neck. Garlic bulbs, after harvest, are cured naturally in the field by windrowing in such a way that the bulbs of one row are protected from the sun by the foliage of the adjacent row. This is practiced in places where the temperature is mild. Exposure of bulbs to the sun for longer period may cause damage to the skin making them more vulnerable to storage rot. Normally, it takes about a week for during of foliage and outer scales. After field curing, the bulbs are cured in a ventilated shed for 7 to 15 days either with tops or after cutting the tops leaving about 2.5 cm neck intact. The roots are removed completely. Artificial curing can be done by blowing hot air at 27 to 35°C through the curing room. It takes about 48 hours for completion of the process when the relative humidity is between 60 to 75% (NHRDF, 1997, Tripathi and Lawande ,2004).

Curing

The purpose of the curing is to store longer duration and prevent diseases/pests, hence prolonging the shelf life After harvesting, the plants should be moved from the field into a dark, dry, well-ventilated area for drying and curing of the bulbs. Bulbs should be moved out of the sunshine as quickly as possible after digging. Do not dry by laying the plants in the sunshine. Tops and roots can be removed after several weeks when drying and curing are complete. The top of a cured bulb is topped at about 2.5cm above the bulb. Once pulled, bulbs can be gathered in the field and left to field cure if there is no chance of rain. If rain is expected, plants should be collected and cured in a dark, dry, well-ventilated covered area. Plants can either be spread flat on benches, racks, slotted trays, or wire screens or by hanging bunches of 10 to 12 bulbs tied with string. Curing or drying of the bulbs for 10 to 14 days is necessary if harvested with some leaves still green (NHRDF, 1997, Tripathi and Lawande ,2004). In Hawaii , If harvesting done after the leaves (tops) have dried in the field, then minimal curing is necessary. When the tops (green leaves) have dried, the roots and the tops are cut off, leaving about one inch (25 mm) above the bulb.

Post-harvest treatment

There are some post harvest treatments which have been found successful in reducing the losses during storage.

Effect of sulfur fumigation

Sulphur fumigation improves the storage life of garlic. The sulphur fumigation was found to decrease the black mould infection in garlic bulbs. The studies conducted at NRC Onion and Garlic revealed that bulbs of

Garlic cv.G-41 when fumigated with 50g sulphur /m3 for more than one hour significantly reduced the soft rot and black mould infection. The sulphur fumigation did not show any effect on weight loss and sprouting. Fumigation should be done after loading of garlic in storage structure (Tripathi *et al*, 2007).

Effect of gamma irradiation

Several workers have attempted irradiation of garlic with gamma rays for controlling sprouting. The dose varies from 50 Gy to 250 Gy. The radiation treatment given to bulbs within 8 weeks of harvest (before sprouting) can inhibit sprouting effectively, reduce weight loss and prolong storage life for about one year (Bongirwar and Shirsat, 2000). The studies conducted at Pune (India) revealed that when well-cured and dried bulbs of garlic irradiated with 75 Gy dose of cobalt-60 package irradiator and stored at ambient condition from May to January, recorded no sprouting even up to 230 days. Under cold storage there was no sprouting in irradiated as well as un-irradiated bulbs. However, when the bulbs were taken out of cold storage un-irradiated bulbs sprouted heavily and it was 74.54 % (Tripathi *et al.*,2007). Ibrahim *et al* (1971) found that Gamma irradiation (12 Krad) was more effective than preharvest application of maleic hydrazide(2500 ppm) in controlling sprouting and extending the storage life of garlic bulbs.

Gamma irradiation decreased the length and thickness of internal sprouts and entirely prevented chlorophyll formation insprouts; it decreased external discoloration and disease to a greater extent than did maleic hydrazide treatment. Both treated and untreated bulbs held in cold storage (0°C; 90-95% RH) showed a longer storage life than did those held in common storage (15-30°C; 50-75% RH). Gamma irradiation, maleichydrazide treatment, and cold storage reduced weight loss and delayed emaciation. Curzio *et al.*(1986) investigated several chemical parameters in 'red' variety garlic irradiated to inhibit sprouting, with doses of 30 Gy and kept under warehouse conditions. It was found that the irradiated garlic showed a significant increase in ascorbic acid content during storage but there was no change in dry matter content compared with non-irradiated garlic**.** The irradiated garlic had a higher index of flavour, measured as enzymatic pyruvate, a higher acidity and a lower content of water-soluble carbohydrates compared with non-irradiated garlic at 270 days of storage. These studies showed that the irradiation of garlic bulbs is was found beneficial for prolonging storage life.

Storage

Storage method

Traditional method of hanging bundled garlic

Hanging garlic bunches under ceilings of houses is also common practice to maintain planting material for next season in all garlic growing regions. Generally 10 -15 garlic are tied in a bundle and their leaves kneaded together. In India, the hanging of garlic in most common practice to store the garlic for domestic consumption and seed purpose. The storage losses in this practice are low and garlic can be stored up to next season (NHRDF, 1997, Tripathi and Lawande ,2004). Sharma *et al* (2010) found that indigenous practice of hanging bulbs in storage significantly resulted in minimum loss of weight and incidence of sprouting, rotting and drying of bulbs. Hanging garlic bunches under ceilings of houses is also common practice to maintain planting material for next season in Ethiopia. The disadvantage of this method is that very limited quantity of garlic can be stored.

Storage in Heaps

The another method used in Indian subcontinent is to stored garlic in heaps of various size along with leaves kneaded togather. Generally the size of head may be different as per requirement. NRC Onion and Garlic ,Pune (india) modified these heap size and found that circular heaps made on ventilated floor in s bottom ventilated structure most efficient in reduction of storage losses. The bet diameter of these circulars heap shoud be around 1 meter and height is around 120 cm. The garlic tied in bundles along with leaves and arranged in these heaps (Tripathi and Lawande , 2004; Tripathi *et al.* 2009). The disadvantage of this method is it can be adopted at only at on farm storage as it is difficult to transport and pack garlic with leaves.

Thus the garlic leaves are cut after proper field and shade curing. The stem of almost 2.5 cm should be kept with the garlic bulbs. It has been found the neck length of 2.5 cm found to increase the storage life and reduce the incidence of disease infection as compared to no neck. (Tripathi *et al*, 2007). After removal of leaves the garlic bubs are packed in different types of bags and market and storage.

Packing

Packing is a vital component of post harvest management to assemble the produce in convenient units and to protect it from deterioration during handling and marketing. Adequate packaging protects the produce from physiological, pathological and physical deterioration in the marketing channels and retains their consumer attractiveness. The garlic is generally packed in Hessian cloth bags of various sizes for marketing. Now the use of netlon bag, Card board boxes, crates and consumers pack (1 to 5 kg) is also getting popularity. Tripathi and Lawande (2009) observed the physiological loss in weight loss of the garlic cv. G41 in cold storage for the hessian cloth bag and netlon bag was lower than plastic crates . In Ethiopia, bulbs are transported and stored in 25, 50, 120kg bags in dry stores by vendors. Storage life under appropriate conditions could be 5 –8 months at room temperature for seed purpose depending on the variety. El-Sayed G. Khater *et al* (2006) found that garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system.

Storage environment

The storage of garlic besides, genotypic factors, largely depend on conditions in the storage structures. There are two distinct temperature regimes where losses are minimum. One is high temperature regime, where storage temperature is 25-30^{0}C and another is low temperature regime, where temperature is augmented maintained 0 to 2^{0}C. Best results under both the temperature regimes are obtained when humidity is maintained at 65 to 70 %. The storage losses in high temperature conditions (25-30^{0}C) are high (30-35%) but storage cost is low. While in low temperature conditions (0-2^{0}C) or cold storage conditions losses are minimum (0.5%) and storage period is longer. However, storage cost is high. Higher temperature (more than 30^{0}C) in ambient storage structures lead to higher weight loss while lower temperatures (less than 10^{0}C) enhance sprouting losses. Higher humidity (more than 70$^{\%}$) coupled with higher temperature enhance storage diseases, while lower humidity enhance weight loss .

Ambient temperature storage

Tripathi *et al*. (2009) evaluated four different types of storage structures for storage of garlic under Western Indian conditions of from April to November. Among the various storage structures evaluated for garlic storage, the lowest losses (25.39%) were recorded in modified top and bottom ventilated double row storage structure. This was followed by modified bottom ventilated double now structure (27.43%). The losses to due soft root infection was lowest (11.49%) in modified bottom ventilated storage structure. Similarly the black mould infection was significantly lower in ventilated storage structure than traditional non-ventilated structure. The discolouration of bulbs from white to yellow, which was measured as per hedonic scale, was highest in traditional non-ventilated storage structure and it was lowest in top and bottom ventilated double row storage structure.

The visual quality of the bulbs in 10 - point scale was highest (6.25) in top and bottom ventilated double row structure. In Hawaii, the dried bulbs are held in a cool, dry, and well-ventilated area in paper or mesh bags, and normally remain in good condition for one to two months at 20-30^o C. Garlic odor can be readily transferred to other fruit, vegetables, and other food products; hence, it needs to be stored separately. The symptoms of the end of storage life include clove shriveling due to water loss, soft and spongy texture, and in some cases, a waxy appearance. A waxy appearance is common when the preharvest weather is hot during harvest, bulbs are exposed to the sun during curing in the field or after harvest, and there is poor ventilation during curing and storage. The waxy cloves are yellow amber and later become translucent, waxy, and sticky, with the scales showing no symptoms. If the storage area is not dry and has a high relative humidity, a number of diseases can occur including Blue mold, Black mold and Grey mold.

El-Sayed G. Khater *et al* (2006) found that under traditional storage system recorded was 36.89 % compared with 12.33 % for the garlic stored in ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. Lawande and Tripathi (2019) and Tripathi and Lawande (2019) concluded that among various storages structures tested, structure with bottom and side ventilation of 10, 25, and 50 tons capacity are recommended. The higher temperature controlled storage (25^{o}C +- 5^{o}C) and 65 +- 5% relative humidity may be good option for tropical region. Although, there will be 15-20% storage losses for a period of 4-5 months. This storage with force ventilation and moisture control system may be a cheaper option. This may be suitable for both on farm and community storage. There is need to design and evaluate force ventilated controlled atmosphere storage structures.

Low temperature Storage

Postharvest life of garlic bulbs can be considerably extended up to 9 months by storage at about 32° F (0° C) and 60-70% relative humidity. Tripathi and Lawande (2007) studied effect of gamma -irradiation and cold storage on storage losses in garlic. It was found that cold storage of garlic reduced physiological weight loss and infection due to diseases. These losses were much less than ambient stored garlic even after 5 months of storage. Unirradiated cold stored garlic showed rapid sprouting during post cold storage period but this low temperature induced sprouting was not noticed in gamma irradiated cold stored garlic. Overall, the gamma irradiation followed by cold storage minimized the storage losses by 15 % to 20 % and increased the shelf life of garlic. The highest total losses (77.4%) were recorded in unirradiated cold stored garlic bulbs after 230 days of storage. This treatment was statistically at par with the unirradiated ambient stored bulbs (74.5%).

The lowest storage losses were found in gamma irradiated cold stored bulbs, which were 54.8 %, and this treatment was significantly lower than all other treatments. Storage losses in ambient stored gamma irradiated bulbs were 64.8 % and this treatment was statistically better than unirradiated ambient and unirradiated cold stored bulbs. Volk *et al.* (2004) reported that the response to cold-storage conditions was cultivar dependent. Several chemical parameters were investigated in 'red' variety garlic irradiated to inhibit sprouting, with doses of 30 Gy and kept under warehouse conditions. The studies were conducted between 210 and 270 days post harvest (critical marketing periods) when this variety was not normally available for raw consumption. It was found that, during storage, the irradiated garlic showed a significant increase in ascorbic acid content but no change in dry matter content compared with non-irradiated garlic.

Compared with non-irradiated garlic, at 270 days' storage, the irradiated garlic had a higher index of flavour, measured as enzymatic pyruvate, a higher acidity and a lower content of water-soluble carbohydrates. From these observations, the irradiated garlic should be suitable for prolonged storage with the object of marketing it during critical periods (Curzio *et al*., 1986). Purwanto *et al.* (2019) studied the effect of storage temperature on the quality of garlic during storage under Bogor conditions in local garlic variety, i.e. Lumbu Kuning . The bulbs were stored at different temperature storage conditions, i.e. 0°C; 7°C (RH 50-70%, darkness), and a room temperature (29-31°C, RH 70-80%) for 6 months. The results revealed that highest weight loss was found from the bulbs stored at 7°C (25.08%), followed those stored at the room temperature (18.76%) and 0°C (10.47%). The highest sprouting percentage occurred in those stored at 7°C (25.16%). El-Sayed G. Khater *et al* (2022) studied the effect of storage system (cold, ventilated and traditional) and package type on the quality of garlic during storage under Egyptian condition.

The results indicated that, the total accumulated weight loss increases with increasing the storage period. The traditional storage system recorded was 36.89 % compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags.

Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. In Ethiopia, it was found that storage at ^{0}C and 60% relative humidity can prolonged storage period. The higher temperature shortened the storage life. Adequate air flow and proper storage containers are important to remove transpired heat and moisture. Otherwise, higher relative humidity provides suitable conditions for development of mold and root growth,

In the Bajio region of Mexico, six batches of 360 bulbs of garlic cv. Perla were stored for 190 days at 0 °C, 0 °C and 70% relative humidity (RH), 5, 20, 30 °C, and at room temperature (RT) (17.7 ± 7 °C). The weight loss and internal sprouting index had a negative correlation on the subjective firmness, penetration resistance, and hue of the cloves. Storage at 5 °C, 20 °C, and RT induced sprouting, and subsequent growth had an effect on a loss of firmness and color. Complete sprouting (>100%) induced a weight loss of 9–11% at these temperatures. In order to maintain an adequate safety margin for marketing, we propose an internal sprouting index of 50% to determining the effective shelf life of garlic cv. 'Perla'. In accordance with this criterion and in conditions studying, shelf life at 0 °C was 155 days; at 5 °C and RT it was 80 days; and at 20 °C it was 60 days.

These results lead us to conclude that it is possible to estimate the shelf life of garlic using the internal sprouting index (Vázquez-Barrios *et al.*, 2006). Bahnasawy and Dabee (2006) studied the effect of storage system (cold, ventilated and traditional) and package type on the quality of garlic during storage. The results indicated that, the total accumulated weight loss increases with increasing the storage period. Storage system had a great effect on the losses, where, the traditional storage system recorded was 36.89 % compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage.

The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. • The total accumulated weight loss recorded was 36.89 % for the garlic stored traditionally, compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage.

Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. • The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system (Ibrahim *et al.*, 2018). All these studies suggested that post-harvest life of garlic bulbs can be considerably extended up to 9 months by storage at about 32° F (0° C) and 60-70% relative humidity with good ventilation in vented bins or mesh bags. There are approved chemicals or gamma irradiation may be used to inhibit sprouting.

The storage losses in garlic is tropical regions are high. Lot of attempts have been made to reduce the losses. Several research findings have shown that the losses cab be reduced. But the storage conditions, climatic conditions, cost of storage, poor adoption of the research findings are the main impediments. There is still needs to develop the cost effective technologies for the garlic storage in tropics.

REFERENCES

Anonymous, 2022. *Website of Ministry of Agric and Farmer's Welfare*, Govt of India, New Delhi.

Atashi, S, Akbarpour, V, Mashayekhi, K, Mousavizadeh, S J. 2011. Garlic physiological characteristics from harvest to sprouting in response to low temperature. *J. Stored Products Postharvest Research* **2**: 285 - 291.

Ayyoubi,Z, and Sharabi,N E. 1993.Effect of gamma radiation on garlic storage under natural conditions. *AEC*. 17 p.

Bahnasawy, A. H. and Dabee, S. A. 2006. Technological Studies on Garlic Storage. https:/ /www. research gate. net/publication/265683989 Technological Studies on Garlic Storage (accessed May 01 2024).

Bahnasawy, A H and Dabee, SA.2006. Technological Studies on Garlic Storage. The *1st Conference of the Agricultural Chemistry and Environment Protection Society*, Ain Shams university, 5 - 7 December, 2006.

Bonginwar, D R and Shirsat, S G.2000.Demonstration Food irradiation facilities for prevention of losses due to sprouting in onion/garlic by use of gamma irradiation at Lasalgoan in Nasik district of Maharashtra. *National Symposium on Onion-Garlic: Production and Post-Harvest Management. In: Challenges and Strategies*. Souvenir, pp. 33-42.

Brewster, J L. 1994. Onions and other vegetable Alliums, *CAB International, UK*,p.236

Cantwell, M I. 2004. Garlic. Recommendations for maintaining postharvest quality. http:/ postharvest .ucdavis.edu/Produce/Produce Facts.

Choudhary, Kavita, Choudhary, M R, Garhwal , O P and Chahar Seema .2017.Effect of sowing date and sulphur levels on growth and yield of garlic (Allium sativum) . *Current Horticulture* **6**(2): 48–51.

Croci, C A and Curio, O A .1983. The influence of gamma irradiation on storage life of red variety of garlic. *J. Food Proc. Preser*.**7**:17.

Curzio, O A, Croci, C A and Ceci, L N. 1986. The effects of radiation and extended storage on the chemical quality of garlic bulbs. *Food Chemistry* **21**(2):153-159.

Curzio, O A. 1982. Sprout inhibition in garlic (*Allium sativum*) and onion (*Allium cepa* L.) by gamma irradiation. *Coordinated programme on pre-commercial scale radiation treatment of food. Final report*, Nov.1980–Oct.1981. International Atomic Energy Agency, Vienna (Austria) : p.26.

Curzio, O A and Urioste, A M. 1994. Sensory quality of irradiated onion and garlic bulbs. *J. Food Proc. Preservation.* : **18**(2) :149-158.

Elke Bloem , Silvia Haneklaus and Ewald Schnug. 2011. Storage Life of Field-Grown Garlic Bulbs (*Allium Sativum* L.) as Influenced by Nitrogen and Sulfur Fertilization. *J. Agricultural and Food Chemistry* **59** (9): 4442-47.

El-Mougy, N S, El-Gamal, N G and Abdel-Kader, M M .2009. Pre-storage application of some essential oils and food preservatives against black mould incidence of garlic cloves during storage . *Archives of Phytopathology and Plant Protection* **42**(11): 1059-1068.

El-Sayed G Khater, Adel H Bahnasawy, Doha M Ibrahim. 2022. Shelf life and quality of garlic as influenced by storage conditions. https://www.researchgate.net/publication/361943383 (Accessed on April20,2024)

Engeland, R L. 1992. Filaree farms: *Description of named strain: Filaree Farms*, Okanogan, Wash pp.21-40.

FAOSTAT .2022. FAO website

Fei, M L, Tong, L I Wei, L I and De Yang, L. 2015. Changes in antioxidant capacity, levels of soluble sugar, total polyphenol, organosulfur compound and constituents in garlic clove during storage. *Industrial Crops and Products* **69**: 137-42.

Hardenburg, R E.1986.The commercial storage of fruits, vegetables and florist and nursery stocks, USDA,ARS ,*Agriculture Handbook* No.66,p.59.

Ibrahim I El-Oksh, Adel S Abdel-Kader, Yussuf A Wally, and Ahmed F El-Kholly.1971. Comparative Effects of Gamma Irradiation and Maleic Hydrazide on Storage of Garlic. *J. Amer. Soc. Hort. Sci.* **96** (5):637-640.

Ibrahim, Doha M , Bahnasawy, Adel H, and El-Sayed G Khater.2018. Effect of storage condition and package type on the quality of garlic during storage. *Misr J. Ag. Eng.* **35** (2): 587 – 602.

Iglesias Enriquez, I and Fraga, R. 1998. Suitable packaging and storage methods for postharvest preservation of garlic irradiated and unirradiated. *Alimentaria* (295): 91-96.

Kambiz Mashayekhi, Siamak Mohammadi Chiane , Manizheh Mianabadi , Farshid Ghaderifar and Seyyed Javad Mousavizadeh .2015. Change in carbohydrate and enzymes from harvest to sprouting in garlic. *Food Science & Nutrition* **4**(3):370-376**.**

Lawande, K E and Tripathi, P C. 2019. On farm storage of onion and garlic: success story. *Proc. International symposium on Edible alliums: Opportunities and challenges*. DOGR, Pune, pp 197-207.

Lawande, K E and Tripathi, P C. 2014.Garlic *In Managing Post Harvest Quality and losses in Horticultural Crops(Eds)* Dr. K. L. Chadha and Dr. R. K. Pal, Daya Publishing House, New Delhi.Vol **3**:643-63.

Maini, S B and Chakravatri, A K. 2000 Post Harvest management of onion and garlic. *National Symposium on onion-Garlic: production and post harvest management. Challenges and Strategies.* Souvenir, p 24-32

Mann, L.K. and D.A. Lewis. 1956. Rest and dormancy in garlic, *Hilgardia* **26**(3):161-189.

NHRDF. 1997. Garlic cultivation in India, *Technical Bulletin 2* , NHRDF, Nasik, pp 52.

Nina Kacjan Marsic, Marijan Necemer, Robert Veberic, Natasa Poklar Ulrih, Mihaela Skrt.2019. Effect of cultivar and fertilization on garlic yield and allicin content in bulbs at harvest and during storage. *Turkish J. Agric. &Fores. Sc.* **43**(4): 414-429.

Park, M H ,Shin,D B and Kim,J P.1988. Studies on cold resistance of garlic bulbs at subzero temperature. *Korean Journal of Food Science & Technology* **20**(2): 200-204.

Purwanto, Y A, Sobir, Sulassih, N, Naibaho, S and Pratama Nurmalia Y. 2019. Effects of temperature on the quality of Garlic (*Allium sativum* L) cv. Lumbu Kuning during Storage. *IOP Conf. Series: Earth and Environmental Science* 309, 012004 IOP Publishing doi:10.1088/1755-1315/309/1/012004.

Ratanamarno, S and Supa, C. 2015. Pre-harvest treatment for sprouting inhibition and storage temperature for garlic (*Allium sativum* L.). *Acta Hortic.* **1088**: 449-452.

Rivlin, R S. 2001. Historical perspective on the use of garlic. *J. Nutr.* **131**:951S–954S

Sankar, V , .Lawande, K E and Tripathi , P C. 2005. Mother clove selection in garlic-A Review . *Spice India* **18** (9):30-33.

Sankar, V , Lawande , K E and Tripathi, P C.2008. Effect of micro irrigation practices on growth and yield of garlic (*Allium sativum* L.) Var. G-41. *J. Spice & Aromatic plants.***17**(3): 230-234.

Sankar,V, Tripathi, P C, .Qureshi, A A and Lawande, K E. 2004. Organic seaweed extract for garlic cultivation. *Spice India.***17** (10):2-3.

Shadia Ismail A, Nadia Ibrahim M, Amany Abdel-Latif A. 2019. Effect of foliar application of potassium silicate and some postharvest treatments on growth, productivity and storability of garlic. *Arab Universities Journal of Agricultural Sciences* **27**(1):761-773.

Sharma Akhilesh, Sharma, K C, Singh, Yudhvir and Pathania, N K.2010. Effect of pre-harvest treatments and indigenous practices on enhancing storage life of garlic (*Allium sativum*). *Indian J. Agric. Sc.,***80** (1): 72–75.

Song, J C ,Park,N K ,Yoon,I W, Lee,Y I, Cho,B H ,Kwon,S H, Lee,Y A and Han,P J .1986.Studies on the prevention of browning during the garlic storage sealed in polyethylene film bag. *Research Reports of the Rural Development Administration Plant Environment, Mycology and Farm Products Utilization* **28**(1): 152-57.

Takagi. 1990. Allium sativum. In: J.L. Brewster and H.D. Rabinowitch, Editors, *Onions and Allied Crops: Biochemistry Food Science and Minor Crops vol. III, CRC Press, Boca Raton, FL*, pp. 109-158.

Thanki J D and Patel C L .2010. Response of Moisture Regimes and Herbigation on Storage of Garlic Bulbs in Gujarat. *Green Farming* **1**(5): 495-496.

Tripathi , P C , Lawande, K E and Mahajan, V. 2002. Garlic Cultivation (In Hindi). *Technical Bulletin No.5* NRC Onion and Garlic, Rajgurunagar, pp32.

Tripathi, P C , Sankar, V and Lawande, K E. 2013 . Medicinal and theuraptic value of garlic. *Spice India*. **26** (12):14-16.

Tripathi, P C and Lawande, K E. 2004.Storage of onion and garlic (in Hindi). *Technical Bulletin No.10* . NRC Onion and Garlic, Rajgurunagar, pp20.

Tripathi, P C and Lawande, K E. 2006. Cold storage of onion and garlic. *Technical Bulletin* No.15 Published by NRC Onion and Garlic, Rajgurunagar, pp 8.

Tripathi, P C and Lawande, K E. 2007.Sceintific storage of garlic (In Hindi).*Phal- Phool* 29(6):22-25.

Tripathi, P C and Lawande, K E.2009. Effect of storage environment & packing material on storage losses in garlic. *Indian J. Hortic*. **66** (4):511-515.

Tripathi, P C and Lawande, K E. 2007. Effect of cold storage and gamma-irradiation on storage losses in garlic. *J. Spices and Aromatic Plants* **17** (1):23-26

Tripathi, P C and Lawande, K E. 2008. Intercropping in sugarcane with onion and other vegetables under different planting and irrigation systems. *Indian J. Agric. Sc.* **78**(1):78-81.

Tripathi, P C and Lawande, K E. 2015. Designing and evaluation of onion storage structures for Indian conditions. *Intl. J. Agric.* Sci.**6**(2):918-24.

Tripathi, P C , Sankar, V and Lawande, K E. 2007. Post harvest studies in Onion and Garlic , *Final report of the project,* NRC OG, Rajgurnagar, Pune, pp.62.

Tripathi, P C , Jadhav, H M, Qureshi, A A, Sankar, V , Mahajan, V and Lawande, K E. 2021. Morphological and biochemical properties of garlic (*Allium sativum* L.) collections. *Journal of Spices and Aromatic Crops* **30**(1):81-89.

Tripathi, P C, Sankar, V and Lawande, K E. 2017. Micro irrigation in onion (*Allium cepa*) and garlic (*A. sativum*)- A Review. *Current Horticulture* **5**(1): 3-14.

Tripathi, P C and Lawande, K E. 2019. Onion storage in tropical region - A Review. *Current Horticulture* **7**(2):15-27.

Vazquez-Barrios, M E, Lopez-Echevarria, G Mercado-Silva, E, Castano-Tostado, E , and Leon-Gonzalez. F.2006. Study and prediction of quality changes in garlic cv. Perla (*Allium sativum* L.) stored at different temperatures. *Sci. Hortic.* **108**:127-132.

Volk, G M, Rotindo, K E and Lyons, W. 2004. Low-temperature storage of garlic for spring planting. *Hort Science* **39**(3): 571-573**.**

Warade, S D and Shinde, K G 1998.Garlic, *In Hand book of vegetable science and technology* (Salunkhe and Kadam, S.S., Eds) Marcel Dekker, Inc, New York, pp: 397-413.

Woodward, P W1996. Garlic and friends: the history, growth and use of edible Alliums. Hyland House , Melbourne.

Research Article

Current Horticulture **13**(1): 35–41, January–March 2025

DOI: 10.5958/2455-7560.2025.00004.7

Received: 03 December 2023; Accepted: 11 November 2024

Evaluation of short-duration cassava (*Manihot esculenta*) cropping system for profitability, energy efficiency and soil restoration

G Suja[1*], J Sreekumar[1], S Sunitha[1] and Jacob John[2]

[1]*ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India*

Abstract

A two-year field experiment was conducted at ICAR-CTCRI, Thiruvananthapuram, Kerala, India, to assess the possibility of nutrient saving and develop viable short-duration cassava cropping system during 2013-15. Rice (*Oryza sativa* L.) var. Aiswarya was sown during the first season, followed by greengram [*Vigna radiata* (L.) R. Wilczek.] (var. Co-Gg-7), blackgram [*Vigna mungo* (L.) Hepper] (var. Co-6) and soybean (*Glycine max* (L.) Merr.) (var. JS-95-60). Thereafter, short-duration cassava was planted in split plot design with two varieties, Sree Vijaya and Vellayani Hraswa, in main plots and combination of three preceding pulses and two fertility levels to cassava (full farmyard manure (FYM), N and K (FYM @ 12.5 t/ha, NPK @ 100:0:100 kg/ha); half FYM and N, full K (FYM @ 6.25 t/ ha, NPK @ 50:0:100 kg/ha) in subplots. Rice-pulse-short-duration cassava was productive, profitable, energy efficient and nutrient saving. Both varieties were suitable for crop intensification. During first year, pulse crops were equally compatible. In subsequent year, greengram proved superior. By the second year, pH, organic C, available N, P and K were not significantly affected, but available N, P and K status was higher under pulses. The tuber yield of cassava (30.82 t/ha), tuber equivalent yield (47.39 t/ ha), production efficiency (131.63 kg/ha/day), energy equivalent (234.07 x 10^3 MJ/ha) and profit (additional profit of ₹ 95,758/ha over sole cassava) were higher for rice (var. Aiswarya)-blackgram (var. Co-6)-short-duration cassava (var. Sree Vijaya) system at the reduced fertility level, resulting in a saving of half FYM and, N and full P.

Key words: Diversification, Cassava-based system, Tuber equivalent yield, Economics, Energy efficiency

Cassava (*Manihot esculenta* Crantz) plays a significant role in food and nutritional security (Sunitha *et al.*, 2024). It is the primary staple food for more than 800 million people in the world, mostly in the poorest tropical countries (Lebot, 2019). The normal duration of cassava is 9-24 months and most of the varieties give the maximum targeted yield at 10-12 months. Presently much emphasis is given to crop diversification, to increase productivity, especially under climate change (Nedunchezhiyan *et al.*, 2022). Hence there is a preference for early-maturing varieties of cassava (6-7 months) as a sequential crop. Short-duration cassava varieties proved promising for better utilization of resources, diversification of food basket and income (Suja *et al.*, 2010a; Suja *et al.*, 2010b; Suja *et al.*, 2011; Suja and Sreekumar, 2015).

The practice of growing a grain-or forage-legume like cowpea, peanut, pigeonpea, velvet bean, *Centrosema pubescens*, *Indigofera hirsuta* and *Pueraria phaseoloides* prior to cassava and incorporation of forages and crop residues into the soil was reported to improve soil fertility and yield of normal duration cassava cv. Mcol 1684 (Howeler, 2012). The intercropping of legumes and groundnut and vegetables like cucumber (*Cucumis sativus*), okra (*Abelmoschus esculentus*) and *Amaranthus* (*Amaranthus viridis*) reduced the yield of cassava of 10-month cycle (Prabhakar *et al.,* 1983; Mohankumar and Ravindran, 1990).

Earlier studies indicated that sequential cropping of vegetable cowpea followed by short-duration cassava was a profitable production system (Suja and Sreekumar, 2015). However, information on cropping systems involving short-duration cassava in rice (*Oryza sativa*)-based system is limited. Hence, an experiment was conducted to develop feasible cropping system involving short-duration cassava and pulses in rice-based system, to assess the scope for nutrient saving and evaluate growth dynamics, yield, soil productivity, system productivity, profitability and energy equivalent of the system.

MATERIALS AND METHODS

The field experiment was conducted during May-June for two consecutive years (2013-2015) at ICAR-CTCRI, Thiruvananthapuram, Kerala (8° 29'N, 76° 57'E, 52 m altitude. The site experiences a typical humid tropical climate. The total rainfall, maximum temperature, minimum temperature and relative humidity during the crop growth period during the first and second years were 1649 and 2046 mm, 31.37 and 31.46°C, 23.90 and 23.76°C and 76.31 and 78.94% respectively. The soil is a well-drained acid Ultisol with pH 4.65 and is characterized

***Corresponding author :** sujagin@yahoo.com

[2]Integrated Farming System Research Station, Kerala Agricultural University, Karamana, Thiruvananthapuram, Kerala

by low available N (145.30 kg/ha), high available P (26.50 kg/ha), medium available K (155.35 kg/ha) and organic C (0.75%) contents.

Rice var. Aiswarya was sown during first season, followed by short-duration greengram (var. Co-Gg-7), blackgram (var. Co-6) and soybean (var. JS-95-60). Thereafter short-duration cassava was planted. The experimental design followed was split plot, with two cassava varieties, Sree Vijaya and Vellayani Hraswa, in main plots and combination of three preceding pulses and two fertility levels to cassava [F1:full FYM, N and K ((FYM @ 12.5 t/ha, NPK @ 100:0:100 kg/ha); F2: half FYM and N, full K ((FYM @ 6.25 t/ha, NPK @ 50:0:100 kg/ha)] in subplots. Sole crop of cassava under full dose of manures and fertilizers were also maintained for comparison. The pulse crop was fertilized with P and cassava was not given P. The gross plot size was 5.4 m x 5.4 m (36 plants), accommodating 16 net plants of cassava.

Aiswarya (PTB 52), a medium-duration rice variety (120-125 days maturity) is resistant to blast and blight diseases, and brown planthopper (KAU, 2016). Sree Vijaya is an early maturing variety with 6-7 months duration. Vellayani Hraswa is a high-yielding early variety with 5-6 months duration. Co-Gg-7 is a short duration greengram variety that matures in 60-65 days. Co-6 is a short duration blackgram variety that matures in 60-65 days. JS-95-60 is an extra early culture that matures in 82-88 days.

Rice var. Aiswarya was sown on 15 May 2013 and 1 June 2014 directly under dry condition at a spacing of 20 cm x 15 cm. The agro-techniques and nutrient management practices were followed according to package of practices recommendation of KAU (KAU, 2016). After the harvest of rice crop in September, pulse crops were sown on 21 September and 8 October respectively during the two years at a spacing of 30 cm x 15 cm and seed rate of 20 kg/ha. Pulse crops were fertilized with NPK @ 20:30:30 kg/ha. Full dose of P and K and half N were applied basally at sowing and the remaining half N was applied 15-20 days after sowing (DAS). Pulse crops were harvested by 75-80 days and short-duration cassava varieties were planted in mounds spaced 90 cm x 90 cm on 11 December 2015 and 29 December 2016. Farmyard manure as per treatments was applied to cassava at the time of planting. For cassava, as per treatment, half N and K were applied immediately after sprouting of cassava setts. After one month, the remaining quantities of N and K were applied along with weeding and earthing up. Cassava was harvested at 6 months after planting.

Biomass measurements were taken 2, 4 and 6 months after planting by uprooting three cassava plants at random per plot at each stage. Plants were then separated into leaves, stems and tubers, air dried and then oven dried at 70°C to constant weight and dry weight of each plant part was recorded and the total plant dry weights were computed and expressed as g per plant. The tuber biomass and total biomass production of cassava at harvest were also calculated and expressed as t/ha. From values of dry matter, various growth indices were computed using growth analysis techniques (Hunt, 1982). These were: crop growth rate (CGR), tuber bulking rate (TBR), relative growth rate (RGR), mean TBR and harvest index (HI).

The yield of rice and pulses were taken and expressed in t/ha. At harvest, the fresh tuber yield of cassava was computed in t/ha based on the data taken from the net plants. The dry matter and cyanogenic glucoside contents of cassava tubers were determined by standard procedures (Indira and Sinha, 1969). Based on the yield of the component crops, tuber equivalent yield and production efficiency and energy equivalent yield were worked out (Devasenapathy *et al.*, 2009).

Total cost of cultivation and gross returns were calculated from average input cost and labour cost for all operations and average market price of the produce, respectively during the period of investigation. Based on this net income and benefit:cost ratio (B:C ratio) were computed as follows:

Net income (₹/ha)=gross income−gross cost of cultivation

B:C ratio=gross income ÷gross cost

Soils were sampled at 0-15 cm depth after harvesting of the crop every year. Three samples were collected per plot. The soil samples were air-dried and sieved through 2-mm sieve before analysis and stored in plastic covers. The soils were analyzed for pH (1:2.5 soil: water suspension) using pH meter with glass electrode, organic carbon by Walkley and Black rapid titration method (Walkley and Black, 1934) available N by alkaline permanganate method (Subbiah and Asija, 1956), available P content was determined by Bray I method as described by Jackson (1973) and readings were taken in spectrophotometer and available K (in neutral 1 N ammonium acetate extract) using a flame photometer.

Two-way analysis of variance (ANOVA) for split plot design (analysing the data from different years separately) was carried out to compare treatment differences for different plant and soil parameters using SAS statistical software (SAS, 2010). The critical difference (CD) test was used at the 0.05 level of significance to compare the treatment means.

RESULTS AND DISCUSSION

Biomass production and growth dynamics

During first year, main effect of pulse was significant for tuber biomass and mean TBR, with soybean outperforming. The interaction effect between pulse and fertility level was significant for tuber biomass at 2 MAP, total biomass at 4 MAP and tuber and total biomass at 6 MAP (Fig.1). The total biomass production and its partitioning to leaf, stem and tuber at 2 and 4 MAP was higher when blackgram preceded and cassava was fertilized at the full dose. By 6 MAP (harvest stage) these attributes were favoured when soybean preceded and cassava was fertilized at the full dose (Fig. 1). At harvest, total and tuber biomass production, crop growth rate, tuber bulking rate, mean tuber bulking rate, relative growth rate and harvest index of short-duration cassava were significantly higher when soybean preceded and cassava was fertilized at the full dose (Table 1, Figs. 1, 2). As expected, pulse crops prior to cassava were beneficial for its growth compared to sole cassava.

During subsequent year, at 2 MAP, total dry matter production and its partitioning to leaf, stem and tuber were higher in cassava fertilized at reduced level of fertility and preceded by blackgram. Thereafter, sole cassava outperformed over different cropping systems (Fig. 1). At harvest, tuber biomass production (14.24 t/ha) and total biomass production (19.37 t/ha) of sole cassava was higher, which was on a par with cassava under reduced level of fertility preceded by blackgram (BG + F2) (10.04, 15.91 t/ha respectively) (Table 1). The CGR, TBR and HI of sole cassava was higher throughout different stages (Fig. 2). Mean TBR of blackgram + F1 (5.25 g/day) and soybean + F1 (5.48 g/day) were on a par with sole cassava (5.28 g/day) (Table 1). In first phase (2-4 MAP), RGR of cassava in systems preceded by all the pulses was equivalent to sole cassava. In second phase (4-6 MAP), RGR of cassava in systems preceded by blackgram and greengram was similar to that of sole cassava (Fig. 2). This indicates the scope of sequential cropping of rice, pulses and cassava.

Rice-pulse-short-duration cassava proved to be feasible. Both Vellayani Hraswa and Sree Vijaya were suitable for sequential cropping. During first year, greengram, blackgram and soybean were equally compatible in rice-based cropping systems involving short-duration cassava. In subsequent year, greengram proved superior and exerted significant impact on cassava tuber yield. There was a possibility to save half FYM and N and full P to short-duration cassava, especially when blackgram and greengram preceded cassava.

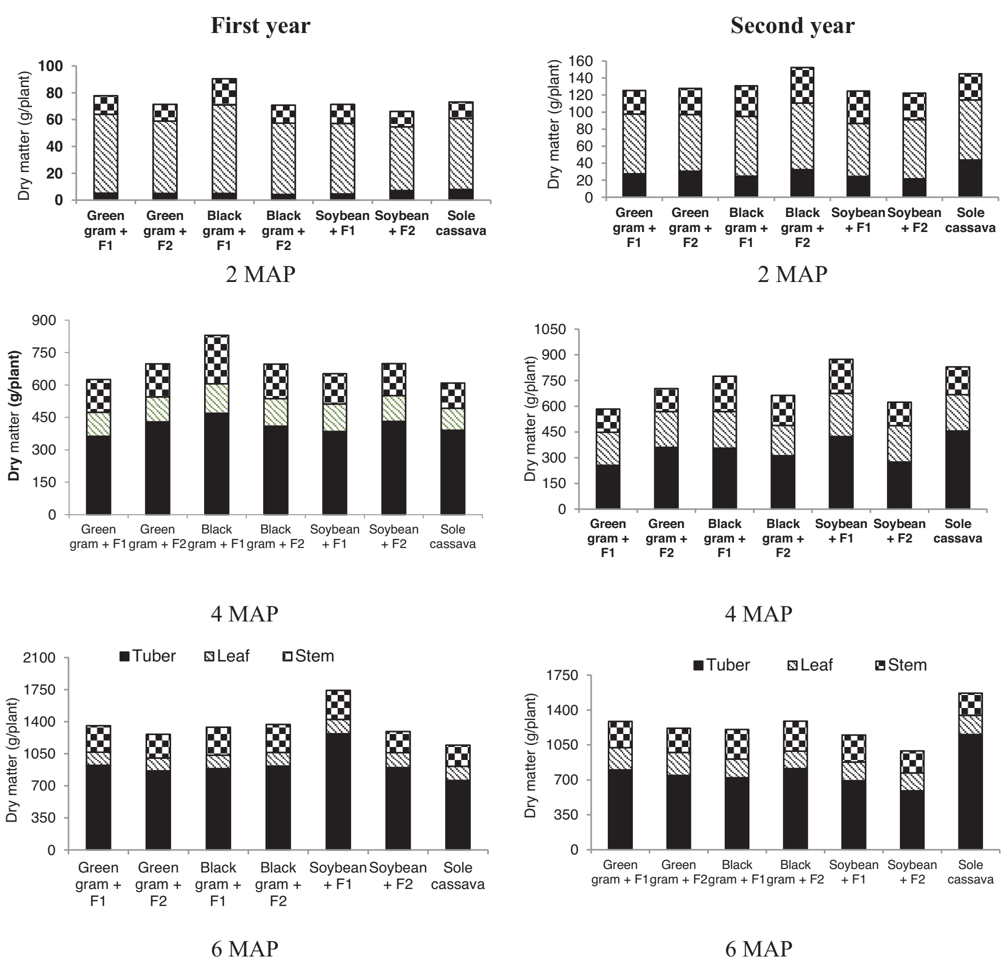

Fig. 1: Interaction effect between pulse crops and fertility levels on biomass production and partitioning at various phases in cassava

Table 1: Interaction effect between pulse crops and fertility levels on biomass production of cassava

Interaction effect between pulse and fertility level	Tuber biomass (t/ha)		Total biomass (t/ha)		Mean tuber bulking rate (g/day)	
	First year	Second year	First year	Second year	First year	Second year
Greengram + F1	11.41	9.88	16.74	15.87	5.14	4.28
Greengram + F2	10.66	9.19	15.59	15.02	4.80	4.60
Blackgram + F1	10.98	8.92	16.53	14.87	4.94	5.25
Blackgram + F2	11.30	10.04	16.91	15.91	5.09	4.87
Soybean + F1	15.64	8.53	21.51	14.20	7.04	5.48
Soybean + F2	11.10	7.28	15.95	12.22	4.99	4.25
Sole cassava	9.37	14.24	14.11	19.37	4.22	5.28
CD (p=0.05)	2.865††	4.736†	4.039††	5.631†	1.289††	0.165††

†Control vs treatment; †† pulse x fertility level

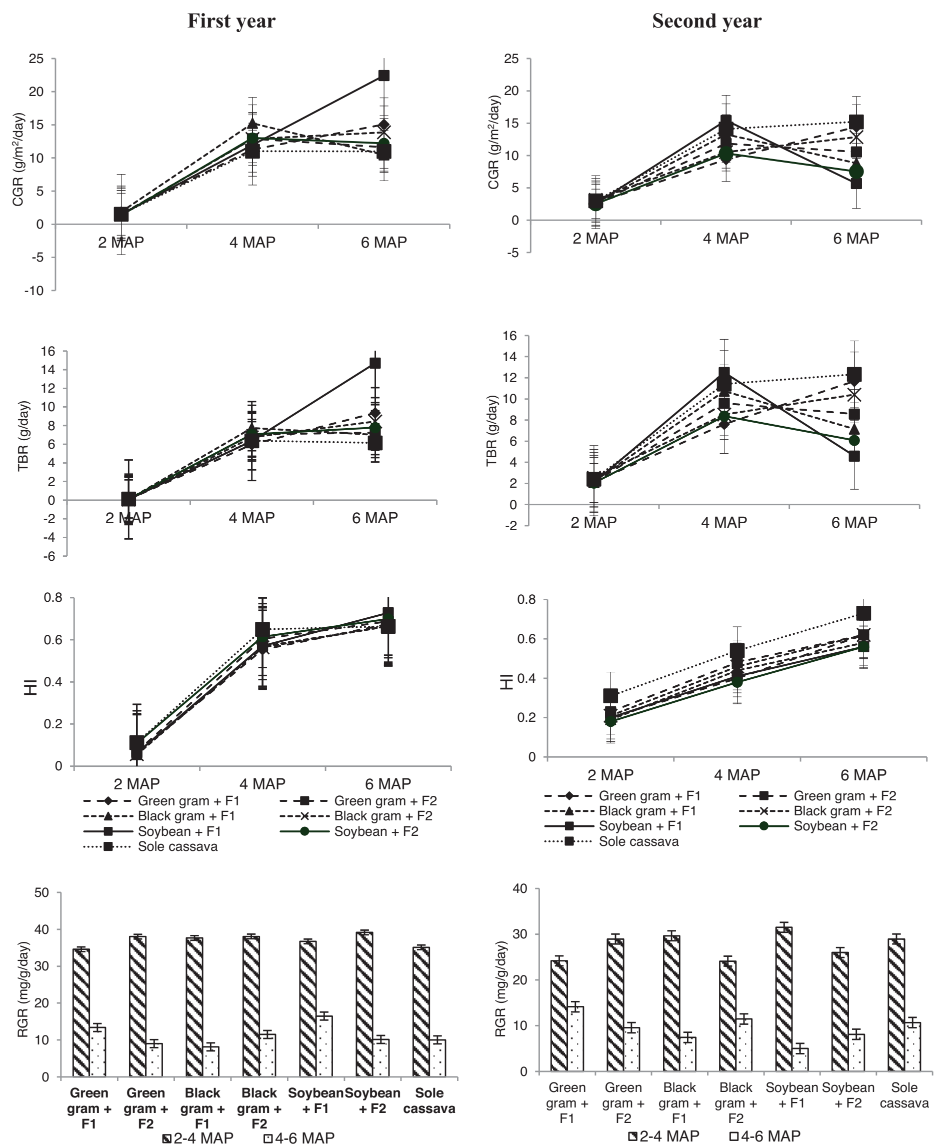

Fig. 2: Growth parameters of cassava at various stages as affected by pulse crops and fertility levels

Yield, and quality of cassava

The control vs treatment was significant for tuber yield during both years, number of tubers in first year and mean weight of a tuber in second year (Table 2). During first year, rice-blackgram-short duration cassava at reduced fertility level resulted in highest yield on a par with sole cassava (both varieties). This may be due to the significantly higher number of tubers produced and almost similar mean tuber weight in above system. Moreover, cassava crop might have benefitted from residual nitrogen fixed by blackgram as well as organic matter added by blackgram residues after its harvest as reported by Njoku and Muoneke (2008) in cowpea-cassava system. However, in the subsequent year, sole cassava out yielded, followed by rice-greengram/blackgram-short duration cassava. This might be due to significantly higher mean weight of tuber in sole cassava due to lack of resource constraints. The tuber length, tuber girth, dry matter and cyanogenic glucoside content of tubers remained unaffected due to cropping systems and fertility levels. This indicates there is a scope for crop diversification involving sequential cropping of pulses and cassava in rice-based systems (Table 2).

Table 2: Effect of cropping systems on yield, yield attributes and quality of short-duration cassava

Cropping systems and fertility levels	Tuber yield (t/ha)		No. of tubers		Mean weight of a tuber (kg)		Tuber length (cm)	Tuber girth (cm)	Tuber dry matter content (%)	Cyanogenic glucoside (μg/g)
	First year	Second year	First year	Second year	First year	Second year				
R-GG-SV (F1)	29.98	26.97	11	9	0.227	0.232	23.22	19.88	36.10	45.9
R- GG-SV (F2)	27.96	25.15	8	10	0.270	0.206	25.22	15.33	39.75	27.2
R- BG-SV (F1)	33.28	24.34	10	10	0.280	0.204	26.33	16.67	36.74	27.7
R- BG-SV (F2)	34.78	26.86	10	10	0.287	0.222	25.78	16.00	35.00	26.4
R- SB-SV (F1)	30.07	25.85	8	8	0.291	0.246	24.22	15.66	39.40	47.4
R- SB-SV (F2)	30.14	21.19	7	7	0.331	0.233	26.11	16.89	39.52	41.4
R-GG-VH (F1)	27.17	26.65	6	7	0.370	0.351	30.22	17.33	43.84	24.9
R- GG-VH (F2)	33.43	26.11	7	7	0.386	0.294	29.22	17.11	36.39	40.5
R- BG-VH (F1)	25.51	22.07	7	6	0.314	0.264	28.33	16.11	41.84	29.1
R- BG-VH (F2)	29.18	24.34	7	7	0.328	0.281	29.89	15.89	44.29	38.4
R- SB-VH (F1)	33.32	16.02	6	4	0.490	0.285	29.11	17.33	44.10	24.0
R- SB-VH (F2)	22.80	15.45	6	5	0.324	0.221	26.89	14.44	41.61	36.6
Sree Vijaya (sole)	29.83	32.49	8	8	0.298	0.325	26.77	17.44	35.96	41.8
Vellayani Hraswa (sole)	31.47	34.95	7	6	0.384	0.450	27.33	17.89	43.45	41.8
CD (p=0.05)	7.622	3.36	1.325	NS	NS	0.033	NS	NS	NS	NS

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Greengram, *BG* Blackgram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Gbanguba *et al.* (2014) also reported that cultivating rice after harvesting cassava + legume intercropping, enhanced soil fertility and had beneficial effects on growth and productivity of rice crop.

System productivity and profitability

Averaging over two years, tuber yield of cassava (30.82 t/ha), tuber equivalent yield (47.39 t/ha), production efficiency (131.63 kg/ha/day) and energy equivalent (234.07 x 10^3 MJ/ha), were higher for the system, rice (Aiswarya)-blackgram (Co-6)-short-duration cassava (Sree Vijaya) (at reduced fertility level) (Table 3). The above system was productive, profitable (additional profit of ₹ 95,758/ha over sole cassava), energy efficient and nutrient saving (could save half FYM and N and full P to short-duration cassava) (Table 4). This corroborates the earlier findings that vegetable cowpea or grain cowpea in sequence before short-duration cassava is a viable proposition than sole cassava (Suja and Sreekumar, 2015).

Table 3: System productivity, tuber equivalent yield, production efficiency and equivalent energy of cropping systems involving short-duration cassava vs sole cassava (mean of two years)

Cropping system and fertility level	System productivity			Tuber equivalent yield (t/ha)				Production efficiency (kg/ha/day)	Equivalent Energy (*10^3 MJ/ha)
	Rice (t/ha)	Pulse (kg/ha)	Cassava (t/ha)	Rice	Pulse	Cassava	Total		
R-GG-SV (F1)	4.34	727.24	28.48	10.85	4.24	28.48	43.57	121.02	217.77
R-GG-SV (F2)	4.10	715.30	26.56	10.25	4.17	26.56	40.98	113.83	204.13
R-BG-SV (F1)	4.20	1177.09	28.81	10.50	6.38	28.81	45.69	126.91	223.34
R-BG-SV (F2)	4.23	1108.68	30.82	10.57	6.01	30.82	47.39	131.63	234.07
R-SB-SV (F1)	4.05	757.63	27.96	10.13	4.10	27.96	42.19	117.19	211.92
R-SB-SV (F2)	3.98	720.25	25.67	9.94	3.90	25.67	39.50	109.73	197.77
R-GG-VH (F1)	4.32	710.08	26.91	10.79	4.14	26.91	41.84	116.22	208.52
R-GG-VH (F2)	4.07	709.25	29.77	10.16	4.14	29.77	44.06	122.40	221.63
R-BG-VH (F1)	4.32	1025.33	23.79	10.80	5.55	23.79	40.14	111.51	194.81
R-BG-VH (F2)	3.98	930.38	26.76	9.94	5.04	26.76	41.74	115.94	206.37
R-SB-VH (F1)	4.25	705.58	24.67	10.63	3.82	24.67	39.12	108.66	195.18
R-SB-VH (F2)	4.11	687.75	19.13	10.28	3.73	19.13	33.13	92.01	162.31
Sree Vijaya (sole)			31.16			31.16	31.16	86.56	174.50
Vellayani Hraswa (sole)			33.22			33.22	33.22	92.28	186.03

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Green gram, *BG* Black gram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Table 4. Economics of cropping systems involving short-duration cassava vs sole cassava (mean of two years)

Cropping system and fertility level	Net returns (₹/ha)	Added profit (₹/ha)	B:C ratio
R-GG-SV (F1)	374386	11614	2.80
R- GG-SV (F2)	345422	-17351	2.70
R- BG-SV (F1)	428215	65443	3.06
R- BG-SV (F2)	458531	95759	3.26
R- SB-SV (F1)	362836	63.63	2.74
R- SB-SV (F2)	329894	-32879	2.63
R-GG-VH (F1)	349295	-44377	2.68
R- GG-VH (F2)	392478	-1194	2.93
R- BG-VH (F1)	342567	-51105	2.64
R- BG-VH (F2)	377654	-16019	2.86
R- SB-VH (F1)	314103	-79570	2.51
R- SB-VH (F2)	232381	-161291	2.15
Sree Vijaya (sole)	362772		4.47
VellayaniHraswa (sole)	393672		4.76

R Rice, *SV* Sree Vijaya, *VH* Vellayani Hraswa, *GG* Greengram, *BG* Blackgram, *SB* Soybean, *F1* full dose of FYM and NPK, *F2* half dose N, full FYM, P and K

Soil nutrient status

Chemical analysis of soil samples in first year, after rice crop, indicated that the pH was 4.851, organic C was medium (0.62) and available N and K contents, low and P content, high (65.54, 34.91 and 54.51 kg/ha). After the second crop of pulse, on an average, pH did not change (4.84), but there was improvement in organic C, available N and P and considerable increase in K status of the soil (0.87%, 84.31, 54.95, 193.16 kg/ha respectively). After short-duration cassava, interaction, pulse x fertility level, which is more important in the present study, was significant for pH, organic C and available P. The pH and available P status was significantly higher under full nutrient dose, when black gram preceded cassava. Greengram when preceded cassava could enhance the organic C status significantly under full nutrient dose. Available N and K were not affected by the various treatments. However, it can be seen that taking a pulse crop before cassava could maintain a higher available K status.

By second season, pH, organic C, available N, P and K was not significantly affected, but available N, P and K status was higher under cropping systems involving pulses. Gbanguba *et al.* (2014) also observed higher soil organic carbon, total N, available P, K, secondary nutrients such as Ca and Mg and cation exchange capacity under cassava-legume association relative to natural fallow. Thus, it can be concluded that growing pulses before short-duration cassava helped maintain soil fertility and impact was more pronounced with blackgram, which may be due to its greater biomass production.

CONCLUSION

Thus, rice-blackgram-short-duration cassava was productive, profitable and energy efficient, besides maintaining soil health. The system will also help to diversify our food basket and achieve self-sufficiency in pulse production in India.

REFERENCES

CTCRI. 2019. *Tuber Crop Varieties Released by ICAR-Central Tuber Crops Research Institute*. Technical Bulletin Series No. **77**. ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. 6p.

Devasenapathy P, Senthilkumar G and Shanmugam P M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**(1): 80-90.

Gbanguba A U, Kolo M G M, Odofin A J and Gana A S. 2014. Performance of rice grown after cassava/legume intercrops at Badeggi in the Southern Guinea Savanna Ecological Zone of Nigeria. *Rice Research* **3**: 129. doi:10.4172/2375-4338.1000129.

Howeler R. 2012. Soil fertility maintenance: Organic solutions. In *The Cassava Handbook: a Reference Manual based on the Asian Regional Cassava Training Course*, held at Thailand, Bangkok, The Nippon Foundation, CIAT.

Howeler R. 2014. Sustainable soil and crop management of cassava in Asia-a reference manual. Centro Internacional de Agricultura Tropical (CIAT), Cali, Columbia. 280p.

Hunt R. 1982. *Plant Growth Curves: The Functional Approach to Plant Growth Analysis*. Arnold Publishers, London.

Indira P and Sinha S K. 1969. Colorimetric method for the determination of HCN in tuber and leaves of cassava (*Manihot esculenta* Crantz). *Indian Journal of Agricultural Sciences* **39** (11): 1021-23.

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd.

KAU 2016. *Package of Practices Recommendations: Crops*, Directorate of Extension, Kerala Agricultural University, Mannuthy, Thrissur.

Lebot V. 2019. *Tropical Root and Tuber Crops: Cassava, Sweetpotato, Yams and Aroids,* 2nd Edn. Crop Production Science in Horticulture Series, CABI International, United Kingdom, 544p.

Mohankumar C R and Ravindran C S 1990. Economics of intercropping short-duration legumes and vegetables with cassava. *Journal of Root Crops*, ISRC Nat Symp 1990, Special: 120-22.

Nedunchezhiyan M, Suja G and Ravi V. 2022. Tropical root and tuber crops based cropping systems – a review. *Current Horticulture*, **10**(1): 14-22.

Njoku D N and Muoneke C O. 2008. Effect of cowpea planting density on growth, yield and productivity of component crops in cowpea/cassava intercropping system. *Journal of Tropical Agriculture, Food, Environment and Extension* **7**:106–13.

Prabhakar M, Mohankumar C R and Nair G M. 1983. Intercropping vegetables with cassava. *Journal of Root Crops* **9**(1-2): 21-26.

SAS 2010. SAS Users Guide. SAS Institute Inc. Cary, North Carolina, USA.

Subbiah B V and Asija L L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-60.

Suja G and Sreekumar J. 2015. Crop diversification with short-duration cassava (*Manihot esculenta*) in the humid tropics for agronomic and economic benefits. *Indian Journal of Agricultural Sciences* **85**(12): 1619-25.

Suja G, Susan John K, Sreekumar J and Srinivas T. 2010a. Short-duration cassava genotypes for crop diversification in the humid tropics: Growth dynamics, biomass, yield and quality. *Journal of the Science of Food and Agriculture* **90**: 188-98.

Suja G, Susan John K and Sreekumar J. 2010b. Soil test based nutrient management for short-duration cassava (*Manihot esculenta*). Analysis of growth, biomass, yield, quality, nutrient uptake and soil nutrient status. *Indian Journal of Agronomy* **55**: 66-72.

Suja G, Susan John K and Sreekumar J. 2011. Impact of nutrient management based on soil test data on biomass production and partitioning and growth indices of short-duration cassava (*Manihot esculenta* Crantz). *Indian Journal of Agricultural Sciences* **81**:.247-51.

Sunitha S, Sheela M N, Suresh Kumar J and Makeshkumar T. 2024. Morphological and physiological responses of CMD resistant cassava (*Manihot esculenta*) genotypes to nutrient regimes. *Current Horticulture* **12**(2): 33-37.

Walkley A and Black J A. 1934. An examination of the Degtijareff method for determining soil organic matter and a proposed modification of the chromic acid filtration method. *Soil Science* **37:** 93-100.

Current Horticulture **13**(1): 42–45, January–March 2025
DOI: 10.5958/2455-7560.2025.00005.3
Received: 11 November 2023; Accepted: 19 July 2024

Effect of soil and soilless media on biochemical composition of lettuce (*Lactuca sativa*) cultivars under open condition

Thushal R Y, Awani Kumar Singh*, Gograj Singh Jat, Jeetendra Kumar Ranjan, Ram Asrey and Gyan Prakash Mishra

ICAR- Indian Agricultural Research Institute, New Delhi, India.

Abstract

A study was carried out at the Centre for Protected Cultivation and Technology (CPCT), ICAR- IARI, New Delhi, during 2022-23 to find out the effect of soil and soilless media on agro-morphological characters, yield, and economics of lettuce (*Lactuca sativa* L.) varieties in open conditions. The experiment was set up in a factorial randomized block design with 3 replications. Various biochemical traits including total soluble solids (5.31 ^{0}Brix), antioxidant activities (40.99 DPPH inhibition %), respiration rate (2.88 ml CO_2/kg/h), moisture content (83.98 %), chlorophyll content (3.05 mg/g FW), total carotenoid content (1.10 mg/g FW) and ascorbic acid content (16.55 mg/100g) of different lettuce genotypes were higher in soil media compared to soilless media (cocopeat). Thus, it can be inferred that soil serves as a suitable medium for cultivation of lettuce varieties.

Key words*:* Soil, Lettuce, Open condition, Biochemical composition, Moisture content, Respiration rate

Lettuce (*Lactuca sativa* L.) is one of the most consumed vegetables across the world. It is an annual crop belonging to the family Asteraceae with chromosome number 2n=18. World production of lettuce is 27 million tonnes and China leads with 53% of production (FAO, 2023). In India, lettuce is widely grown in the northern part of the country, especially in Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. The growing medium is a substrate or potting soil or any substance other than soil used to cultivate its plants. Numerous materials can be used to make a growing medium, such as sawdust, peat, rice husk, perlite, cocopeat and vermiculite (Douglass *et al*., 2009; Rahman *et al*., 2019). Lettuce can be grown in soil (traditional system) and soilless media. Soil-based techniques may be highly productive but the relative use of water may be high due to runoff and infiltration. As a result, the relative water-use efficiency will be lower. Soilless techniques offer a way of improving water-use efficiency and obtaining better water management in its production.

Hence, an attempt was made to compare the effect of soil and soilless media on agro-morphological, yield, and economics of lettuce production under open cultivation.

MATERIALS AND METHODS

The experiment was conducted at CPCT, ICAR-IARI, New Delhi from November 2022 to March 2023. The region has a sub tropical climate, with an average maximum temperature of 17.9^0 C, an average minimum temperature of 9.9^0 C and annual rainfall is around 33.70 mm. A total of 16 genotypes were obtained from ICAR-NBPGR, New Delhi and private sector. The seeds were initially sown in 98-cell trays and later transplanted to the main field after one month. The experiment was designed according to the factorial randomised block layout, with three replications at 50 cm × 20 cm spacing. The plot size was 2.0 m × 2.0 m.

The total soluble solids (TSS) (^{0} Brix), antioxidant activity (DPPH inhibition %), respiration rate (ml CO_2/kg/h), moisture content (%), chlorophyll content (mg/g FW), total carotenoid content (mg/g FW), and ascorbic acid content (mg/100g) were measured.

The refractometer was used to estimate the TSS by dripping the extract onto the detector, and the readings were duly recorded. The antioxidant activity was determined through the DPPH assay described by Blois in 1958 and Desmerchelier *et al*. in 1997. The DPPH assay involved dissolving 2,2-diphenyl-1-picrylhydrazyl (DPPH) in 100% ethanol to a concentration of 200μM, followed by sonication for 5 minutes to stabilize the free radical DPPH. The test compound was then diluted in a 1:1 ratio with the DPPH solution in a 96-well microplate, with appropriate controls in each series.

Fresh DPPH solution was prepared daily. Leaf samples weighing 0.5g were crushed with 5 ml of 70% ethanol, and centrifuged for 20 minutes, and 0.1 ml of the sample extract was mixed with 3.9 ml of DPPH solution, followed by a 30-minute incubation in the dark. The absorbance was measured after 25 minutes using a microplate spectrophotometer at 517 nm.

Inhibitor ratio = (AC-AS/AC) ×100,
where AC is the OD of DPPH, AS is the OD of the sample

*Corresponding author : singhawani5@gmail.com

The moisture content of samples was assessed utilizing the procedure outlined by Ranganna (2007). About 5g samples were extracted and weighed together with the container, with the initial weight being documented. Subsequently, samples were subjected to drying at 65°C until reaching a consistent weight, and the final weight was recorded. The moisture content was then computed using the subsequent formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Fresh weight}} \times 100$$

The 40g leaf samples were finely chopped and placed in a plastic container. Subsequently, top lid was securely sealed with paraffin film to prevent any air from escaping. The CO_2 and O_2 levels were then measured for each sample, and the respiration rate was determined using a specific formula:

$$\text{Respiration Rate (ml } CO_2\text{/kg/h)} = \frac{CO_2 \times \text{head space}}{\text{Fresh weight}}$$

The levels of chlorophyll and total carotenoids were determined post-harvest through the utilization of dimethyl sulfoxide (DMSO) technique. About 100 mg of leaf fragments were ground with 20 ml of DMSO. Subsequently, samples were placed in an oven at 65°C for 4 hours in the dark until the cap exhibited a white colour. Following this, centrifugation at 16000xg for 15 minutes was conducted to obtain the supernatant. The optical density of extract was then gauged at 645, 663, and 470 nm with DMSO serving as the blank. The quantification of chlorophyll and total carotenoids was carried out using a specific formula:

Chlorophyll a = $(12.7 \times OD_{663}) - (2.69 \times OD_{645})\ V \times 1/1000 \times W$

Chlorophyll b = $(22.9 \times OD_{645}) - (4.68 \times OD_{663})\ V \times 1/1000 \times W$

Total chlorophyll= $(20.2 \times OD_{645}) - (8.02 \times OD_{663})\ V \times 1/1000 \times W$

Total carotenoids = $(1000 \times OD_{470}) - (3.29 \times \text{Chl. a}) - (104 \times \text{Chl. b})/198$

The concentration of ascorbic acid was determined through a titrimetric technique employing 2, 6-dichlorophenol indophenol dye. A 5 g leaf sample was blended in 50 ml of HPO_3. The mixture was then filtered using Whatmann No.1 filter paper. Subsequently, a 10 ml portion was transferred to a conical flask and titrated with the dye until a pink colour emerged. The findings were denoted as milligrams of ascorbic acid per 100 grams of the sample.

Ascorbic acid content =

$$\frac{\text{Titration value} \times \text{dye factor} \times \text{Volume made up (ml)}}{\text{Aliquot (ml)} \times \text{weight or volume of sample (g)}} \times 100$$

The statistical analysis of data was performed using R 3.4.1 software (InQuest Data Analytics, Bengaluru). Significance was determined by calculating F values and P values ≤0.05.

RESULTS AND DISCUSSION

All the biochemical compositions of lettuce genotypes grown under open conditions showed better performance in soil than in soilless media (Table 1). The soil-grown lettuce exhibited slightly higher levels of TSS (5.31 ^{0} Brix), antioxidant activity (40.99 DPPH inhibition %), respiration rate (2.88 ml CO2/kg/h), moisture content (83.98 %), chlorophyll content (3.05 mg/g FW), total carotenoid content (1.10 mg/g FW), and ascorbic acid content (16.55 mg/100g) compared to that lettuce grown in soilless media. This can be attributed to soil that provides more nutrients, resulting in a greater biochemical composition in plants. These findings align with those of Pace *et al.* (2018). However, our results contradict the findings of Majid *et al.* (2021) regarding TSS and chlorophyll, as well as the research conducted by Gonnella *et al.* (2020) on chlorophyll and total carotenoid content, and Buchanan and Omaye (2013) on ascorbic acid content.

Within leafy-type cultivars, Romaine II exhibited the highest TSS, moisture content, and chlorophyll content; Lollo Rossa showed the highest level of ascorbic acid, aligning with the research conducted by Selma *et al.* (2012) but specifically in soilless growing conditions. Red Romaine exhibited the greatest antioxidant activity. Red Salad showed a higher respiration rate, while Oak Leaf Red had the lowest TSS. Tango had the lowest antioxidant activity and ascorbic acid content. Oak Leaf Green had the lowest respiration rate. New Red Fire had lowest moisture content. Red Rose had a lower chlorophyll content. Romaine I and Harit Baigani had the lowest total carotenoid content among leafy types. Among head types, Butterhead Green had the highest TSS, antioxidant activity, and ascorbic acid contents.

Great Lakes had highest chlorophyll and total carotenoid content. Iceberg Salista had highest respiration rate, while lowest TSS was found in Great Lakes. Iceberg Salista had lowest antioxidant activity. Butterhead Green had the lowest respiration rate, moisture content, chlorophyll content, and total carotenoid content. Iceberg Crispiano had the lowest ascorbic acid content. Parikh *et al.* (2023) also recorded excellent quality parameter in turmeric crop when grown under soil conditions along with spray of organic liquids. Poonia *et al.* (2024) also recorded excellent

Table 1 Effect of growing media on biochemical composition of lettuce genotypes

Treatment	Total soluble solids/TSS (^{0} brix)			Antioxidant activity (DPPH inhibition %)			Respiration rate (ml CO_2/kg/h)			Moisture content (%)			Chlorophyll content (mg/g FW)			Total carotenoid content (mg/g FW)			Ascorbic acid content (mg/100g)		
	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean	M_1 (Soil)	M_2 (Soilless)	Mean
V_1 – Romaine I	4.33	4.15	4.24	24.16	24.01	24.09	2.22	2.04	2.13	82.32	82.13	82.06	2.17	2.12	2.15	0.39	0.34	0.37	12.37	12.22	11.35
V_2 – Romaine II	7.82	7.64	7.73	23.07	22.92	22.99	2.77	2.59	1.56	88.07	87.88	87.98	4.34	4.29	4.32	1.13	1.08	1.11	16.34	16.19	14.42
V_3 – Tango	4.60	4.42	4.51	23.03	22.88	22.96	2.87	2.69	2.78	86.53	86.34	86.44	4.26	4.21	4.24	0.88	0.83	0.86	11.22	11.07	11.15
V_4 – Oak Leaf Green	5.13	4.95	5.04	26.01	25.86	25.94	2.21	2.03	1.11	84.86	84.67	82.72	4.16	4.11	4.14	0.79	0.74	0.77	20.17	20.02	19.99
V_5 – Grand Rapids	6.53	6.35	6.44	33.21	33.06	33.14	3.64	3.46	3.55	84.13	83.94	83.55	3.18	3.13	3.16	0.57	0.52	0.55	16.24	16.09	13.79
V_6 – Harit Baigani	6.13	5.95	6.04	34.56	34.41	34.49	3.24	3.06	3.15	83.38	83.19	83.29	2.28	2.23	2.26	0.44	0.40	0.42	11.51	11.36	10.94
V_7 – Oak Leaf Red	3.23	3.05	3.14	52.39	52.24	52.32	2.73	2.55	2.64	83.44	83.25	83.35	3.02	2.97	2.99	1.39	1.34	1.37	16.43	16.28	13.55
V_8 – Red Romaine	4.07	3.89	3.98	62.89	62.74	62.82	2.72	2.54	2.63	83.17	82.98	83.08	2.23	2.18	2.21	1.28	1.23	1.26	11.99	11.84	11.26
V_9 – Lollo Rossa	4.53	4.35	4.44	61.29	61.14	61.22	3.51	3.33	3.42	93.22	93.03	91.64	4.24	4.19	4.22	1.25	1.19	1.22	26.46	26.31	23.34
V_{10} – New Red Fire	6.53	6.35	6.44	29.66	29.51	29.59	3.11	2.93	1.64	81.86	81.67	81.77	2.12	2.07	2.10	1.18	1.15	1.16	21.93	21.78	20.23
V_{11} – Red Salad	4.73	4.55	4.64	62.16	62.01	62.09	3.67	3.49	3.58	81.82	81.63	81.23	2.11	2.06	2.09	2.27	2.22	2.25	16.43	16.28	16.36
V_{12} – Red Rose	5.33	5.15	5.24	63.06	62.91	62.99	2.25	2.07	2.16	81.02	80.83	81.16	2.02	1.97	1.99	2.11	2.06	2.09	21.99	21.84	19.31
V_{13} – Iceberg Salista	5.33	5.15	5.24	33.99	33.84	33.92	3.43	3.25	3.34	83.25	83.06	82.19	3.16	3.11	3.14	0.98	0.93	0.96	12.89	12.74	12.82
V_{14} – Iceberg Crispiano	5.73	5.55	5.64	35.42	35.27	35.35	2.74	2.56	1.63	81.73	81.54	81.64	3.11	3.06	3.09	0.96	0.91	0.94	15.27	15.12	13.76
V_{15} – Butterhead Green	6.27	6.09	6.18	56.16	56.01	56.09	2.27	2.09	2.18	81.48	81.29	80.81	2.88	2.83	2.86	0.86	0.81	0.84	16.76	16.61	15.59
V_{16} – Great Lakes	4.66	4.48	4.57	34.72	34.57	34.65	2.71	2.53	2.62	83.48	83.29	83.39	3.56	3.51	3.54	0.99	0.94	0.97	16.74	16.59	15.09
Mean	5.31	5.14	5.22	40.99	40.84	40.91	2.88	2.70	2.79	83.98	83.79	83.51	3.05	3.00	3.03	1.10	1.00	1.10	16.55	16.40	15.18

quality parameters in tomato crop using the plant growth regulators.

CONCLUSION

The biochemical composition of lettuce genotypes grown in soil were rich in total soluble solids, antioxidant activity, moisture content, chlorophyll, total carotenoid, ascorbic acid and other essential nutrients, due to presence of nitrogen, phosphorus, potassium, and other micronutrients in soil that are crucial for the growth and development of the plant. Additionally, soil provides a stable and supportive structure for the roots of lettuce plants, allowing them to access water and nutrients efficiently. Overall, the findings of this research highlight the importance of soil as a key factor in successful lettuce cultivation, and emphasize the benefits of utilizing soil as the primary medium for growing lettuce.

REFERENCES

FAO, Rome 2023. Lettuce (with chicory) production in 2021; Countries/ Regions/ Production Quantity from pick lists. *UN Food & Agriculure Organization, Statistics Division (FAOSTAT).* Retrieved 12 April 2023.

Blois, M.S. 1958. Antioxidant determinations by the use of a stable free radical. *Nature* **181**: 1199-200.

Buchanan, D.N. and S.T. Omaye 2013. Comparative study of ascorbic acid and tocopherol concentrations in hydroponic- and soil-grown lettuces. *Food and Nutrition Sciences* **4**(10): 1047-53.

Desmarchelier, C., M.J. Novoa Bermudez, J. Coussio, G. Ciccia, and A. Boveris 1997. Antioxidant and prooxidant activities in aqueous extracts of Argentine plants. *International Journal of Pharmacognosy* **35**(2): 116-20.

Douglass, F. J., Thomas D., L., and Tara, L. 2009. Nursery manual for native plants: A Guide for Tribal Nurseries **1**: 302.

Gonnella, M., M. Renna, and F. Serio (2020). Yield and quality of greenhouse multi-leaf lettuce cultivars grown in soil and soilless culture under Mediterranean conditions. *Italus Hortus* **27**: 18-30.

Kim, M.J., Y. Moon, J. Tou, B. Mou, and N. Waterland (2016). Nutritional value, bioactive compounds and health benefits of lettuce (*Lactuca sativa* L.): study review. *Journal of Food Composition and Analysis* **49**: 19-34.

Majid, M., J.N. Khan, Q.M.A. Shah, K.Z. Masoodi, B. Afroza, and S. Parvaze, (2021). Evaluation of hydroponic systems for the cultivation of Lettuce (*Lactuca sativa* L., var. *Longifolia*) and comparison with protected soil-based cultivation. *Agricultural Water Management* **245**: 106572.

Oh, M.M., H.N. Trick, and C.B. Rajashekar (2009). Secondary metabolism and antioxidants are involved in environmental adaptation and stress tolerance in lettuce. *Journal of Plant Physiology* **166**(2): 180-91.

Pace, B., I. Capotorto, M. Gonnella, F. Baruzzi, and M. Cefola, (2018). Influence of soil and soilless agricultural growing system on postharvest quality of three ready-to-use multi-leaf lettuce cultivars. *Advances in Horticultural Science* **32**(3): 353-62.

Parikh, R.P., P.P. Bhalerao, P.P. Bhalerao, and S.J. Patil (2023). Effect of foliar application of organic liquids on yield and quality of turmeric (*Curcuma longa*). *Current Horticulture* **11**(1): 30–32.

Poonia S, S. Choudhary, S.K. Moond, M. Ram, and R. Kuri. (2024). Effect of PGRs on growth, reproductive efficiency, and quality of tomato (*Solanum lycopersicum*) in arid regions. *Current Horticulture* **12**(1): 81–85.

Rahman, J., R. Ahasan Chawdhery, P. Begum, M. Quamruzzaman, M. Zannat Zakia, and A. Raihan, (2019). Growth and yield of hydroponic Lettuce as influenced by different growing substrates. *Azarian Journal of Agriculture,* 6(1): 215-220. https://doi.org/10.29252/azarinj.001

Ranganna, S. 2007. Handbook of analysis and quality control for fruits and vegetable products. Tata McGraw-Hill.

Selma, M.V., M.C. Luna, A. Martínez-Sánchez, J.A. Tudela, D. Beltrán, C. Baixauli, and M.I. Gil 2012. Sensory quality, bioactive constituents and microbiological quality of green and red fresh-cut lettuces (*Lactuca sativa* L.) are influenced by soil and soilless agricultural production systems. *Postharvest Biology and Technology* **63**(1): 16-24.

Siomos, A.S., G. Beis, P.P. Papadopoulou, P. Nasi, I. Kaberidou, N. Barbayiannis, E. Maloupa, and D. Gerasopoulos 2001. Quality and composition of lettuce (cv.'Plenty') grown in soil and soilless media. *Acta Horticultirae* **548**: 445-49.

Current Horticulture **13**(1): 46–49, January–March 2025
DOI: 10.5958/2455-7560.2025.00006.X
Received: 13 July 2023; Accepted: 19 September 2024

Effect of growing systems on yield and quality of lettuce (*Lactuca sativa*) under subtropical climatic condition

Anand Sahil1[*#], SR Singh[*], AK Singh[#] and Sonu Kumar[1]

[1]*ICAR-Central Institute for Subtropical Horticultural Research, Lucknow, Uttar Pradesh, India*

Abstract

The study was carried out to indentify suitable growing system for higher yield of lettuce (*Lactuca sativa* L.) at ICAR-CISH, Lucknow during 2021-22. The experiment was conducted with two growing, aeroponic and geoponic systems. Five lettuce varieties were sown in portray by using mixture combination of coco peat, vermiculite, and perlite in a 3:1:1 ratio. After 30 days, plants were transplanted in both aeroponic and geoponic systems. The maximum yield (181.90 q/ha) was found in aeroponic system followed by geoponic system (144.73 q/ha). However, vitamin C content and total carotenoid content were non significantly highest (12.09mg/100g) and (6.13) in geoponic system respectively. Chlorophyll 'a' (0.70 mg/g FW) was observed in geoponic system, while chlorophyll 'b' (0.119 mg/g FW) under aeroponic system.

Key words: Growing system, Growth, Yield, Quality, Subtropical climate

Lettuce (*Lactuca sativa* L.), of Asteraceae family and chromosome (2n=2x=18), is most significant leafy vegetable crops worldwide. Recently, greenhouses have broadened its cultivation methods to encompass soilless techniques like aeroponics, alongside traditional soil-based methods (Koukounaras, 2021). In recent decades, there has been a notable shift from soil cultivation to soilless systems for lettuce production, offering various benefits. These include shortened growth cycles, enabling multiple harvests per year, precise control over nutrient solutions to reduce nitrates in the final product, the capability to incorporate essential trace elements crucial for human nutrition, and the potential for shelf-life extension (Gordana *et al.*, 2022). Additionally, the system shows promise in nutrient and water recycling, mitigating climate change effects, enhancing production, and decreasing pest and soil disease incidences (Gashgari *et al.*, 2018). The main differences between conventional cultivation and hydroponics growing system are water and nutritional supply availability (De Souza *et al.*, 2019). Hence an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at ICAR-CISH, Rehmankhera, Lucknow, during winter season to see the performance of aeroponic and geoponic systems. Lettuce crop was grown under both system during 2021-22. During first week of October 2021, seeds of lettuce cultivars, Tango, Summer Star, Grand Rapid, Bingo, and Black Rose, were sown in portray by using mixture consisting of coco peat, vermiculite, and perlite in a (3:1:1) ratio, which was sterilized using hydrogen peroxide (0.02%). The seedlings with 4-5 leaves were transplanted in both aeroponics unit and open field conditions. The aeroponics unit was set up in an automatically controlled polyhouse environment, featuring green shade netting on exterior, silver shade netting inside, along with fans, pads, and a misting system.

The aeroponic units were constructed in an A-frame configuration, measuring 1.4 m wide, 1.4 m high, and 6 m long. The planting density was upheld at 25 plants m^2 with a spacing of 20cm x 20 cm. The plants were treated with nutrient solutions CISH A and B having 3x strength (one litter each) under aeroponic system. Nutrient solution misting occurred at 30-minute intervals, with each misting session lasting for one minute.

In the auto hydroponic system, electrical conductivity (EC) of the nutrient solution was kept at 1.0 - 1.2 (mS/cm) by supplementing the tank with additional solution, while the pH of nutrient solution was 5.5 - 6.5 and 15 - 18 ^{0}C during the growing season. Flat beds measuring 2.0 m x 2.4 m were prepared for transplanting seedlings in open field conditions, with a spacing of 40cm x 40cm. Ten fully grown seedlings at of each treatment were selected randomly in each replication, to record the data.

Observations were recorded on plant height (cm), plant weight (g), plant stem diameter (mm). root length (cm), no. of leaves / plant, plant shoot weight (g), leaf length (cm), leaf width (cm), leaf weight (g), root weight(g), leaf index, yield (q/ha). For quality parameter, dry - matter content, 25g of leaf samples were dried

***Corresponding author :** anandmaharana19981998@gmail.com
[#]Present Address- ICAR- Central Horticultural Experiment Station, Vejalpur

in an oven at 60°C until reaching a constant weight (AOAC, 2005). The determination of ascorbic acid was conducted using 2,6-dichlorophenol titration method and expressed as mg/100g (AOAC, 1996). The carotenoid content was determined as per Kemmerer and Frap, (1943). Chlorophyll a, Chlorophyll b, and total chlorophyll were assessed utilizing the standard spectrophotometric method recommended by Ameel and Axler, (1998); Gowthami *et al.* (2022). The mean values of all parameters were noted. The results underwent a two-way analysis of variance (ANOVA) utilizing SPSS Statistics 19.0 to analyze the effects of cultivation systems, cultivars, and their interaction.

RESULTS AND DISCUSSION

Growth parameters

The maximum plant height (27.11 cm) was recorded under aeroponic system as compared to geoponics system (22.52cm) this might be due to better aeration in root zone and better growing conditions in aeroponics. These findings are inconformity with those of Sapkota *et al.* (2019); Helaly and Darwish, (2019); Margaret *et al.* (2021). The highest weight was observed in geoponics system(325.31 g) as compared to aeroponic systems (181.80 g) due to crops growing in soil benefit from soil nutrient mineralization and microbial activity, whereas aeroponic plants depend exclusively on fertilizer addition to solution (Djidonou and Leskovar, 2019). However, non-significant difference in plant weight of hydroponic and soil grown system was observed.

It supports to those findings of Goddek and Vermeulen (2018). The highest plant stem diameter (14.66 mm) was observed in geoponics system compared to aeroponic systems due to continuous supply of nutrients in geoponics system conditions to shoot growth. These results are conformity with the findings of Qiansheng *et al.* (2018); Sarkhel *et al.* (2022). Root length (56.07 cm) was observed significantly under aeroponic system as compared with geoponics system (11.60 cm) .

This might be due to congenial environment for root growth under aeroponic owning to its high aeration. This result corroborates with findings of Qiansheng *et al.* (2018); Helaly and Darwish (2019); Agarwal *et al.* (2019). Number of leaves/plants (22.97) were found to be non - significant and geoponics system produced a more number of leaves / plants as compared to aeroponics (22.77). This might be due regular nutrient availability in soil in contrary to aeroponics intermittent misting of nutrient. The similar results had been reported by Helaly and Darwish, (2019).

Shoot weight (19.67 g) was observed significantly highest under geoponics system as compared to aeroponic system (15.00 g). growing to constant and regular availability of nutrients and water under geoponics system. Leaf length was influenced significantly with different treatment combinations and highest leaf length was recorded under aeroponic system (21.12 cm) as compared to geoponics system (19.71 cm) due to control environment under polyhouse of aeroponic system resulted for larger leaf length. The findings are in conformity with findings of Lie and Engeseth (2021). Leaf width which determines the yield of lettuce has influenced by different treatment.

The highest leaf width (18.31cm) was recorded under geoponics as compared to aeroponic (16.87cm) due to open environment of soil growing which received high light intensity more or less similar result has also been reported by Lie and Engeseth (2021). Leaf weight (290.67g) was recorded significantly maximum under geoponics system as compared aeroponic system (139.17g) due to condense environment and regular regular nutrient supply to plant under soil condition and the results corroborates with findings Sahil *et al.* (2023); Lie and Engeseth, (2021). They reported higher fresh weight of leaf soil grown lettuce as compared to aeroponics.

Significant differences on root weight in different growing system were observed and same condense environment might have played positive role for better growth and development of root Lie and Engeseth (2021); Ali *et al.* (2015); Qiansheng *et al.* (2018); Sayad and Khater, (2016). Leaf index showed significant differences in different growing system and highest leaf index was recorded under aeroponic (0.89) as compared to geoponics system (0.76) when might be due to proper maintenance of environment under polyhouse in aeroponic system. Similar findings have been reported by Kim *et al.* (1995). The total yield was observed significant differences in different growing system and the highest total yield was recorded under aeroponic system (181.90 q/ha) as compared to geoponics system (144.73 q/ha) it might be due higher plant population /unit area and proper control environment and condensive controlled environment plant population/ unit area light have played important role in yield under aeroponics similar results had been reported by Majid *et al.* (2021).

Quality parameters

The highest dry-matter content was recorded under geoponics system as compared to aeroponic system. It might be due to better assimilation of nutrient and high light intensity contribution in open conditions, Similar findings had been reported by Helaly and Darwish, (2019). The highest Vitamin C content (12.09 mg/100g) was recorded under geoponics system as compared to aeroponic system. Available of better light intensity and nutrient assimilation under soil might have enhanced then value calculated get support with findings of Lie and Engeseth, (2021). Carotenoid was observed statistically non-significant and highest total carotenoids content (6.13mg/100g) was recorded under geoponics as compared to aeroponic system (6.01 mg/100g) due to environmental effect, more or less similar findings had been reported by Lie and Engeseth (2021).

The highest chlorophyll 'a'content was recorded non-significant under geoponics (0.70 mg/g) as compared to aeroponic system (0.32 mg/g). It might be due to higher light intensity and favourable plant growth due to contant and reuse nutrient availability in soil. These findings are corroborating with findings of Lie and Engeseth (2021). There was highest chlorophyll 'b' content (0.119 mg/g) under aeroponic system as compared to geoponics system (0.083 mg/g) (Table 2). The total chlorophyll was observed statically non-significant and highest total chlorophyll was recorded under aeroponic system as compare to geoponics systems and these result in consonance with the finding or reported by Helaly and Darwish (2019).

CONCLUSION

The aeroponic system produced the highest yield of 181.90 q/ha under subtropical climatic conditions, making it the most effective method for growing lettuce and an excellent option for farmers during the *kharif* season.

REFERENCES

Agarwal A. Prakash O. Sahay D. Swati A. Dwivedi S.K. and Bala M. 2019. Performance of lettuce (*Lactuca sativa*) under different soil-less culture .*Progressive Horticulture* **51**(1):81-84.

Ali M.M., El-Sayad G.K., Samir A.A. and Zakaria A. El-H. 2015. Comparison Between Hydroponic and Aeroponic systems for Lettuce production, *Proceeding of 20th Annual confrance of Misr. Soc. Of Eng* 12dec 2015. httpsi//www.researchgate.net/publication /317561671.

Ameel J.E. Ruzycki R.P. and Axler. 1998. Analytical chemistry and quality assurance procedures for natural water sample 6th edition.

AOAC. 1996. Methods of vit. Assay. The Association of vit. p287. 3 rd edn, Chemists

AOAC. 2005. Official methods of Analysis, 18 th edn. Association of official Analytical chemists: Arlington, VA, USA.

Djidonou D. and Leskovar I.D. 2019. Seasonal Changes in growth, Nitrogen Nutrition and Yield of hydroponic Lettuce, *Hort. science* **54**(1):76-85.

Table 1: Effect of growing system on yield and yield - attributing traits of lettuce

Growing system	Plant weight(g)	Leaf length(cm)	Leaf width(cm)	Leaf weight(g)	Stem diameter(mm)	Average shoot weight(g)	Average root weight(g)	Root length(cm)	Plant height (cm)	Number of leaves	Area leaf index	Yield (q/ha)
Aeroponics	181.80	21.13	16.87	139.17	11.61	15.00	23.60	56.07	27.11	22.77	0.89	181.90
Geoponics	325.31	19.71	18.31	290.67	14.66	19.67	8.57	11.60	22.52	22.97	0.76	144.73
C D @5 %	7.07	1.00	0.83	3.00	0.57	0.83	1.32	0.79	1.13	N.S	0.05	1.64
S E(d)	3.34	0.47	0.39	1.42	0.27	0.39	0.62	0.37	0.54	0.53	0.02	0.77
S E(m)	2.36	0.33	0.28	1.00	0.19	0.28	0.44	0.27	0.38	0.38	0.02	0.55

*N.S. = non-significant

Table 2: Effect of growing systems on quality attribute of lettuce

Component	Vit. C(mg/100g)	Total carotenoids (mg/100g)	Chlorophyll 'a' (mg/g fresh weight)	Chlorophyll 'b' (mg/g fresh weight)	total chlorophyll (mg/g fresh weight)	Dry -matter content (%)
Aeroponics	12.08	6.01	0.32	0.119	0.42	6.56
Geoponics	12.09	6.13	0.70	0.083	0.40	6.82
C D @5 %	N.S*	N. S	N/S	0.009	N/S	N.S
S E(d)	0.33	0.06	0.35	0.004	0.02	0.28
S E(m)	0.23	0.04	0.25	0.003	0.01	0.19

*N.S. = Non- significant

Gashgari R., Alharbi K. Mughrbil K., Jan A. and Glolam A. 2018. Comparison between growing plants in hydroponic system and soil-based system, In Proceedings of the 4th World congress on Mechanical, Chemical, and Material Engineering, *ICMIE*, Madrid, Spain, pp. 1-7.

Goddek S. and Vermeulen. 2018. Comparison of *Lactuca sativa* growth performance conventional and RAS-based hydroponics system, *Aquaculture International*, **26**:1377-1386.

Gordana P. Rukie A. Zvezda B. and Margarita D. 2022. lettuce (*lactuca sativa* L.) the neglected vegetable in the mace donian production and trade. *Journal of Agricultural, Food and Environmental Sciences*. **76** (5) :56-62.

Gowthami L. Bhaskar V.V. and Padmaja V.V. 2022. Effect of essential heavy metals on chlororophyll and carotenoied content in tuberose (*Polianthus tuberosa*) *Current Horticulture* **10**(2): 44-47.

Helaly E.L.M.A and Darwish S.O. 2019. Effect of culture system, Aeroponic, Hydroponic and Sandy substrate on growth, yield and chemical composition of Lettuce, *Plant Archives* **19**(2) :2543-2550.

Kemmerer A. and Fraps G. 1943. Constituents of carotene extracts of plants. Industrial & *Engineering Chemistry Analytical Edition*, **15**: 714-6.

Kim H.K. Lee J.H. Lee B.S. and Chung S.J. 1995. Effect of selected hydroponic system and nutrient solutions on the grown of leaf lettuce (*Lactuca sativa,* L. *Var, Crispa*), *Journal of the Korean Society for Horticultural Science* **36**(2):151-157.

Koukounaras. 2021. Advanced Greenhouse Horticulture, New Technologies and cultivation practices. *Horticulturae* 2021, **7**(1). https://dx.doi.org/10.3390/horticulturae7010001.

Lei C. and Engeseth J.N. 2021. Comparison of growth characteristics, functional qualities, and texture of hydroponically grown and soil grown lettuce, *LWT-Food science and technology*, 150,111931. https://doi.org/10.1016/J.Iwt.2021.111931

Majid M. Khan J.N, Shah Q.M.A. Masoodi K.Z. Baseerat A. and Saqib P. 2021. Evaluation of hydroponic systems for the cultivation of lettuce (*Lactuca sativa L, Var Longifolia)* and comparison with protected soil-based cultivation, *Agricultural water management* 2021, 245. procedures for natural water samples 6 th edition.

Margaret G.S. Ernest M. Patrick N. and Deo K.2021. Effect of bat guano and rabbit urine liquid fertilizers on growthphysiognomies of *Spinacia oleracea* under hydroponics *Current Horticulture* **9**(2): 22–25.

Qiansheng L. Xiaoqiang L. Tang B. and Mengmeng G. 2018. Growth responses and root characteristics of lettuce grown in aeroponics, hydroponics and substrate culture, *Horticulturae*, **35**(4), doi:10.3390/ horticulturae 4040035.

Sahil A. Singh S.R. Kumar K. Tiwari J.N. and Mukesh N. Performance evaluation of lettuce (*Lactuca sativa* L.) growth, yield and quality under subtropical climate, *journal of agriculture and ecology.* Vol 17 https://doi.org/10.58628/JAE-2317-306

Sapkota S. Sanjib S. and Zhiming L. 2019. Effects of Nutrient Composition and Lettuce Cultivaron Crop Production in Hydroponic culture, *Horticulturae.* 5,72. doi: 10.3390/horticulturae5040072.

Sarkhel S. Kumari S. and Roy C. 2022. Evaluation of yield characters of marigold (*Tagetes* species) genotypes under summer condition in alluvial Gangetic plains of North India. *Current Horticulture* **11**(3): 59-61.

Sayed E.L. and Khater G. 2016. Effect of the ecological system on lettuce production grown under different soilless system, *Misr Journal of Agricultural Engineering* 2016, Doi:10.21608/mjae.2016.97623.

Souza D. Priscila F. Marcelo B. Zappelini, J. Carvalho D. Lara R. Joseph R. Jorge L.B. O. and Rosete P. 2019. Physiological differences of 'Crocantela' lettuce cultivated in conventional and hydroponic system, *Hortic. Bras, Brasilia.* **37**(1):101-105.

Current Horticulture **13(1): 50–54, January–March 2025**
DOI: 10.5958/2455-7560.2025.00008.2
Received: 12 November 2023; Accepted: 26 October 2024

Compatibility and enhanced efficacy of mixtures of insectopathogenic fungi and neonicotinoid insecticides: an ecofriendly strategy to combat *Aphis craccivora*

Jaydeep Halder[*] and Suraj Soni[1]

[*]*ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India*

Abstract

The black bean aphid, *Aphis craccivora,* is a sap sucking insect that feeds on leguminous vegetable crops. Both nymphs and adults suck the sap from young shoots, tender fruits, apical buds and devitalizing the plants. To control this sucking pests, different entomopathogenic fungi, *viz. Beauveria bassiana, Metarhizium anisopliae,* and *Lecanicillium lecanii,* were tested alone and their half of their recommended doses with neonicotinoids insecticides (Imidacloprid 17.8% SL, Thiamethoxam 25% WG and Acetamiprid 20% SP) against *A. craccivora* during 2022 and 2023. For both consecutive years (2022 and 2023), *L. lecanii* had the lowest median lethal time (44.29 and 46.60 h) to kill 50% of the test population, followed by *B. bassiana* (45.77 and 47.89 h) and *M. anisopliae* (46.45 and 48.27 h). Similarly, among neonicotinoids examined, Acetamiprid was the most toxic (LT_{50} = 26.39 and 28.78 h). The combination of *L. lecanii* + Acetamiprid at half of their recommended doses was found to be the most effective, leading to the lowest median lethal time of 21.85 and 22.67 h during 2022 and 2023, respectively, followed by *B. bassiana* + Acetamiprid (22.82 and 23.29 h). Combination of EPF like *B. bassiana, M. anisopliae,* and *L. lecanii* with neonicotinoids at half of their recommended concentrations are not only compatible but also synergistic in action and could be a viable ecofriendly option in the management of *A. craccivora.*

Key words: Entomopathogenic fungi, Neonicotinoids, *Aphis craccivora,* Median lethal time, Co-toxicity coefficient

Leguminous vegetables are important economic crops globally, cowpea [*Vigna unguiculata* (L.)], peas (*Pisum sativum* L.), French beans (*Phaseolus vulgaris* L.), Indian beans [*Lablab purpureus* (L.) Sweet] etc. being important ones. In India, potential yield of legume vegetables is not fully achieved. One of the key causes of its reduced output and productivity is occurrence of various biotic stresses thorough out its growth period. Insect pests alone cause 10-30 percent yield losses in vegetables (Halder *et al.,* 2018a). The black bean aphid, *Aphis craccivora* Koch (Aphididae: Hemiptera) is an important polyphagous sap-sucking insect that exclusively feed on the leguminous vegetable crops. Both nymphs and adults of aphids sip the sap from young shoots, apical buds, flowers and flower buds and even from tender fruits and devitalizing the plants. The leaves became yellowish in colour, curled, and had a leathery texture (Rai and Halder, 2023). To manage this nefarious sucking pest, Indian farmers mostly use chemical pesticides, which are frequently employed indiscriminately, and excessively. This results in development of pesticide resistance, resurgence of target insects and secondary pest outbreaks, residues in food and beverages, groundwater contamination, health risks for people, and widespread killing and decimation of non-target organisms (Halder *et al.,* 2019 and 2023).

***Corresponding author :** jaydeep.halder@gmail.com

[1]Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Due to their target specificity, self-perpetuity, and apparent environmental safety, biological insect pests control method of using various entomopathogenic microorganisms, as well as predator and parasitoid insects, are currently gaining importance in light of the negative effects of these synthetic insecticides (Roy *et al.,* 2017). The pest control potential of the entomopathogenic fungi *Beauveria bassiana* (Balsamo) Vuillemin (Hypocreales: Clavicipitaceae), *Metarhizium anisopliae* (Metchnioff) Sorokin (Hypocreales: Clavicipitaceae) and *Lecanicillium* (= *Verticillium*) *lecanii* R. Zare & W. Gams (Hypocreales: Clavicipitaceae) (Rai *et al.,* 2014a,b; Halder *et al.,* 2016 and 2018b) have been proved beyond doubt over the past decades.

There is not much information on the interactions between various entomopathogenic fungus and neonicotinoid pesticides against this pest. In order to determine whether there was any compatibility between various entomopathogenic fungi and neonicotinoid pesticides, an attempt was undertaken to determine the median lethal time (LT_{50}). In an analogous way, relative lethal toxicity was estimated for various entomopathogenic fungi and neonicotinoids with a focus on changes in susceptibility over time, in order to evaluate the emergence of resistance, if any.

MATERIALS AND METHODS

Talc-based formulations of the three entomopathogenic fungi (EPF), *viz. Beauveria bassiana*

(Balsamo) Vuillemin (Hypocreales: Clavicipitaceae) (1×10^{10} cfu/g), *Metarhizium anisopliae* (Metchnioff) Sorokin (Hypocreales: Clavicipitaceae) (1×10^{10} cfu/g) and *Lecanicillium* (=*Verticillium*) *lecanii* R. Zare and W. Gams (Hypocreales: Clavicipitaceae) were utilized at their recommended doses, *i.e.* 5 g/L of water. Proprietary insecticidal formulations of three neonicotinoids *viz.*, Imidacloprid 17.8% SL, Thiamethoxam 25% WG, and Acetamiprid 20% SP, were used @ 0.35 mL/L, 0.35 g/L, and 0.14 g/L, respectively. The effectiveness of each microbial pesticides and neonicotinoid insecticides against *A. craccivora* were evaluated alone at their above-mentioned doses as well as at half of their respective doses in a 1:1 ratio when used in conjunction/mixture.

Direct spray method The aphid infested leaves, twigs and tender pods of Indian bean, were brought from the experimental farm of the ICAR-IIVR, Varanasi (82°86′ E longitude and 25°18′ N latitude), and only viviparous apterous adults were used for bioassays. Twenty insects were placed in each petri-dish (9 cm in diameter), and under Potter's tower at 340 g/cm^2 pressure, they were sprayed directly with 1 mL of each concentration of various entomopathogenic fungi, three neonicotinoid pesticides, and their above-mentioned combinations. The aphids in sprayed petri-dishes were dried for five minutes under the fan. Fresh, uninfested, and untreated plant parts were offered as food. All bioassays were conducted in Insect Toxicology laboratory at 27±1°C temperature, a relative humidity of 70±5, and a photoperiod of 12:12 hours of light and dark. Every 12 hours, observations were taken for each case. Moribund insects were considered as dead. In January and February during both years (2022 and 2023), all experiments were carried out.

Data analysis Mortality data were corrected by Abbott's formula (Abbott, 1925) and analyzed by Probit analysis (Finney, 1971) with SAS program (version 9.2). Control mortality in almost all cases was below 10%. The median lethal time values (LT_{50}) were determined and any two values were considered significantly different if their respective 90% confidence limits (CL) did not overlap. Co-toxicity coefficient (CTC) or synergistic ratio (SR) was calculated with respect to entomopathogenic fungi as well as neonicotinoids and expressed by the following formulae:

$$\text{Co-toxicity co-efficient w.r.t. EPF} = \frac{LT_{50}\text{ value of entomopathogenic fungi alone}}{LT_{50}\text{ values of insecticide and EPF mixture}}$$

$$\text{Co-toxicity co-efficient w.r.t. neonicotinoids} = \frac{LT_{50}\text{ value of neonicotinoid insecticide alone}}{LT_{50}\text{ values of insecticide and EPF mixture}}$$

Values of CTC > 1 indicated they are compatible and synergistic in action with each other and when CTC < 1 showed that they are not compatible and antagonistic in action (Sun and Johnson, 1960; Corbel *et al.*, 2006, Halder *et al.*, 2021). Similarly, relative lethal time of all these insecticides and EPF alone and their 1:1 combination were calculated using the formula:

$$\text{Relative lethal time} = \frac{LT_{50}\text{ value during 2022}}{LT_{50}\text{ value during 2023}}$$

RESULTS AND DISCUSSION

Marked differences were observed among the three microbial insecticides alone and their 1:1 combinations with neonicotinoids. The white halo fungus, *L. lecanii*, has been proven to be the most promising entomopathogen against viviparous, apterous adults of *A. craccivora* during both the years. During 2022, a talc-based formulation of *L. lecanii* at its prescribed dose took 44.29 h to kill 50% of the test aphid population, followed by *B. bassiana* (45.77 h) and *M. anisopliae* (46.45 h). Acetampirid 20% SP was shown to be the most effective of the three neonicotinoid insecticides, with a lowest median lethal time (26.39 h) than Imidacloprid (27.43 h) and Thiamethoxam (26.82 h). The combination of *L. lecanii* + Acetamiprid was found to be the most effective, leading to lowest median lethal time of 21.85 h during 2022, followed by *B. bassiana* + Acetampirid (22.82 h), when these EPF and neonicotinoids were combined at half of their recommended doses and sprayed under a Potter's tower.

The combination of EPF and neonicotinoids (in 1:1 ratio) had a CTC > 1 value, indicating that they are compatible and work synergistically at half of their recommended doses when compared with respect to neonicotinoids or entomopathogenic fungi alone. The combinations of *M. anisopliae* + Thiamethoxam and *L. lecanii* + Acetamiprid (1:1) recorded the highest co-toxicity coefficient value (1.19) when neonicotinoid insecticide was considered as base. In enigma, combination of *L. lecanii* + Acetamiprid and *B. bassiana* + Thiamethoxam had the highest CTC (2.03) with respect to white halo fungus *L. lecanii* and *B. bassiana*, respectively, during 2022 (Table 1).

During 2023 also, the same pattern was recorded. *Lecanicillium lecanii* amongst the EPF and acetamiprid amongst the neonicotinoids were found to be the most effective. Imidacloprid had a median lethal time of 28.85 h when sprayed at the recommended dose; however a 1:1 combination with various EPF at half of each of their respective recommended doses resulted in lower LT_{50} values than Imidacloprid and EPF alone (Table 2). Similar to this, when combined with *L. lecanii*, *B. bassiana*, and *M. anisopliae*, Thiamethoxam's median lethal time values were dropped to 22.93, 23.80 and 26.11 h, respectively. In all combinations, CTC values were more than 1, showing their compatibility and potential for synergy. A consistent trend was also observed during 2023. In comparison to the three neonicotinoids, all entomopathogens exhibited a median fatal time that were considerably higher (Tables 1 and 2). Their 1:1 combo had a shorter median lethal time than either of them alone. In every instance, their combined CTC values were greater than 1, showing compatibility. A gradual change of LT_{50} over the years is evident (Table 2). The median lethal duration for *L. lecanii* was 44.29 hours in 2022, and it increased slightly to 46.60 hours in 2023.

With 2022's LT_{50} value as a base (1), 2023's median lethal durations for *L. lecanii* was 1.05 times longer. Similar to Imidacloprid, the median lethal times in 2023 was 1.05 times longer than in the base year, ranging from 27.43 to 28.85 hours within the same period. The relative lethal times for thiamethoxam were 1.09 times greater in 2023 than in the preceding year (Table 3). It's interesting to note that killing 50% of the test population required less time when EPF and neonicotinoids were combined at half of their respective recommended doses.

Table 1: Median lethal time of EPF and neonicotinoid insecticides alone and their combinations at half of the recommended doses against A. craccivora during 2022

Insecticide	Heterogenity		Regression Equation (Y=)	LT_{50} (hr)	Fiducial limit	Co-toxicity coefficient w.r.t.	
	df	χ^2				EPF	Neonicotinoid
Beauveria bassiana	3	0.153	5.798X – 4.629	45.77	50.31 – 41.64	--	--
Metarhizium anisopliae	3	1.598	5.676X – 4.462	46.45	51.14 – 42.19	--	--
Lecanicillium lecanii	3	2.714	5.204X – 3.567	44.29	49.13 – 39.92	--	--
Imidacloprid 17.8% SL	3	0.105	3.971X – 0.711	27.43	33.22 – 22.64	--	--
Thiamethoxam 25% WG	3	0.276	4.023X – 0.747	26.82	32.61 – 22.06	--	--
Acetamiprid 20% SP	3	1.004	5.012X – 2.125	26.39	30.09 – 22.41	--	--
B. bassiana + Imidacloprid	4	2.837	1.908X + 2.335	24.92	32.40 – 19.16	1.84	1.10
M. anisopliae + Imidacloprid	4	1.085	1.991X + 2.191	25.76	33.06 – 20.07	1.80	1.07
L. lecanii + Imidacloprid	4	1.039	2.449X + 1.595	24.54	29.97 – 20.10	1.81	1.12
B. bassiana + Thiamethoxam	4	5.057	1.871X + 2.462	22.59	29.35 – 17.38	2.03	1.19
M. anisopliae + Thiamethoxam	4	5.379	1.697X + 2.600	25.94	34.99 – 19.23	1.79	1.03
L. lecanii + Thiamethoxam	4	2.986	2.401X + 1.741	22.55	27.74 – 18.32	1.96	1.19
B. bassiana + Acetamiprid	4	3.312	1.907X + 2.409	22.82	32.04 – 16.26	2.01	1.16
M. anisopliae + Acetamiprid	4	6.209	1.999X + 2.265	23.32	32.34 – 16.82	1.99	1.13
L. lecanii + Acetamiprid	4	6.456	2.486X +1.669	21.85	28.14 – 16.97	2.03	1.21

Table 2: Median lethal time of EPF and neonicotinoid insecticides alone and their combinations at half of the recommended doses against *A. craccivora* during 2023

Insecticide	Heterogenity		Regression Equation (Y=)	LT_{50} (hr)	Fiducial Limit	Co-toxicity coefficient w.r.t.	
	df	χ^2				EPF	Neonicotinoid
Beauveria bassiana	3	4.479	4.641X – 2.798	47.89	52.94 – 43.34	--	--
Metarhizium anisopliae	3	0.226	5.389X – 4.074	48.27	52.68 – 44.23	--	--
Lecanicillium lecanii	3	1.569	5.123X – 3.547	46.60	51.13 – 42.47	--	--
Imidacloprid 17.8% SL	4	1.381	4.399X – 1.424	28.85	33.89 – 24.56	--	--
Thiamethoxam 25% WG	3	0.476	5.066X – 2.424	29.21	33.79 – 25.25	--	--
Acetamiprid 20% SP	4	0.182	3.526X – 0.146	28.78	35.28 – 23.48	--	--
B. bassiana + Imidacloprid	5	5.291	2.646X + 1.277	25.51	30.85 – 21.09	1.88	1.13
M. anisopliae + Imidacloprid	4	0.183	4.341X – 1.159	26.25	31.63 – 21.78	1.82	1.10
L. lecanii + Imidacloprid	4	5.729	2.418X + 1.628	24.81	30.42 – 20.23	1.93	1.16
B. bassiana + Thiamethoxam	4	1.829	2.597X + 1.424	23.80	28.62 – 19.80	2.03	1.23
M. anisopliae + Thiamethoxam	4	4.475	2.549X + 1.379	26.11	32.05 – 21.60	1.85	1.12
L. lecanii + Thiamethoxam	4	6.332	2.575X + 1.497	22.93	27.67 – 19.01	2.11	1.27
B. bassiana + Acetamiprid	4	6.043	2.546X + 1.518	23.29	28.17 – 19.26	1.99	1.24
M. anisopliae + Acetamiprid	4	6.005	2.576X + 1.445	24.01	29.14 – 19.79	1.94	1.20
L. lecanii + Acetamiprid	4	1.265	3.003X + 0.898	22.67	26.60 – 19.33	2.06	1.27

Table 3: Relative lethal time of entomopathogens and neonicotinoid insecticides alone and their combination at half of their recommended doses to *A. craccivora* by direct spray method

Pesticide	Median lethal time (LT_{50}) in hour	
	2022	2023
Beauveria bassiana	45.77 (1)[#]	47.89 (1.05)
Metarhizium anisopliae	46.45 (1)	48.27 (1.04)
Lecanicillium lecanii	44.29 (1)	46.60 (1.05)
Imidacloprid 17.8% SL	27.43 (1)	28.85 (1.05)
Thiamethoxam 25% WG	26.82 (1)	29.21 (1.09)
Acetamiprid 20% SP	26.39 (1)	28.78 (1.09)
B. bassiana + Imidacloprid	24.92 (1)	25.51 (1.02)
M. anisopliae + Imidacloprid	25.76 (1)	26.25 (1.02)
L. lecanii + Imidacloprid	24.54 (1)	24.81 (1.01)
B. bassiana + Thiamethoxam	22.59 (1)	23.80 (1.05)
M. anisopliae + Thiamethoxam	25.94 (1)	26.11 (1.01)
L. lecanii + Thiamethoxam	22.55 (1)	22.93 (1.02)
B. bassiana + Acetamiprid	22.82 (1)	23.29 (1.02)
M. anisopliae + Acetamiprid	23.32 (1)	24.01 (1.03)
L. lecanii + Acetamiprid	21.85 (1)	22.67 (1.04)

[#]Figures in parenthesis are relative lethal time

Black bean aphid, *Aphis craccivora* Koch is a highly polyphagous pest that attacks a series of agri-horticultural crops belonging to eight plant families. As part of its feeding damage, it sucks and drains the plant sap, which ultimately lowers the availability of nutrients and water to the plants and spreads plant viruses. When infestations are severe, especially during the seedling stage, aphid feeding can cause symptoms such as chlorosis, stunting that delays the commencement of blooming, and even plant death in cowpea (Blackman and Eastop, 2006; Keating *et al.,* 2015). Aphids secrete sugar-rich honey dews that, in addition to acting as a vector and draining plant sap, serve as an ideal medium for the growth of fungi that causes sooty-mould, which ultimately impedes photosynthesis. Numerous plant viruses, including rosette, mottle, stunt, and stripe, are spread by it (Porter *et al.,* 1984). The bean aphid is viviparous, polymorphic (having both apterous and alate forms), and undergoes year-round parthenogenetic reproduction in tropical regions (Namitha *et al.,* 2021).

The insectopathogenic fungi are possible options for the management of vegetable insect pests (Halder *et al.,* 2016 and 2018a). Al Mazraáwi (2007) tested several combinations of *B. bassiana* and Imidacloprid for controlling onion thrips (*Thrips tabaci*) in both field and greenhouse settings. When *B. bassiana* (at field rates) and Imidacloprid (at 1/10 of field rates) were applied together in laboratory bioassay, the highest mortality (97%) was achieved compared to 88%, 94%, and 21% for *B. bassiana* alone, Imidacloprid alone, and the control, respectively. In greenhouse bioassay, significantly highest mortality (80%) was achieved in combination of *B. bassiana* and Imidacloprid at field rates. Additionally, they hypothesized that combining *B. bassiana* and Imidacloprid might result in a decrease in the rate of insecticide application while increasing the effectiveness of the biological control agent.

Furlong and Groden, (2001) reported that Imidacloprid interacted with *B. bassiana* to produce a synergistic response in larval mortality of Colorado potato beetle, *Leptinotarsa decemlineata* Say. They also suggested that possible role of starvation-induced stress factors underlying the observed synergistic interactions. Rajanikanth *et al.* (2010) further proved the effectiveness and compatibility of Imidacloprid and *B. bassiana* against the polypaghous insect pest *Spodoptera litura* (Fab.).

Paula *et al.* (2011) documented that the combining *M. anisopliae* with a very low concentration of the chemical insecticide Imidacloprid improved its effectiveness against *Aedes aegypti* (Linn.) and resulted in higher mortality following relatively short exposure times. According to Reddy *et al.* (2016), Imidacloprid combined with entomopathogenic fungi (*B. bassiana, M. anisopliae*, and *L. lecanii*) at recommended concentrations showed increased mortality compared to Imidacloprid alone against brown plant hopper (*Nilaparvata lugens* (Stål)) infesting paddy under glasshouse conditions. The neonicotinoids insecticide, Imidacloprid (at half the mean concentration) was found by Alizadeh *et al.* (2007) to be compatible with formulations of *V. lecanii* and they concluded that this could be used simultaneously with this entomopathogenic in integrated pest management.

Conclusion

Thus it is concluded that neonicotinoids insecticides combined with insectopathogenic fungi each at half their recommended doses were not only compatible but also synergistic in action. Without compromising the mortality of sucking pest, their mixtures would help lessen the load of toxic pesticides in environment and can be considered as an ecofriendly technology for sucking pest management like *A. craccivora*.

REFERENCES

Abbott WS. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* **18**:265–67.

Al Mazraáwi MS. 2007. Interaction effects between *Beauveria bassiana* and imidacloprid against *Thrips tabaci* (Thysanoptera: Thripidae). *Commun. Agric. Appl. Biol. Sci.* **72**(3):549-55.

Alizadeh A, Samih MA, Izadi H. 2007. Compatibility of *Verticillium lecani* (Zimm.) with several pesticides. *Commun. Agric. Appl. Biol. Sci.* **72**(4):1011-15.

Blackman RL, Eastop V. 2006) Aphids on the World's Herbaceous Plants and Shrubs; John Wiley and Sons: Chichester, UK, pp. 1460.

Corbel V, Stankiewicz M, Bonnet J, Grolleau F, Hougard JM and Lapied B. 2006. Synergism between insecticides permethrin and propoxur occurs through activation of presynaptic muscarinic negative feedback of acetylcholine release in the insect central nervous system. *Neurotoxicology* **27**:508–519. https://doi:10.1016/j.neuro.2006.01.011

Finney OJ. 1971. Probit analysis. Cambridge University Press, Cambridge. p 333.

Furlong MJ, Groden E. (2001. Evaluation of synergistic interactions between the Colorado potato beetle (Coleoptera: Chrysomelidae) pathogen *Beauveria bassiana* and the insecticides, imidacloprid, and cyromazine. *J. Econ. Entomol.* **94**(2):344-56.

Halder J, Khushwaha D, Rai AB, Dey D, Chaubey T, Singh B. 2016. First record of *Acythopeus curvirostris citrulli* (Marshall) (Coleoptera: Curculionidae) on sponge gourd, *Luffa cylindrica* (Linn.), its bionomics, diurnal activity and ecofriendly management. *Veg. Sci.* **43**(2):190-97.

Halder J, Khushwaha D, Rai AB, Nagendran K, Singh B. 2018a. Host plant mediated susceptibility of *Phenacoccus solenopsis* (Tinsley) to *Lecanicillium lecanii* (Zimmermann) Zare and Gams, neem oil and their combination. *Proc. Natl. Acad. Sci. India Sec. B Biol. Sci.* **88**(1):241-48.

Halder J, Kushwaha D, Rai AB and Singh B. 2019. Biology and Biorational Management of Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae): A Global Challenge to Tomato Production. *Proc. Zool. Soc.* **72**(2):107-10.

Halder J, Majumder S and Pandey KK. 2023. Whether the addition of neem oil increases the bioefficacy of entomopathogenic fungi against sucking pests? A case study from eggplant ecosystem. *Munis Ento. Zool.* **18**(1):409-17.

Halder J, Majumder S, Rai AB. 2021. Compatibility and combined efficacy of entomopathogenic fungi and neonicotinoid insecticides against *Myzus persicae* (Sulzer): An ecofriendly approach. *Entomologia Hellenica* **30**(1):24–32.

Halder J, Rai AB, Dey D and Singh B. 2018b. Abundance of important parasitoids in the vegetable ecosystem and their prospects in integrated pest management. *J. Ent. Zool. Stu.* **6**(4):762-69.

Keating JDH, Wang JF, Dinssa FF, Ebert AW, Hughes JDA, Stoilova T, Nenguwo N, Dhillon NPS and Easdown WJ. 2015. Indigenous vegetables worldwide: Their importance and future development. *Acta. Hortic.* **1102**:1–20.

Namitha NV, Kencharaddi RN, Hegde JN, Girijesh GK and Sridhara HP. 2021. Biology of bean aphid, *Aphis craccivora* Koch on field bean. *J. Ent. Zool. Stud.* **9**(1):1280-82.

Paula AR, Carolino AT, Paula CO, Samuels RI. 2011. The combination of the ntomopathogenic fungus *Metarhizium anisopliae* with the insecticide Imidacloprid increases virulence against the dengue vector *Aedes aegypti* (Diptera: Culicidae). *Parasites and Vectors* **4**:8.

Porter DM, Smith DH, Rodriguez-Kabana R. 1984. Compendium of peanut disease. St. Pauls. Minnesota, 18-226.

Rai AB, Halder J, Kodandaram MH. 2014a. Emerging insect pest problems in vegetable crops and their management in India: An appraisal. *Pest Management Horticul. Ecosys*. **20**(2):113-22.

Rai AB and Halder J. 2023. Insect pests of underutilized vegetable and their management: An appraisal. *Current Horticulture*, 13(3):9-22.

Rai AB, Loganathan M, Halder J, Venkataravanappa V, Naik PS. 2014b. Eco-friendly approaches for sustainable management of vegetable pests. Technical Bulletin, Indian Institute of Vegetable Research, Varanasi - 221305, Uttar Pradesh, pp: 104.

Rajanikanth P, Subbaratna GV, Rahaman SJ. 2010. Compatibility of insecticides with *Beauveria bassiana* (Balsamo) Vuillemin for use against *Spodoptera litura* Fabricius. J. Biol. Cont. **24**:238–43.

Reddy BN, Lakshmi VJ, Laha GS, Maheswari TU. 2016. Compatibility of entomopathogenic fungi with Imidacloprid for management of Brown plant hopper, *Nilaparvata lugens* Stal. (Delphacidae: Hemiptera) in rice. *J. Plant Development Sci.* **8**(2):71-74.

Roy S, Halder J, Singh V, Rai AB, Prasad RN, Singh B. 2017) Do vegetable growers really follow the scientific plant protection measures? An empirical study from eastern Uttar Pradesh and Bihar. *Ind. J. Agricul. Sci.* **87**(12):1668–72.

Sun YP and Johnson ER. 1960. Synergistic and antagonistic actions of insecticide- synergist combinations and their mode of action. *J. Agric. Food Chem.* **8**:261-66.

Current Horticulture **13**(1): 55–58, January–March 2025
DOI: 10.5958/2455-7560.2025.00009.9
Received: 03 December 2023; Accepted: 11 November 2024

Interaction effect of boron and zinc on growth, yield and quality of chilli (*Capsicum annuum*)

Krishan Kant Tyagi, Rajendra P Maurya, Radha Kushum, Kavita Regar and Sandeep Verma

Department of Horticulture, Suresh Gyan Vihar University, Rajasthan, India

Abstract

The study was carried out at School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan), during 2022-23, in Factorial Randomized Block Design, comprising nine treatment combinations, *viz.* control (T_0), boron @ 0.2% (T_1), boron @ 0.4% (T_2), zinc @ 0.2% (T_3), zinc @ 0.4% (T_4), boron @ 0.2% + zinc @ 0.2% (T_5), boron @ 0.2% + zinc @ 0.4% (T_6), boron @ 0.4% + zinc @ 0.2% (T_7) and boron @ 0.4% + zinc @ 0.4% (T_8). The treatments were replicated three times. The effect of different concentrations of micronutrients on growth, yield and quality attributes were significantly influenced by different concentrations of boron and zinc under local agroclimatic conditions of Jaipur. The maximum (31.64 cm) and (49.98 cm) plant height at 45 and 60 DAT, respectively, 162.47 leaves per plant, 14.54 branches per plant, 16.67 flower clusters per plant, 50.10 fruits per plant, (2.66 cm) fruit girth, minimum (45.10 days) and (50.03 days) took for 50% flowering and first harvesting, respectively and longest (8.15 cm) fruit length, heaviest (11.79 g) fruit and maximum (468.73 g/plant and 18.03 t/ha) green chilli yield and (3.20 t/ha) dry red chilli yield and highest B: C ratio (3.25)were recorded under foliar spray of boron @ 0.2% + zinc @ 0.4% treatment. Hence, foliar application of boron @ 0.2% + zinc @ 0.4% performed significantly superior over control and remaining treatments to get highest green chilli production.

Key words: Boron, Zinc on growth, Yield, Quality, Growth, Parameters, Economics

Chilli (*Capsicum annuum* L.) is an important vegetable and spice crop in the family of Solanaceae. With diploid chromosome number, 2n=24.India is one of the largest producers, consumers and exporters of India chilli in the world (Anonymous, 2021). India ranks first in area and second in production. It contributes 4.26 million ha area and 34.5 million tonnes production in the world (FAO, 2018). In Rajasthan chilli is cultivated in 13,812 ha area with 13,649 tonnes. The important chilli-producing districts are Jodhpur, Alwar, Jaipur, Bhilwara, Tonk, Swai Madhopu and Udaipur. Boron plays an important role in cell wall synthesis and membrane stability (Iwai *et al.,* 2006). It improves flowering and fruit setting, fruit formation and fruit quality (Rawaa *et al.,* 2014). Translocation of sugar, starches, nitrogen, phosphorus synthesis of amino acids and proteins are also influenced by boron (Rawaa *et al*., 2014). Zinc is also most important micronutrient (Mousavi, 2011). The information on impact of micronutrients on chilli is scanty. Keeping in view, study was undertaken to find out best combination of micronutrients with optimum concentration for quality chilli production.

MATERIALS AND METHODS

The study was carried out at Suresh Gyan Vihar University, Jaipur (Rajasthan) to see the effect of different boron and zinc on chilli during 2022-23. The experiment was laid out in FactorialRandomized Block Design which comprises nine treatment combinations, *viz.* control (T_0), boron @ 0.2% (T_1), boron @ 0.4% (T_2), zinc @ 0.2% (T_3), zinc @ 0.4% (T_4), boron @ 0.2% + zinc @ 0.2% (T_5), boron @ 0.2% + zinc @ 0.4% (T_6), boron @ 0.4% + zinc @ 0.2% (T_7) and boron @ 0.4% + zinc @ 0.4%@ 0.4% (T_8) replicated three times. The observations were measured on five randomly selected and tagged plants in each plot and their mean value was calculated. Significance of difference in treatment effect was tested through 'F' test at 5 per cent level of significance and CD (critical difference) was calculated, wherever results were found significant.

RESULTS AND DISCUSSION

Growth parameters

The maximum (26.55 cm), (44.89 cm) and (70.89 cm) plant height was recorded underfoliar spray of boron @ 0.2% treatment at 45, 60 and 75 DAT, respectively. It might be due to boron application and it plays an important role in activation of cell division and cell elongation. The boron strengthens the number of metabolic activities for building plant organs that consequently increased the plant height (Marschner, 1995). Maximum (17.94 cm), (36.27 cm) and (62.27 cm) plant height was recorded under foliar spray of zinc @ 0.4% treatment at 45, 60 and 75 DAT, respectively. This attribute might be due to active synthesis of tryptophane; a precursor of auxin, besides the

***Corresponding author :** mauryarose@gmail.com

synergistic effect of zinc which may serve as asource of energy for the synthesis of auxin. It could be attributedas one of the key factor for the growth of plant (Raghav and Singh, 2004).

The maximum interaction effect (31.64 cm) and (49.98 cm) plant height were recorded under foliar spray of boron @ 0.2% + zinc @ 0.4% treatment at 45 and 60 DAT. At 75 DAT, maximum (75.98 cm) plant height was recorded under foliar spray of boron @ 0.2% + zinc @ 0.4% treatment followed by (73.00 cm), (70.20 cm) and (69.05 cm) plant height under boron @ 0.2% + zinc @ 0.2%, boron @ 0.4% + zinc @ 0.2% and boron @ 0.4% + zinc @ 0.4% but all treatments performed at par with boron @ 0.2% + zinc @ 0.4% treatment and had significant effect over control. It might be due to synergistic effect of boron and zinc on vegetative characters. The produced auxin promotes the apical dominance that ultimately enhanced the plant height.

The maximum (162.47) leaves/plant was observed under foliar sprayed plants with boric acid @ 0.6% (T_3), whereas maximum (14.54) branches/plant was observed under boron @ 0.2% + zinc @ 0.4% and it showed significant effect. The maximum (16.67) flower clusters/plant was observed on same treatment. The increase of leaves and branches/plant might be due to enhancing of metabolic reaction for building of plant organs by exogenous application of boron that increased cell wall plasticity and cell wall elongation (Yugandhar *et al.*, 2014 and Somkuwar *et al.*, 2023). The plant height augmented with foliar application of boron. It might be due to production of more branches and more available space and photosynthates. These results are in agreement with those of Sugania and Kumuthini (2015) and Bohra and Nautiyal (2019).

The minimum (38.85) and (45.10) days took for 50% flowering and first harvesting, respectively under foliar spray of boron @ 0.4% (T_2) treatment, whereas maximum (38.51 days) took for 50% flowering and (46.03 days) took for first picking under foliar spray of boron @ 0.2% + zinc @ 0.4%, followed by (51.70 days) under foliar spray of boron @ 0.2% + zinc @ 0.2% treatment. These results are in line of Elankavi *et al.* (2009) who also observed that exogenous application of boron significantly reduced number of days to 50% flowering and first picking. It might be due to application of boron which increased fruit set and advanced flowering (Khatri *et al.*, 2022 and Vyas *et al.*, 2024). The results are in conformation with those of Gopal and Sarangtham (2021) and Khan *et al.* (2023).

Reproductive structures

Fruit setting increased dramatically with spraying of low concentration of micronutrients in chilli (Nawaz *et al.,* 2008). The maximum flower clusters/plant (16.67), fruits/plant (48.10), minimum days (38.51) took for 50% flowering and days (46.03) took for first picking under foliar spray of boron @ 0.2% + zinc @ 0.4% treatment, whereas minimum flower clusters/plant (11.38) and fruits/plant (29.67) under control (Table 1). It might be due to foliar feeding of micronutrients that strengthen the photosynthetic activity. The accumulation of carbohydrates favors the flower retention in fruit vegetables.

The foliar spray of micronutrients was most effective in reducing premature fruit drop. It might be due to absorption of boron that promoted the production of more photosynthates required for more number of fruits (Vyas *et al.*, 2016). Similar results were also reported by Gopal and Sarangtham (2021) and Meriño-Gergichevich *et al.* (2021).

Yield-attributing parameters

The application of boric acid and zinc sulphate spray significantly increase in length, breadth, weight and volume. It may be due to boron improved fruit weight and and fruit size may be due to its role in increasing cell elongation and cell division (Eman *et al.*, 2007). The maximum fruit length (8.15 cm) was observed in foliar spray of boron @ 0.2% + zinc @ 0.4% treatment followed by (7.41 cm) under boron @ 0.2% + zinc @ 0.2% treatment (Table 1). These results are in close conformity with those of Singh *et al.* (2019). The increase in fruit length and fruit diameter might be due to accumulation of photosynthates which were synthesized in leaves and translocated towards fruits. The increased fruit size due to accumulation of photosynthates was probably due to more and growth (Singh *et al.,* 2019 and Vyas *et al.*, 2024).

The application of boric acid had significant effect on fruit length, girth and diameter. The maximum fruit girth (2.66 cm) was observed in foliar spray of boron @ 0.2% + zinc @ 0.4% treatment, followed by (2.47 cm) under foliar spray of boron @ 0.2% + zinc @ 0.2% treatment, whereas minimum fruit girth (1.20 cm) was recorded in control (Table 1). It might be due to boron that promoted photosynthesis rate and cell divisions that increased fruit diameter. Boron and zinc encouraged tryptophan formation which helped in the biosynthesis of proteins and auxins (Khan *et al.,* 2023 and Nehra and Malik, 2024).

The highest fruit weight (11.79 g) was recorded in foliar spray of boron @ 0.2% + zinc @ 0.4% treatment, whereas the lowest fruit weight (6.51 g) was recorded under the control (T_0). These results are in line of Khan *et al.* (2023) and Somkuwar *et al.* (2023).

Table 1: Effect of plant growth regulators on yield and yield-attributing characters

Treatment	Number of flowers /plant	Number of days to first picking	Number of fruits / plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green chilli yield			Dry chilli yield (tonnes/ ha)	B:C ratio
							(g/ plant)	(kg/ plot)	(tonnes/ ha)		
Control	11.38	71.16	29.67	4.81	1.20	6.62	191.70	4.60	7.10	1.25	1.04
Boron											
Boron @ 0.2%	13.30	57.61	39.10	6.39	2.15	8.68	322.85	7.75	11.96	2.12	2.18
Boron @ 0.4%	12.63	59.83	38.50	5.86	2.03	8.12	318.49	7.64	11.80	2.08	1.87
S.Em+	0.30	1.55	0.59	0.20	0.11	0.12	12.48	0.30	0.46	0.08	
C.D. (p=0.05)	0.90	4.68	1.79	0.60	0.32	0.36	37.73	0.91	1.40	0.23	
Zinc											
Zinc @ 0.2%	11.79	61.50	35.50	5.37	1.71	7.47	253.01	6.06	9.38	1.67	1.83
Zinc @ 0.4%	11.91	60.70	37.17	6.01	2.18	8.08	290.76	6.98	10.79	1.91	1.87
S.Em+	0.30	1.55	0.59	0.20	0.11	0.12	12.48	0.30	0.46	0.08	
C.D. (p=0.05)	0.90	N.S.	1.79	0.60	0.32	0.36	37.73	0.91	1.40	0.23	
Interaction between boron and zinc											
Boron @ 0.2% + Zinc @ 0.2%	16.67	51.70	43.50	7.41	2.47	10.84	417.27	10.01	15.45	2.74	2.95
Boron @ 0.2% + Zinc @ 0.4%	14.71	46.03	48.10	8.15	2.66	11.79	486.73	11.68	18.03	3.20	3.25
Boron @ 0.4% + Zinc @ 0.2%	14.53	54.20	41.90	7.17	2.42	9.91	369.22	8.86	13.67	2.42	2.57
Boron @ 0.4% + Zinc @ 0.4%	14.39	57.50	39.50	6.47	2.39	8.72	324.60	7.79	12.02	2.14	2.51
S.Em+	0.52	2.68	1.03	0.35	0.18	0.21	21.35	0.52	0.80	0.13	
C.D. (p=0.05)	1.56	8.10	3.10	1.04	0.55	0.62	65.35	1.57	2.42	0.39	

Yield parameters

The highest fruit yield (468.73 g) was observed under foliar spray of boron @ 0.2% + zinc @ 0.4% treatment. Similar trend was also reported on green chilli yield and highest green chilli fruits (11.68 kg/plot) were produced in boron @ 0.2% + zinc @ 0.4% treatment (Table 1). The highest green chilli yield (18.03 tonnes/ha) was obtained in foliar spray of boron @ 0.2% + zinc @ 0.4% treatment. Hence, boron @ 0.2% + zinc @ 0.4% treatment performed significantly superior over foliar spray of different concentrations of boron, zinc individually and their interaction treatments on green chilli yield (Table 1). Similarly, interaction of boron and zinc had significant effect on dry red chilli yield. The highest dry red chilli yield (3.20 t/ha) was recorded in foliar spray of boron @ 0.2% + zinc @ 0.4% treatment, whereas lowest dry red chilli yield (1.25 t/ha) was recorded under water sprayed plants in control (Table 1). Foliar application of B and Zn increased the yield of chilli significantly as it enhanced the vegetative growth, retention of flowers and fruits (Nehra and Malik, 2024). These results are in close conformity with the findings of Khan *et al.* (2023) and Vyas *et al.* (2024).

Economics

The highest B: C ratio (3.25) was recorded in boron @ 0.2% + zinc @ 0.4% treatment, followed by (2.95) in boron @ 0.2% + zinc @ 0.2% and (2.57) B: C ratio in boron @0.4% + zinc @ 0.2% as compared to lowest B: C ratio (1.04) in control (Table 1). It might be due to increasing fruit set, fruit retention, number of fruits/plant and minimized fruit drop percentage in foliar application of boron that ultimately increased the yield. These results are in close conformity with those of Gopal and Sarangtham (2021) and Khan *et al.* (2023).

CONCLUSION

Thus, it may be concluded that boron @ 0.2% + zinc @ 0.4% was found the best treatment followed by boron @ 0.2% + zinc @ 0.4% treatment.

REFERENCES

Anonymous. 2021. Horticulture statistics at a glance.*Govt. of India, Ministry of Agriculture and Farmers Welfare, Dept. of Agriculture, Cooperation and Farmers Welfare, Horticulture Statistics Division* 2020-21.

Bohra M and Nautiyal B P. 2019. Sustainable production of tuberose (*Polianthes tuberosa*) through integrated nutrient management: a review. *Current Horticulture* **7**(1): 12-17.

Elankavi S, Kuppuswamy G, Vaiyapuri V and Raman R. 2009. Effect of phytohormones on growth and yield of rice. *Oryza* **46**(4): 310-13.

Eman A A, El-moneim M M M A, El-Migeed O A and Ismail M M. 2007. GA_3 and Zinc Sprays for Improving Yield and Fruit Quality of Washington Navel Orange Trees Grown under Sandy Soil Conditions, *Research Journal Agriculture & Biological Sciences* **3**(5): 498-503.

Food Agriculture Organization. 2018. Statistics Retrieved 5th August 2019. *Countries Select All; Regions World, Production, Quantity; Items Plums and sloes*.

Gopal D. and Sarangthem I. 2021. Effect of zinc on growth and yield of tomato (*Lycopersicon esculentum* cv. Pusa Ruby). *International Journal of Current Research* **21:** 151-57.

Iwai H, Hokura A, Oishi M, Chida H, Ishii T, Sakai S and Satoh S. 2006. The gene responsible for borate cross-linking of pectin Rhamnogalacturonan-II (RG-II) is required for plant reproductive tissue development and fertilization. *Plant Natural Academy Science, USA* **103:** 16592–97.

Khan M N, Rab A, Sajid M, Khan M W, Khan M A, Ahmad M, Sadiqullah, Suhail S, Din I and Khan M A. 2023. Influence of boron and zinc on the growth of chilli under the agro-climatic condition of swat. *Journal of Xi'an Shiyou University, Natural Science Education* **19**(2): 1273-1282.

Khatri D, Bhattarai K, Thapa P, Wagle N and Yadav P K. 2022. Effect of foliar spray of zinc and boron on performance of tomato (*Solanum lycopersicum*) cv. 'Manisha' under net house condition. *RJOAS* **5**(125): 252-261.

Marschner H. 1995. The soil root interface (*rhizosphere*) in relation to mineral nutrition. Mineral nutrition of higher plants.

Meriño-Gergichevich C, Luengo-Escobar A, Alarcón D, Reyes-Díaz M, Ondrasek G, Morina F and Ogass K. 2021. Combined spraying of boron and zinc during fruit set and premature stage improves yield and fruit quality of European hazelnut cv. **'**Tonda di Giffoni**'**. *Front Plant Science* **12:** 661542.doi: 10.3389/fpls.2021.661542.

Mousavi S R. 2011. Zinc in crop production and interaction with phosphorus. *Australian Journal of Basic and Applied Science* **5**(9): 1503-1509.

Nehra M K and Malik J K. 2024. Effect of copper and zinc as a supplement fertilizer on growth of radish (*Raphanus sativus*) root and foliage. *Current Horticulture* **12**(2): 67–69.

Raghav R and Singh N P. 2004. Effect of zinc application on growth and yield of potato, *Progressive Horticulture* **36:** 135-37.

Rawaa S S, Prasad V M and Saravanan S. 2014. Effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill) cv. Heem Sohna, under protected cultivation. *European Acaddemic Research* **2**(3): 4573-97.

Singh A, Bahadur V, Dixit P S, Yadav G K, Singh S and Singh P K. 2019. Effect of micronutrients on vegetative growth, yield and quality of Chilli (*Capsicum annum*), *International Journal of Chemical Studies* **7**(4): 1320-23.

Somkuwar A R, Singh A K, Sisodia A, Lamsal A and Giri S. 2023. Effect of boron on growth and flowering in gladiolus (*Gladiolus* sp.). *Current Horticulture* **11**(2): 56–59.

Vyas S S, Singh A K, Sisodia A and Barman K. 2024. Effect of zinc and corm size on growth and corm yield in gladiolus (*Gladiolus* spp.). *Current Horticulture* **12**(2): 63–66.

Yugandhar P, Vasavi T, Shanmugam B, Devi P U M, Reddy K S and Savithramma N. 2014. Biofabrication, characterization and evaluation of photocatalytic dye degradation efficiency of *Syzygium alternifolium* leaf extract mediated copper oxide nanoparticles. *Materials Research Express* **6** (6): 141 – 47.

Current Horticulture **13**(1): 59–62, January–March 2025
DOI: 10.5958/2455-7560.2025.00010.X
Received: 03 December 2023; Accepted: 11 November 2024

Effect of pinching and plant growth regulators on yield and quality of fenugreek (*Trigonella foenum-graecum*)

Kamlesh Kumar Yadav*, DK Rana*, TS Bisht*, KN Shah* and Hemant Kumar Gurjar*

**Department of Horticulture, HNB Garhwal University (A Central University), Srinagar (Garhwal), Uttarakhand, India*

Abstract

A field experiment was conducted to find out the effect of pinching and plant growth regulators on yield and quality of fenugreek (*Trigonella foenum-graecum* L.) cv. Pant Ragini during 2020-21 at Department of Horticulture, H N B Garhwal University, Srinagar (Garhwal), Uttarakhand. Minimum days taken to first and 50 % first pod formation (89.88 and 93.97 days), significantly maximum length of pod (11.23 cm), pod diameter (2.13 mm), pods/plant (51.85), number of seeds/pod (18.92), seed yield/plant (8.02g), seed yield/plot (657.78 g) and seed yield/ha (39.70 q), and quality parameters, *viz.* TSS (13.08 ^{0}Brix) and ascorbic acid (60.73 mg/100g) were recorded with seed soaking of S_1 (GA_3 50 ppm). Among plant growth regulators, foliar spray of G_1 (GA_3 50 ppm) twice (30 and 60 DAS) took minimum days to first and 50 % first pod formation (89.88 and 93.97 days), maximum length of pod (11.23 cm) and pod diameter (2.13 mm), number of pods/plant (51.87), number of seeds/pod (18.85), seed yield/plant (7.86g), seed yield/plot (609.62 g) and seed yield/ha (37.13 q) and quality parameters, *viz.* TSS (13.75 ^{0}Brix) and ascorbic acid (62.29 mg/100g) of different pinching applications, P_1 (no pinching) took minimum days to first and 50 % first pod formation (90.55 and 94.31 days) and different yield application of P_2 (double pinching at 60 DAS) were maximum length of pod (10.91 cm), pod diameter (2.50 mm), number of pods/plant (54.87), number of seed/pod (18.61), seed yield/ plant (7.11 g), seed yield/plot (596.40 g) and seed yield/ha (35.51 q), highest TSS (11.73 ^{0}Brix) and ascorbic acid (60.16 mg/100g).

Key words: Growth regulators, Pinching, Yield, Pod length, Quality parameters

Fenugreek (*Trigonella foenum-graecum* L.) chromosome number 2n = 16, is commercially cultivated for its leaves and seeds. The plant growth regulators (PGRs), GA_3 and NAA, improves its growth, yield and quality attributes. They enhance nucleic acid activities, flowering, fruit setting, fruit retention and fruit quality in various horticultural crops (Alagukannan and Vijay Kumar, 1999; Dodiya *et al.*, 2021). Pinching is done to affect canopy structure. It redirects movement of auxin from apical part of a plant to lower areas, stimulating the development of lateral branches which increases the potential podding points on a plant thereby increasing the number of fruits. Cutting management or pinching practice greatly influences growth and yield attributes in fenugreek (Baboo, 1997).

MATERIALS AND METHODS

This field experiment was conducted at Department of Horticulture, H.N.B. Garhwal University, Srinagar (Garhwal), Uttarakhand, during *rabi* season of 2020-21, with three replications in a Factorial Randomized Block Design. Fenugreek cv. Pant Ragini was used. The experiment consisted of two seed soaking levels, *viz.* control (S_0) and GA_3 50 ppm (S_1), spraying of PGRs with three levels, *viz.* control (G_0), GA_3 50 ppm (G_1) and NAA 50 ppm (G_2) and three pinching levels, *viz.* no pinching (P_0), single pinching at 45 days (P_1) and double pinching at 60 days after sowing (P_2). The seeds were sown manually in rows at a spacing of 20 cm and plants to plants 10 cm. Before soaking, seeds were first cleaned to remove the broken and other foreign materials and then soaked in GA_3 50 ppm for 8-10 hr at room temperature. Then seeds were dried at room temperature. The plant growth regulators, *i.e.* GA_3 50 ppm and NAA 50 ppm were sprayed 30 and 60 days after sowing with the help of hand sprayer. The pinching was done by removing apical buds manually without causing damage to plant parts.

The data were recorded on yield and quality parameters, viz. days taken to first pod formation, days taken to 50 % pod formation, pod length (cm), pod diameter (mm), number of pods/plant, number of seeds/pod, seed yield/plant (g), seed yield/plot (g), seed yield/ha (q), total soluble solids (^{0}Brix) and ascorbic acid (mg/100g). The data were analysed according to the procedure of analysis of FRBD with three replications (Snedecor and Cochran, 1961). The significance of treatments was tested through F test at 5 per cent level of significance. The critical difference was calculated to assess the significance of difference among different treatments.

***Corresponding author :** kamalyadav664@gmail.com

RESULTS AND DISCUSSION

Effect of seed soaking

The data on showed that treatment S_1 (GA_3 50 ppm) had minimum days taken to first pod formation (89.88

days) and days taken to 50 % pod formation (93.97), whereas treatment S_0 (control) had maximum days taken to first pod formation (98.39 days) and days taken to 50 % pod formation (101.40). The maximum length of pod (11.23 cm) and pod diameter (2.13 mm) were observed in treatment S_1 (GA_3 50 ppm), whereas minimum length of pod (10.30 cm) and pod diameter (2.03 mm) in treatment S_0 (control). There were maximum number of pods/plant (51.85), number of seeds/pod (18.92), seed yield/plant (8.02g), seed yield/plot (657.78 g) and seed yield/ha (39.70 q) in treatment S_1 (GA_3 50 ppm), whereas minimum number of pods/plant (46.44), number of seeds/pod (17.87), seed yield/plant (4.29 g), seed yield/plot (351.98 g) and seed yield/ha (21.25 q) were observed in treatment S_0 (control) (Table 1). The maximum TSS (13.08 ^{0}Brix) and ascorbic acid (60.73 mg/100g) were observed in treatment S_1 (GA_3 50 ppm), whereas minimum TSS (9.72 ^{0}Brix) and ascorbic acid (55.47 mg/100 g) in treatment S_0 (control) (Table 2).

The increasing yield parameters following soaking of seed with GA_3 might be due to higher rate of cell division in root and shoot tips incited by the application of GA_3. These studies are in conformity with those of Sharma (2012), Tania *et al.* (2015), Tavelu *et al.* (2018), Karn *et al.* (2022) and Pangtu *et al.* (2024).

Effect of plant growth regulators

The spraying of plant growth regulators, G_1 (GA_3 50 ppm) had minimum (89.88) days taken to first pod formation and days taken to 50 % pod formation (93.97 days), whereas treatment G_0 (control) had maximum days taken to first pod formation (99.88 days) and days taken to 50 % pod formation (101.61). Maximum length of pod (11.23 cm) and pod diameter (2.13 mm) were observed in treatment G_1 (GA_3 50 ppm), whereas minimum length of pod (10.19 cm) and pod diameter (1.96 mm) in treatment G_0 (control). Maximum number of pods/plant (51.87), number of seeds/pod (18.85), seed yield/plant (7.86g), seed yield/plot (609.62 g) and seed yield/ha (37.13 q) were observed in G_1 (GA_3 50 ppm), whereas minimum number of pods/plant (44.51), number of seeds/pod (17.58), seed yield/plant (4.16 g), seed yield/plot (334.69 g) and seed yield/ha (20.64 q) in G_0 (control). The data revealed treatments significantly affected to all characters. Maximum TSS (13.75 ^{0}Brix) and ascorbic acid (62.29 mg/100g) were observed in G_1 (GA_3 50 ppm), whereas minimum TSS (9.96 ^{0}Brix) and ascorbic acid (51.87 mg/100g) were observed in treatment S_0 (control) (Table 2).

The yield parameters were comparatively better with treatment G_1 (GA_3 50 ppm) compared to other treatments. The positive influence of GA_3 can be attributed to increased photosynthetic activity and more efficient nutrient translocation from roots to apical parts of plants. This made the treated plants physiologically more active, resulting in improved growth, yield, and quality. This enhancement is likely due to rapid cell division and elongation, which stimulated growth and increased nutrient uptake. Similar effects of GA_3 on plant yield have been reported by Gour *et al.* (2009), Vasudevan *et al.* (2008), Meena *et al.* (2014), Yugandhar *et al.* (2015), and Poonia *et al.* (2024).

Effect of pinching

The treatment P_1 (control) had minimum days taken to first pod formation (90.55 days) and days taken to 50 % pod formation (94.31 days), whereas treatment P_2 (double pinching at 60 DAS) had maximum days taken to first pod formation (98.86 days) and days taken to 50 % pod formation (101.12 days). Maximum length of pod (10.91 cm) and pod diameter (2.50 mm) were observed in treatment P_2 (double pinching at 60 DAS), whereas minimum length of pods (10.57 cm) and pod diameter (1.81 mm) were observed in P_0 (control). Maximum number of pods/plant (54.87), number of seeds/pod (18.61), seed yield/plant (7.11 g), seed yield/plot (596.40 g) and seed yield/ha (35.51 q) were observed in P_2 (double pinching at 60 DAS), whereas minimum number of pods/plant (42.52), number of seeds/pod (18.11), seed yield/plant (4.41 g), seed yield/plot (334.16 g) and seed yield/ha (21.14 q) were observed in P_0 (control). Maximum TSS (11.73 ^{0}Brix) and ascorbic acid (60.16 mg/100g) in P_2 (double pinching at 60 DAS), whereas minimum TSS (10.93 ^{0}Brix) and ascorbic acid (55.23 mg/100g) in P_0 (control).

The effect of pinching on early pod formation, pod length, pod diameter, number of pods/plant, number of seeds/pod, seed yield/plant (g), seed yield/plot (g), seed yield/ha (q), TSS (^{0}Brix) and ascorbic acid (mg/100g) observed the maximum increase was observed with treatment P_2 (double pinching at 60 DAS). This might be due to that second pinching provided sufficient time for regeneration of vegetative parts and enhanced the development of lateral productive branches. These changes influenced the plant parts by maintaining the source-sink relationship of nutrients. This could be attributed to pinched plants producing a greater number of branches/plant, which led to early pod formation, increased pod length, and pod diameter, as well as a higher number of pods per plant. As a result, there was an increase in seed yield and quality parameters. Similar results were reported by Vasudevan *et al.* (2008), Krishnaveni *et al.* (2016), Sowmya *et al.* (2017), and Kauser *et al.* (2018) in fenugreek.

Table 1: Effect of pinching and plant growth regulators on days taken to first, 50 % pod formation, pod length, pod diameter, number of pods/plant and number of seeds/pod

Treatment	Days taken to first pod formation	Days taken to 50 % pod formation	Length of pod (cm)	Pod diameter (mm)	Number of pods/plant	Number of seeds/pod
Seed Soaking						
S_0 (Control)	98.39	101.40	10.30	2.03	46.44	17.87
S_1 (GA_3 50 ppm)	89.88	93.97	11.23	2.13	51.85	18.92
SEm±	0.72	0.74	0.08	0.02	0.37	0.14
CD (0.05%)	2.05	2.12	0.23	0.05	1.05	0.40
Spraying of PGRs						
G_0 (Control)	99.88	101.61	10.19	1.96	44.51	17.58
G_1 (GA_3 50 ppm)	89.88	93.97	11.23	2.13	51.87	18.85
G_2 (NAA 50 ppm)	92.71	97.49	10.90	2.16	51.07	18.77
SEm±	0.88	0.91	0.10	0.02	0.45	0.17
CD (0.05%)	2.51	2.60	0.28	0.06	1.28	0.49
Pinching						
P_0 (Control)	90.55	94.31	10.57	1.81	42.52	18.11
P_1 (Single pinching at 45 DAS)	93.00	97.62	10.82	1.93	50.07	18.47
P_2 (Double pinching at 60 DAS)	98.86	101.12	10.91	2.50	54.87	18.61
SEm±	0.88	0.91	0.10	0.02	0.45	0.17
CD (0.05%)	2.51	2.60	0.28	0.06	1.28	0.49
CV (%)	6.96	6.95	6.90	6.98	6.87	6.92

Table 2: Effect of pinching and plant growth regulators on seed yield TSS and ascorbic acid

Treatment	Seed yield g/plant	Seed yield g/plot	Seed yield q/ha	TSS (^{0}Brix)	Ascorbic acid (mg/100g)
Seed Soaking					
S_0 (Control)	4.29	351.98	21.25	9.72	55.47
S_1 (GA_3 50 ppm)	8.02	657.78	39.70	13.08	60.73
SEm±	0.04	3.36	0.20	0.08	0.44
CD (0.05%)	0.12	9.60	0.58	0.24	1.24
Spraying of PGRs					
G_0 (Control)	4.16	334.69	20.64	9.96	51.87
G_1 (GA_3 50 ppm)	7.86	609.62	37.13	13.75	62.29
G_2 (NAA 50 ppm)	6.45	570.33	33.68	10.48	60.13
SEm±	0.05	4.12	0.25	0.10	0.53
CD (0.05%)	0.14	11.76	0.71	0.29	1.52
Pinching					
P_0 (Control)	4.41	334.16	21.14	10.93	55.23
P_1 (Single pinching at 45 DAS)	6.95	584.08	34.77	11.54	58.91
P_2 (Double pinching at 60 DAS)	7.11	596.40	35.51	11.73	60.16
SEm±	0.05	4.12	0.25	0.10	0.53
CD (0.05%)	0.14	11.76	0.71	0.29	1.52
CV (%)	6.47	6.46	6.46	6.81	6.90

CONCLUSION

Thus, it was concluded that application of seed soaking and foliar application of GA_3 at 50 ppm (30 and 60 DAS), along with pinching treatment P_2 (double pinching at 60 DAS), had a beneficial effect on yield and quality of fenugreek cv. Pant Ragini. The double pinching and GA_3 at 50 ppm treatment showed superior effectiveness in improving the yield and quality of fenugreek.

REFERENCES

Alagukannan G and Vijayakumar M. 1999. Effect of plant growth substances on yield attributing parameters, yield and quality in fenugreek (*Trigonella foenum- graecum* Linn.). *South-Indian Horticulture* **47**(1-6):130 -33.

Baboo, R.1997. Effect of cutting management, nitrogen and phosphorous on growth and yield of fenugreek (*Trigonella foenum – graecum* L.). *Annals of Agriculture Research* **18**(3): 380-82.

Dodiya VC, Vala GS, and Senjaliya HJ. 2021. Effect of different shade net on performance of fenugreek (*Trigonella foenum-graecum* L.) in summer season. *Current Horticulture* ***9***(1), 63-64.

Gour R, Naruka IS, Singh PP, Rathore SS, and Shaktawat RPS. 2009. Effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Spices and Aromatic Crops* **18**(1): 33-36.

Karn R, Ranjan JK, Ranjan P, Das B and Attri BL. 2022. In-vitro regeneration in long-day garlic (*Allium sativum*). *Current Horticulture* **10**(1): 37-40.

Kauser H, Bhoomika HR and Ibaad MH. 2018. Effect of sowing dates and stage of pinching on growth, seed yield and quality of fenugreek (*Trigonella foenum-graecum* L.). *Research in Environment and Life Science* **7**(9): 276-79.

Krishnaveni V, Padmalatha T, Padma SSV and Prasad ALN. 2016. Influence of pinching and plant growth regulators on flowering, yield and economics of fenugreek. *Journal of Spices and Aromatic Crops* **25**(1): 41-48.

Meena SS, Mehta RS, Bairva M and Meena RD. 2014. Productivity and profitability of fenugreek as influence by bio-fertility and plant growth regulators. *Legume Research* **37**(6): 646-50.

Pangtu, S., Sharma, P., Dhiman, S. R., Sharma, P., & Thakur, D. 2024. GA_3 priming, biopriming and hydropriming effect on quality nursery production of China aster (*Callistephus chinensis*). *Current Horticulture* **12**(1), 76-80.

Poonia, S., Choudhary, S., Moond, S. K., Ram, M., & Kuri, R. (2024). Effect of PGRs on growth, reproductive efficiency, and quality of tomato (*Solanum lycopersicum*) in arid regions. *Current Horticulture* **12**(1), 81-85.

Sharma R K. 2012. Effect of salicylic acid and gibberellic acid on seed germination and growth of pea. *International Journal of Plant Sciences*, **7**(2): 322-24.

Snedecor GW and Cochran WG. 1961. Statistical Methods. *The Iowa State University Press, Ames, IOWA*, USA.

Sowmya PT, Naruka IS, Saktawat RPS and Kushwa SS. 2017. Effect of sowing dates and stage of pinching on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.). *International Journal of Bio-resource and Stress Management* **8**(1): 91-95.

Tania C, Kumara JN, Chatterjee R, Chattopadhyay PK 2015. Influence of gibberellic acid on growth and quality of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Spices & Aromatic Crops* **24**(1):56-57.

Tavelu V. 2018. Effects of gibberellic acid and auxins on growth and yield on pea. *International Journal of Advances in Science Engineering and Technology* **6**(2): 2321-91.

Vasudevan SN, Sudarshan JS, Khurdikeri MB and Dharmatti PR. 2008. Influence of pinching of apical bud and chemical sprays on seed yield and quality of fenugreek. *Karnataka Journal of Agriculture Science* **21**(1): 26-29.

Yugandhar V, Reddy PSS, Sivaram GT and Reddy DS. 2015. Influence of plant growth regulators on growth, seed yield, quality and economics of coriander (*Coriandrum sativum* L.) cv. Sudha. *Journal of Spices and Aromatic Crops* **25** (1): 1-82.

Current Horticulture 13(1): 63–66, January–March 2025
DOI: 10.5958/2455-7560.2025.00011.6
Received: 3 December 2023; Accepted: 11 November 2024

Comparative evaluation of decontamination processes for mitigating profenofos residues in chili (*Capsicum annuum*)

Komal Rawat[1], Anjana Srivastava*, Shishir Tandon and Gajanpal Singh

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Abstract

A study to assess the efficacy of ten decontamination processes in reducing the pesticide residue load of profenofos from chili (*Capsicum annuum* L.) was undertaken at College of Basic Science and Humanities, G. B. Pant University of Agriculture and Technology, Pantnagar, during September 2022 to April 2023. The extraction of insecticide from chili was initiated after 48 hr of pesticide formulation spray and was done using the QuEChERS (quick, easy, cheap, effective, rugged, and safe) method. The study included a control treatment too in which the pesticide residues were extracted without following any decontamination procedure. The quantitative analysis of insecticide was done by coupled gas chromatography–electron capture detection. The results depicted reduction of pesticide residues in all decontamination treatments compared with the control. Solutions of 1% NaCl and soaking in lukewarm water served as efficient decontaminants for removal (up to 90%) of profenophos residues from chili. Among commercially available decontamination products, soaking in nimwash solution showed remarkable effectiveness followed by veggie clean and Arka Herbiwash.

Key words: Decontamination; Pesticide residues; Organophosphate; GC-ECD

Chili (*Capsicum annuum* Linn) is most valuable spice crops of India as it is the largest producer, consumer and exporter of chili. The yield of any horticultural crop can be enhanced through proper irrigation practice (Halder *et al*., 2022).

Profenofos (O,O-diethyl O-quinoxalin-2-yl phosphorothioate), is a non-systemic organophosphorus insecticide widely used to control various insect pests on chili crops. Pesticides are often used to help increase the yield of pepper crops by reducing the damage caused by pests. This improves farmer's profitability in terms of chili production (Radwan *et al*., 2005). The risk of contamination with pesticide residues increases significantly if pesticides are not applied correctly and pre-harvest interval is not properly determined and followed (Souza *et al*., 2019). Pesticide residues present at the time of harvest can accumulate and bio-magnify as they move up the food chain (Rawat *et al*., 2023). Consuming raw and cooked vegetables, such as chilies, is a common route of pesticide exposure (Keikotlhaile *et al*., 2010). Growing evidence links pesticide exposure to an increased incidence of chronic diseases in humans, such as cancer, Parkinson's, Alzheimer's, multiple sclerosis, diabetes, cardiovascular diseases, chronic kidney disease, and premature aging (Mostafalou, and Abdollahi, 2013).

Hence, removing surface pesticide residues from vegetables is crucial. Decontamination treatments for fruits and vegetables to reduce pesticide residues have proven highly effective (Bhilwadikar *et al*., 2019; Rani *et al*., 2019 ; Cengiz and Certel 2012). Researchers have observed that certain pesticide residues can diminish with pre-harvest intervals and/or culinary practices such as washing, peeling, cooking, boiling, and storage (Cengiz *et al*., 2007).In recent years, the presence of pesticide residues in harvested chilli has become increasingly important, presenting not only health challenges but also serving as a significant barrier to international trade (Rawat *et al*., 2024). Therefore, study was undertaken to investigate the impact of various washing solutions on removal of profenofos residues present on field-treated chili crops.

MATERIALS AND METHODS

The analytical grade profenofos standard was obtained as a certified reference material from IARI, New Delhi, India. The Formulation product (celcron 50% EC) was used in the field experiment and was purchased from the local market at Rudrapur, Uttarakhand, India. All chemicals and solvents used were of analytical grade (AR) or HPLC grade, and all glassware used was sourced from Borosil (India) or Rivera (India).

A standard stock solution of profenofos of 100 mg / kg was prepared by dissolving the insecticide in n-hexane. Serial dilutions covering a range of concentrations from 0.005 to 2 mg / kg were then prepared. The working standard of profenofos was injected three times at six linear concentrations, and the calibration curve was plotted by determining each peak area with its

***Corresponding author :** anj612003@gmail.com

corresponding concentration. Pesticide concentrations were subsequently determined using this calibration curve and the regression equation derived from the linearity plot. The limit of detection (LOD) and limit of quantification (LOQ) were calculated on the basis of signal-to-noise ratio.

Profenophos was analyzed by GC (Trace 1110), of Thermo Fisher Scientific, Mumbai, India make, equipped with an electron capture detector and a capillary column (30 m by 0.25 mm internal diameter and film thickness of 0.25 μm). The column temperature was initiated at 100°C, increased at a rate of 20°C per minute to 180°C for 4 minutes, then at 5°C per minute to 270°C for 18 minutes and finally at 5°C per minute to 300°C. The injection volume was 1 μL, with injector and detector temperatures set at 250°C and 300°C, respectively. Nitrogen (99.99% purity) was used as the carrier gas at a flow rate of 1.2 ml per minute.

Chili crop (cv. Pant1) was planted in plots (5 m by 5 m) in triplicate. All the recommended cultural practices were followed. Upon maturity, plants were sprayed with Celcron 50% EC at a rate of 800 g a.i/ha. The control plots were not subjected to any spraying, and vegetable samples weighing approximately 250–300 g were harvested at 50%–60% fruiting stage for recovery studies. Recovery studies involved spiking untreated/control chili samples at three different concentrations i.e. 0.02, 0.1 and 0.2 mg/kg (LOQ, 5 LOQ and 10 LOQ respectively). Subsequent extraction and clean-up procedures for profenofos residues were conducted following modified QuEChERS method (Srivastava *et al.*2021) The percent recovery was calculated using the specified formula.

Recovery (%) = [Recovered concentration/Actual concentration] × 100

Accuracy was determined by performing five replicates at each recovery level, and the % relative standard deviation (RSD) was then calculated.

% RSD = (Standard Deviation/Mean) × 100

The extraction procedure followed was a s follows : Each 10 g portion of chopped vegetable sample was placed in triplicate into a 50 mL centrifuge tube along with 10 mL of distilled water and 10 mL of n-hexane. After vortexing for 2–3 min, the mixture was allowed to stand for 10 minutes. Then, 3 g of anhydrous magnesium sulfate and 1 g of sodium chloride were added, followed by shaking for an additional minute. The tubes were vortexed again and centrifuged at 3000 rpm for 5 min. For cleanup, dispersive solid-phase extraction (dSPE) was utilized. This involved adding 1 g of $MgSO_4$, 150 mg of PSA (primary secondary amine) reagent, and graphitized carbon black to the mixture, which was then centrifuged at 3000 rpm for another 5 min. The top supernatant layer was extracted using a pipette and passed through a dispersive solid-phase extraction (SPE) cartridge for further cleanup. The samples were then filtered through 0.45-μm-pore-size polytetrafluoroethylene disc filter membrane for analysis by GC-ECD.

For decontamination studies samples were collected from the plot, 48 hr after the application of Celcron 50% EC formulation and divided into eleven equal portions. Every portion was subjected to different cleansing treatment to investigate the impact of different culinary processes on reducing profenofos residues. These included washing with running tap water, soaking in lukewarm water, soaking in a 1% NaCl solution, soaking in a 5% $NaHCO_3$ aqueous solution, soaking in a 2% CH_3COOH solution, soaking in a 0.01% $KMnO_4$ solution, and dipping in commercially available decontaminant formulations (such as Veggi Clean, Nimwash, and Arka Herbiwash) for 10 min. Each treatment was replicated three times. Samples of chili without any processing (Control) were also analyzed for residues alongside the processed samples.

RESULTS AND DISCUSSION

The recovery of different pesticides at three concentrations in chilli crop ranged between 83.2 and 87.3% (Table 1), which denotes the acceptability of extraction method. The correlation coefficient (r) value of $r^2 \geq 0.99$ was obtained, which indicated a good linear relationship. The limit of detection and limit of quantification was 0.005 and 0.02 mg/kg^{-1} respectively. Additionally, retention times of profenofos remained consistently at 16.7 minutes.

Table 1: Validation data of standardized analytical method

Pesticide	Linear range (mg/kg^{-1})	Variation coefficient	LOD (mg/kg^{-1})	LOQ (mg/kg^{-1})	% Recovery with RSD
Profenofos	0.005-2	0.999	0.005	0.02	83.2 ± 2.3 to 87.3 ± 1.7

Profenofos residues obtained in different treatments were calculated relative to pesticide residues in T0 where no treatment was done and the % decontamination was zero. As evident from the data, treating chili crop with 1% NaCl was the most effective method for removing profenofos residues (Table 2). The strong electrolytic properties of salt solutions with a net charge enable them to interact with pesticides, creating an attractive force that facilitates their removal from the vegetable matrix (Rasolonjatovo *et al.*

2017). Washing with lukewarm water was the second most effective treatment for removing residues, slightly more effective than using running tap water. This effectiveness is likely due to slight solubility of profenofos in water, influenced by its high oil-water partition coefficient and low vapor pressure. Soaking in an acetic acid solution was also effective, removing residues up to 80%.

Adding reagents such as CH_3COOH and NaCl to washing water can significantly decrease pesticide residues by affecting the chemical bonds between the pesticide and the plant surface (Srivastava *et al.* 2022). It is therefore likely that cations (H^+ from acetic acid or Na^+ from sodium chloride) present in decontaminants might bind with charged moieties on cuticular surface of chili fruits and expel the pesticides sorbed on its surface, reducing the firmness with which the organic pesticides are bound to cuticular surface of the fruits and vegetables and hence effect their removal during washing (Srivastava *et al.* 2021). Acidic reagents are particularly effective in reducing organophosphates and pyrethroids from spinach (Amir *et al.,* 2019).

The effectiveness of commercially available decontaminants such as Veggie Clean, Nimwash, and Arka Herbiwash varied slightly, likely due to differences in their chemical compositions. Though all three were effective in removing profenofos residues, but Nimwash emerged as the most effective commercial decontaminant for all tested pesticides, while Arka Herbiwash was the least effective among the treatments employed. The efficacy of pesticide decontamination depends on the interactions between the pesticide and the physicochemical properties of the applied decontaminants.

CONCLUSION

Thus it is concluded that thorough washing and dipping chili in saline solutions can effectively reduce high concentrations of pesticides applied on the crop. Since pesticide residues are typically higher in market-sold vegetables, it is crucial to monitor and decontaminate them. Household methods like washing, cooking, washing followed by cooking, and washing with salt water help in lowering pesticide residues. These decontamination methods are cost-effective as most solutions are household items and inexpensive. However, it is important to note that the treatment solutions should be used only once, as reusing them can reduce their effectiveness in removing pesticides. Commercial decontaminants can also be used for reduction of profenofos residues in chili but they are not so cost-effective.

Table 2: Effect of different decontamination methods in the removal of profenofos residues from chili

Decontamination Treatments	Profenofos (50%EC) Residues (mg / Kg)	Reduction (%)
T-0 (Without any decontamination)	30.87	0
T-1 (Washing with Running Tap water for 1min.)	5.68	81.60
T-2 (Soaking in water for 10 min.)	7.56	75.51
T-3 (Soaking in Lukewarm water for 10 min.)	3.08	90.03
T-4 (1% NaCl for 10 min.)	5.88	90.95
T-5 (5%NaHCO3 for 10 min.)	7.99	74.11
T-6 (2% Acetic acid for 10 min.)	5.87	80.98
T-7 (0.01% KMnO4 for 10 min.)	6.56	78.75
T-8 (Veggie clean for 10 min.)	6.82	77.91
T-9 (Nimwash for 10 min.)	6.51	78.91
T-10 (Arka Herbiwash for 10 min.)	8.62	72.05

ACKNOWLEDGMENT

The authors are thankful for the financial assistance provided by Coordinator, All India Network Project (AINP) on Pesticide Residue Analysis, IARI, New Delhi, for carrying out these studies.

REFERENCES

Amir R. M., Randhawa M. A., Nadeem M., Ahmed A., Ahmad A., Khan M. R. and Kausar, R. 2019. Assessing and reporting household chemicals as a novel tool to mitigate pesticide residues in spinach (Spinacia oleracea). *Scien. Reports* **9**(1) : 1125.

Anita S. A. and Devi S. 2018. Impact of different decontamination processes on the reduction of pesticide residues in fruits and vegetables. *Internat. J. Curr. Microbiol. and Appl.Sci.* **7** : 869-876.

Bhilwadikar T., Pounraj S., Manivannan S., Rastogi N. K. and Negi, P. S. 2019. Decontamination of microorganisms and pesticides from fresh fruits and vegetables: A comprehensive review from common household processes to modern techniques. *Comprehen. Reviews in Food Sci. and Food Safety* **18**(4) : 1003-38.

Cengiz M. F. and Certel M. 2012. Decontamination techniques of pesticide residues before food processing or consumption. *Akad. Gıda* **10**(2) : 69-74.

Cengiz M. F., Certel M., Karakaş B. and Göçmen H. 2007. Residue contents of captan and procymidone applied on tomatoes grown in greenhouses and their reduction by duration of a pre-harvest interval and post-harvest culinary applications. *Food Chem* **100**(4) : 1611-1619.

Halder J., Srivastava K. and Rai A.B. 2023. Irrigation, a potential tool for insect pest management in horticultural crops — a review. *Current Horticulture* **11**(1) : 3-7

Keikotlhaile B. M., Spanoghe P. and Steurbaut W. 2010. Effects of food processing on pesticide residues in fruits and vegetables: A meta-analysis approach. *Food and Chem. Toxicol* **48**(1) : 1-6.

Mostafalou S. and Abdollah, M. 2013. Pesticides and human chronic diseases: evidences, mechanisms, and perspectives. *Toxicol. and Appl. Pharmacol* **268**(2) : 157-77.

Radwan M. A., Abu-Elamayem M. M., Shiboob M. H. and Abdel-Aal A. 2005. Residual behaviour of profenofos on some field-grown vegetables and its removal using various washing solutions and household processing. *Food and Chem.l Toxicol* **43**(4) : 553-57.

Rani G. B., Sri C. N. S., Rishita Y., Saikia, N. and Rao C. S. 2019. Domestic methods for the removal of pesticide residues in chilies. *JPP* **8**(4) : 2690-93.

Rasolonjatovo M. A., Cemek M., Cengiz M. F., Ortaç D., Konuk H. B., Karaman E. and Göneş S. 2017. Reduction of methomyl and acetamiprid residues from tomatoes after various household washing solutions. *International J. Food Prop* **20**(11) : 2748-59.

Rawat K., Srivastava A., Tandon S. and Singh G. 2024. Validation and efficacy of various decontamination solutions in eliminating acephate residues from okra. *Trends in Hort.* **7**(2) : 07

Rawat K., Srivastava A., Tandon S. and Singh G. P. 2023. Method validation for simultaneous determination of four neonicotinoids in vegetables by liquid chromatography. *Anal. Sci* **39**(4) : 431-39

Reddy M.R.S.and Reddy G.S. 1999. An ecofriendly method to combat Helicoverpa armigera (Hub.). *Insect Environ* **4**(4) : 143- 44.

Sarkar S.K., Panwar S., Paul R.K., Tomar S., Kumar N. and Morya O.P. 2020. Assessment of pre- and post-harvest losses of vegetables in Kanpur district of Uttar Pradesh. *Current Horticulture* **8**(2): 29–33.

Shi Xiang Guo S. X., Gu AiHua G. A., Ji Gui Xiang, J. G., Li Yuan L. Y., Di Jing D. J., Jin Jing J. J., and Wang XinRu W. X. 2011. Developmental toxicity of cypermethrin in embryo-larval stages of zebrafish. *Chemosphere* **85**(6) : 1010–16.

Souza L. P., Faroni L. R. D. A., Heleno F. F., Pinto F. G., Queiroz M. E. L. R. and Prates L. H. F. 2019. Difenoconazole and linuron dissipation kinetics in carrots under open-field conditions. *Ecotoxico. and environ. safety* **168** : 479-85.

Srivastava A., Chabra A., Singh G. P. and Srivastava P. C. 2021. Efficacy of different decontamination processes in mitigation of pesticide residues from chili crop. *J. Food Prot.* **84**(5) : 767-71.

Srivastava A., Singh G. P., Chhabra A. and Srivastava, P. C. 2022. Determination of pesticides residues and evaluation of decontamination treatments in chili. *Indian J. Hort.* **79**(2) : 249-255.

Srivastava A., Singh G.P. and Srivastava P.C. 2021. Method validation for determination of nine pesticides in okra and their mitigation using different solutions PLoS ONE **16**(12):e0260851. https://doi.org/10.1371/journal.pone.0260851

Current Horticulture **13**(1): 0–0, January–March 2025
DOI: 10.5958/2455-7560.2025.00012.2
Received: 03 November 2023; Accepted: 11 December 2024

Effect of phosphorus, biofertilizers and zinc application on growth and quality-attributing characteristics of garden pea (*Pisum sativum*)

Mahendra Yadav, RS Meena, ARK Pathan and OP Garhwal

Sri Karan Narendra Agricultural University, Jobner, Jaipur (Rajasthan), India

Abstract

A field experiment was conducted during November 2021 to February 2022 and November 2022 to February 2023, comprising 32 treatment combinations replicated three times, at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan. It followed a split plot design with main plots assigned to four phosphorus levels (P_2O_5 @ 0, 20, 40 and 60 kg/ha) and two biofertilizer conditions (without inoculation and with inoculation of Rhizobium + PSB). Sub-plots were dedicated to four zinc levels (control, 2.5, 5.0 and 7.5 kg Zn/ha). There was significantly maximum plant height (65.17, 63.47 and 64.32 cm), number of primary branches (2.57, 2.45 and 2.51), minimum days to 50 % flowering (41.90, 41.51 and 41.70), nitrogen content (3.74, 3.52 and 3.63 %) and protein content (23.40, 21.97 and 22.69 %) were recorded with application up to P_2O_5 40 kg/ha, In biofertilizer, maximum plant height (64.42, 63.03 and 63.72 cm), number of primary branches (2.61, 2.52 and 2.57), minimum days to 50 % flowering (42.30, 42.82 and 42.56) nitrogen content (3.66, 3.39 and 3.53 %) and protein content (22.90, 21.20 and 22.05 %) were recorded with inoculation (Rhizobium+PSB) and In zinc treatments the maximum plant height (65.05, 64.06 and 64.56 cm) number of primary branches (2.58, 2.50 and 2.54) minimum days to 50 % flowering (42.09, 41.25 and 41.67) nitrogen content (3.57, 3.39 and 3.48 %) and protein content (22.31, 21.19 and 21.75 %) were recorded with 5.0 kg Zn/ha, respectively.

Key Words : Biofertilizer, Protein, Phosphorus, Zinc levels, Growth Flowering

Garden pea (*Pisum sativum* var. *hortense* L.), Leguminosae family, is highly valued for its protein content and its supply of various minerals and vitamins. (Gopalan *et al.*, 2007). Adequate phosphorus application improved growth, yield, quality, and nodule formation in legumes. More than 30% of the world's arable land used for pea production is limited by phosphorus availability (Tesfaye *et al.*, 2007). Phosphorus is especially critical for legumes in nutrient-poor environments due to its significant role in nitrogen fixation process (Tsvetkova and Georgiev, 2007). Sharma and Chandra (2004), reported that supplying plants with phosphorus is the development of deeper and more extensive root systems. Similarly use of biofertilizers plays an important role in improving fertilizers use efficiency. These days biofertilizers have emerged as an important component to improve an overall crop performance (Yadav and Kavita, 2016). The most crucial micronutrient zinc is required for cell division and the metabolism of nitrogen and carbohydrates and the relationship between water and plant growth (Brady, 1990). Zinc is necessary for metabolism and helps to create nodules that fix nitrogen (Patel *et al.*, 2011). Zinc is requires in auxin metabolism like tryptophan synthesis and tryptamine metabolism (Kuldeep *et al.,* 2018). Phosphorus and zinc interaction affects the availability and utilization of both nutrients and dynamics are impacted by an imbalance in soil matrix (Singh *et al.,* 2017).

***Corresponding author :** ymahendra51@gmail.com

MATERIALS AND METHODS

The experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, during November 2021 to February 2022 and November 2022 to February 2023. There was 32 treatment combinations replicated three times, following a split plot design with the main plots assigned to four phosphorus levels (P_2O_5 @ 0, 20, 40 and 60 kg/ha) and two biofertilizer conditions (without inoculation and with inoculation of Rhizobium + PSB). Sub-plots were dedicated to four zinc levels (control, 2.5, 5.0 and 7.5 kg Zn/ha).

The pea variety Azad P-3 was sown on November, 2021 and November, 2022, maintaining a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm. The geographical location of this place is 75^0 47' east (longitude), $26^0$51' North (latitude) and 393 m above MSL. The experimental field with loamy sand texture, had slightly alkaline, and low levels of organic carbon. The soil was deficient in available nitrogen but had medium levels of available phosphorus and potassium. The pH was 8.2-8.4 with electrical conductivity of 0.19-0.25 dS/m throughout the growing period, the recommended cultural practices were followed. The soil analysis was performed as per AOAC (2005) guidelines. Phosphorus and zinc were applied at sowing through diammonium phosphate (DAP) and zinc sulphate (21%), respectively.

Nitrogen was applied at sowing in the form of urea and a biofertilizer was introduced through seed inoculation.

The plant height was studied 60 days after sowing (DAS) by meter scale, number of primary branches 50 DAS, and days to 50 % flowering. The nitrogen (%), protein (%) and total soluble solids (TSS), which were used to judge the quality of peas. Protein content was estimated by multiplying the nitrogen content (determined by digesting samples with concentrated H_2SO_4 and using a digestion mixture, by colorimetric method of Snell and Snell, 1949) by a factor of 6.25. TSS content was determined using a Zeiss Pocket refractometer (0 to 32.0 Brix), where a drop of extracted juice from fresh pea grains was placed on the prism and the reading was taken (AOAC, 1975). The data were statistically analysed as per Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever 'F' test was found significant at a 5 % level of probability. Mention the parameters used for data recordings to decide performance of the plants.All the standard cultural practices were followed during the crop growth.

RESULTS AND DISCUSSION

Growth attributes

The plant height was significantly influenced by the application of phosphorus biofertilizer and zinc fertilizers 60 days after sowing. The plant height 60 DAS increased notably with the application of phosphorus up to 40 kg/ha compared to the control and 20 kg/ha application. This increase was also statistically at par to P_2O_5 @ 60 kg/ha during 2021-22 and 2022-23, pooled basis. The use of phosphorus can enhance plant development due to its role in synthesis of proteins, vitamins and chlorophyll. These findings are consistent with those of Kumar and Puri (2002), Kumar *et al. (*2009), and Sonet *et al.* (2020). In biofertilizer, highest plant height was recorded with B_1 (Rhizobium + PSB) treatment (64.42, 63.03 and 63.72 cm, respectively.) while lowest plant height was found in B_0 (without inoculation) treatment (56.86, 55.66 and 56.26 cm, respectively.). Rhizobium increased fixation of atmospheric nitrogen in the soil, making it available for plant use and promoting vigorous plant growth. Similar results were also reported by Sibbal *et al.* (2002) and Tyagi *et al.* (2003). The PSB facilitated increased nutrient absorption, elevated photosynthesis and enhanced assimilate production (Table 1).

Applying 2.5 kg Zn/ha resulted in a significant increase in plant height compared to plants that did not receive any zinc treatment. Plant height increased further with a treatment of 5 kg Zn/ha compared to 2.5 kg Zn/ha. However, increasing zinc application rate from 5 kg Zn/ha to 7.5 kg Zn/ha led to a decrease in plant height, likely due to antagonistic effect of phosphorus at higher zinc levels. Thus, application of 5 kg Zn/ha resulted in tallest plants (Table 1). This effect can be attributed to zinc's role as a catalyst or stimulant in numerous physiological and metabolic processes, as well as its enzyme-activating properties, which enhanced plant growth and development. Comparable findings were reported by Ullah *et al.* (2018).

The number of primary branches/plant (2.57, 2.45 and 2.51, respectively.) was observed up to the application of P_2O_5 @ 40 kg/ha (P_2). This level of phosphorus application was significantly higher than the control (P_0) (2.24, 2.12 and 2.18, respectively) and the application of P_2O_5 @ 20 kg/ha (P_1) (2.32, 2.24 and 2.28, respectively.). Moreover, it remained at par with the application of P_2O_5 @ 60 kg/ha (P_3). Kumar *et al.* (2009) and Sonet *et al.* (2020) reported similar results. In biofertilizer, highest number of branches/plant (2.61, 2.52 and 2.57, respectively.) was recorded with B_1 (Rhizobium + PSB) treatment while lowest number of branches/plant (2.28, 2.16 and 2.22, respectively.) was found in B_0 (without inoculation) treatment during 2021-22, 2022-23, polled basis.

Similar results were reported by Sibbal *et al.* (2002), Tyagi *et al.* (2003) and Gaind and Guar (1991). The number of primary branches/plant at 50 days after sowing (DAS) increased significantly with zinc application. The highest number of primary branches/plant was observed with the 7.5 kg Zn/ha treatment, followed by 5 kg Zn/ha treatment and the control. However, higher levels of zinc (5 and 7.5 kg Zn/ha) were statistically similar in terms of number of primary branches/plant. Similar results were reported by Ullah *et al.* (2018).

The number of days to 50 % flowering varied with different phosphorus levels. The shortest time to 50 % flowering was observed (41.21, 40.12 and 40.66) with application of P_2O_5 60 kg/ha which was significantly shorter than the control and P_2O_5 20 kg/ha treatments. However, it was statistically at par to the P_2O_5 40 kg/ha (41.90, 41.51 and 41.70) treatment during 2021-22 and 2022-23 seasons a pooled basis. The reduction in number of days to 50 % flowering may be attributed to the readily available applied phosphorus, promoting enhanced root and shoot growth. This, in turn, translated into improved vegetative growth and earlier flowering, aligning with findings from Magani and Kuchinda (2009). In biofertilizer, the shortest time to 50 % flowering was recorded with B_1 treatment (42.30, 42.82 and 42.56 days), while longest time was observed with B_0 treatment (45.27, 43.55 and 44.41 days) during 2021-22, 2022-23 seasons, pooled mean, respectively. The application of 5.0 kg Zn/ha resulted in shortest time to 50% flowering (42.09, 41.25

Table 1. Effect 0f fertilizer on plant height, number of primary branches and day to 50% flowering

Treatment	Plant height (cm)			No. of primary branches			Days to 50 % flowering		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Phosphorus									
P_0-Control	51.94	50.87	51.41	2.24	2.12	2.18	46.64	46.10	46.37
P_1-20 kg P_2O_5/ha	59.06	57.80	58.43	2.32	2.24	2.28	45.40	45.01	45.20
P_2-40 kg P_2O_5/ha	65.17	63.47	64.32	2.57	2.45	2.51	41.90	41.51	41.70
P_3-60 kg P_2O_5/ha	66.38	65.23	65.81	2.64	2.56	2.60	41.21	40.12	40.66
SEm±	1.37	1.29	0.94	0.06	0.05	0.04	0.98	0.92	0.67
CD (P=0.05)	4.09	3.83	2.73	0.18	0.16	0.12	2.91	2.75	1.95
Biofertilizer									
B_0-Without inoculation	56.86	55.66	56.26	2.28	2.16	2.22	45.27	43.55	44.41
B_1-With inocultion (Rhizobium+PSB*)	64.42	63.03	63.72	2.61	2.52	2.57	42.30	42.82	42.56
SEm±	0.97	0.91	0.67	0.04	0.04	0.03	0.69	0.65	0.48
CD (P=0.05)	2.89	2.71	1.93	0.13	0.11	0.08	2.06	1.94	1.38
Zinc									
Z_0-Control	55.81	53.65	54.73	2.29	2.17	2.23	44.69	44.16	44.43
Z_1-2.5 Kg Zn/ha	57.73	56.35	57.04	2.40	2.25	2.33	45.38	45.10	45.24
Z_2-5.0 Kg Zn/ha	65.05	64.06	64.56	2.51	2.44	2.48	42.09	41.25	41.67
Z_3-7.5 Kg Zn/ha	63.97	63.31	63.64	2.58	2.50	2.54	42.98	42.23	42.61
SEm±	0.74	0.72	0.52	0.05	0.05	0.03	0.72	0.70	0.50
CD (P=0.05)	2.10	2.05	1.45	0.15	0.13	0.10	2.04	1.97	1.41

and 41.67) outperforming the control and 2.5 kg Zn/ha treatments. However, this result was statistically at par to the 7.5 kg Zn/ha (42.98, 42.23 and 42.61) treatment across both individual years and on a pooled basis. These consequences are in agreement with Neenu *et al.,* (2014) who informed delay in flowering and physiological maturity in control plots.

Quality attributes

This increase was found to be statistically significant compared to the preceding levels of application, with highest nitrogen content (3.83, 3.64 and 3.73 %, respectively) observed at P_2O_5 @ 60 kg/ha (P_3) consistently during the 2021-22, 2022-23 and on a pooled basis. In biofertilizer highest nitrogen content in seeds was recorded as 3.66, 3.39 and 3.53 % was observed under treatment B_1 (Rhizobium + PSB). In contrast, lowest nitrogen content, measured at 3.05, 2.97 and 3.01 % was found in treatment B_0 (without inoculation) during 2021-22, 2022-23 pooled analysis, respectively. In zinc treatments highest increase in nitrogen content (3.57, 3.39 and 3.48 % during 2021-22 and 2022-23, respectively) observed with application of 5.0 kg Zn/ha, followed by 7.5 kg Zn/ha (3.51, 3.32 and 3.42 % during 2021-22 and 2022-23, respectively.). The application of phosphorus likely improved nutritional environment in rhizosphere and plant system, resulting in an enhanced uptake and translocation of nutrients, particularly nitrogen and phosphorus (Table 2).

The higher levels of phosphorus led to a significant increase in protein content, peaking at P_2O_5 @ 40 kg/ha. The application of P_2O_5 @ 40 kg/ha was statistically equivalent to P_2O_5 @ 60 kg/ha during 2021-22, 2022-23 and in the pooled analysis. The highest protein content (22.90, 21.20 and 22.05 %, respectively) was observed under treatment B_1 (Rhizobium + PSB) whereas lowest protein content (19.03, 18.58 and 18.81 %, respectively) was recorded in treatment B_0 (without inoculation) during 2021-22, 2022-23 and in pooled analysis. The protein content (21.94, 20.75 and 21.34 per cent, respectively) achieved with application of 5.0 kg Zn/ha (Z_2) was notably higher than the control and 2.5 kg Zn/ha (Z_1) but statistically on a par (21.94, 20.75 and 21.34 %, respectively) to that of 7.5 kg Zn/ha (Z_3) during both years and on a pooled basis. Similar findings were reported by Ahmed *et al.* (2003), Vikrant *et al.* (2005) and Tripathy *et al.*

Table 2. Effect of phosphorus, biofertilizers and zinc on nitrogen and protein content in garden pea seed (%)

Treatment	Nitrogen content (%)			Protein content (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Phosphorus						
P_0-Control	2.72	2.59	2.66	16.97	16.21	16.59
P_1-20 kg P_2O_5/ha	3.13	2.98	3.06	19.53	18.65	19.09
P_2-40 kg P_2O_5/ha	3.74	3.52	3.63	23.40	21.97	22.69
P_3-60 kg P_2O_5/ha	3.83	3.64	3.73	23.96	22.72	23.34
SEm±	0.05	0.05	0.04	0.38	0.37	0.27
CD (P=0.05)	0.16	0.15	0.11	1.14	1.10	0.77
Biofertilizer						
B_0-Without inoculation	3.05	2.97	3.01	19.03	18.58	18.81
B_1-With inocultion (Rhizobium+PSB*)	3.66	3.39	3.53	22.90	21.20	22.05
SEm±	0.04	0.04	0.03	0.27	0.26	0.19
CD (P=0.05)	0.11	0.10	0.07	0.81	0.78	0.55
Zinc						
Z_0-Control	3.04	2.87	2.96	19.00	17.94	18.47
Z_1-2.5 Kg Zn/ha	3.30	3.15	3.23	20.63	19.69	20.16
Z_2-5.0 Kg Zn/ha	3.57	3.39	3.48	22.31	21.19	21.75
Z_3-7.5 Kg Zn/ha	3.51	3.32	3.42	21.94	20.75	21.34
SEm±	0.04	0.04	0.03	0.22	0.21	0.15
CD (P=0.05)	0.11	0.11	0.08	0.63	0.58	0.42

(2020). Singh and Singh (2012) reported that application of increasing doses of Zn resulted in a significant increase in protein content of chickpea over control which might be attributed to its involvement in nitrogen metabolism of plants.

CONCLUSION

Thus applying 40 kg/ha of phosphorus (P_2O_5) and 5.0 kg/ha of zinc significantly enhanced plant height, number of branches/plant, reduced days to 50 % flowering, and enhanced nitrogen and protein quality. Therefore, it can be concluded that the optimal treatment for improving the growth and quality parameters of garden pea crops is the application of P_2O_5 40 kg/ha, biofertilizer (inoculated with Rhizobium and PSB) and 5.0 kg/ha of zinc.

REFERENCES

Ahmed, M.K.A., Afifi, M.H. and Mohamed, M.F. 2003. Effect of biofertilizers, chemical and organic fertilizers on growth, yield and quality of some leguminous crops. *Egyptian Journal of Agronomy* **25**: 45-52.

AOAC, Virginia USA. 2005. Official methods of analysis. 18th rev. edn. Association of Official Analytical Chemists, Arlington, Virginia, USA

AOAC, Washington, D.C. 1975. Official methods of analysis, *Association of Analytical Chemists.* Benjamin Franklin Station, Washington, D.C

Brady, N.C. 1990. The Nature and Properties and Soils.10th edn. Ghosh (Ed.) Printing Hall of India Pvt. Ltd., New Delhi, pp. 383.

Gaind, S. and Gaur, A.C. 1991. Thermotolerant phosphate solubilizing micro-organisms and their interaction with mung bean. *Plant and Soil* **133**: 141-49.

Gopalan, R., Nanda, V. and Seru, A. 2007. Affiliated firms and financial support: Evidence from Indian business groups. *Journal of Financial Economics* **86**(3): 759-795.

Kuldeep., Kumawat P.D., Bhadu, V., Sumeriya, H.K. and Kumar, V. 2018. Effect of Iron and Zinc Nutrition on Growth Attributes and Yield of Chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences* **7**(8): 2837-841.

Kumar P, Puri UK. 2002. Response of french bean (*Phasiolus vulgaris*) varieties to phosphorus and farmyard manure application. *Indian Journal of Agronomy* **47**(1):86-88.

Kumar V., Dwivedi K.N. and Tiwari D.D. 2009. Effect of phosphorus and iron on yield and mineral nutrition in chickpea. *Annals of Plant* and *Soil Research* **11**(1):16-18.

Magani, I.E. and Kuchinda, C. 2009. Effect of phosphorus fertilizer on growth, yield and crude protein content of cowpea [*Vigna unguiculata* (L.) Walp.] in Nigeria. *Journal of Applied Biosciences* **23**: 1387-93.

Neenu, S., K. Ramesh, S. Ramana, A.K. Biswas and A.S. Rao. 2014. Growth and yield of different varieties of chickpea (*Cicer arietinum* L.) as influenced by the phosphorus nutrition under rainfed conditions on vertisols. *International Journal of Bio-resource and Stress Management* **5**(1): 053-057.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers, ICAR, New Delhi.

Patel, M.M., Patel, I.C., Patel, R.I. and Acharya, S. 2011. Effect of zinc and iron on yield and yield attributes of rainfed cowpea (*Vigna unguiculata* L. Walp). *Annals of Arid Zone* **50**(1): 17-19.

Sharma, A. and Chandra, A. 2004. Effect of plant density and nitrogen levels on physicochemical parameters of cauliflowers. *Haryana Journal* of *Horticultural Sciences* **33**(2): 148–149.

Sibbal, A., Gupta, K.P., Pandher, M.S. and Kanwar, J.S. 2002. Effect of Rhizobium culture inoculation on different pea (*Pisum sativum* L.) varieties. *Legume Research-An International Journal* **25**(1): 21-26.

Singh, D. and Singh H. 2012. Effect of phosphorus and zinc nutrition on yield, nutrient uptake and quality of chickpea. *Annals* of Plant and *Soil* Research **14**: 71-74.

Singh, L. Sharma, P.K., Jajoria, M., Deewan, P. and Vermam, R. 2017. Effect of phosphorus and zinc application on growth and yield attributes of pearl millet (*Pennisetum glaucum* L.) under rainfed condition. *Journal of Pharmacognosy and Phytochemistry* **6**(1): 388-91.

Snell, F.D. and Snell, C.T. 1949. Colorimetric Methods of Analysis. 3rd edn. Vol. II D. Van Nostrand Co. Inc., New York.

Sonet, R.A., Ali, M.H., Amin, A.K.M.R., Haque, M.N., Masum, S.M. 2020 Influence of phosphorus levels on growth and yield of four lentil varieties. *Bangladesh Agronomy Journal* **23**(1): 29-36.

Tesfaye, M., Liu, J., Allan, D.L. and Vance, C. P. 2007. Genomic and genetic control of phosphate stress in legumes. *Plant* Physiology **144**: 594–603.

Tripath, D.K., Kumar, S. and Zaidi, S.F.A. 2020. Effect of phosphorus, sulphur and micronutrients (Zinc and Boron) levels on performance of chickpea (*Cicer arietinum* L.). *National Academy Science Letters* ***43***: 9-11.

Tsvetkova, G.E. and Georgiey, G.I. 2007. Changes in phosphate fractions extracted from different organs of phosphorus starved nitrogen fixing pea plants. *Journal of Plant Nutrition* **30**: 2129–40.

Tyagi, M.K., Singh, C.P., Bhathcharayya, P. and Sharma, N.L. 2003. Dual inoculation effect of rhizobium and phosphate solubilizing bacteria on pea (*Pisum sativum L.*). *Indian Journal of Agricultural Research* **37**: 1-8.

Ullah, S., Jan, A., Ali, M. and Ahmad, B. 2018. Response of Chickpea (*Cicer Arietinum* L.) to Phosphorus and Zinc levels and their application methods. *Sarhad Journal of Agriculture* **34**(3): 575.

Vikrant, V., Singh, H., Malik, C.V.S. and Singh, B.P. 2005. Grain yield and protein content of cowpea as influenced by farm yard manure and phosphorus application. *Indian Journal of Pulses Research* **18**(2): 250-251.

Yadav, L P and Kavita A. 2016. Yield and quality response of cabbage *(Brassica oleracea)* var. Pride of India to nitrogen and biofertilizers. *Current Horticulture* **4**(2): 7-10.

Current Horticulture 13(1): 72–74, January–March 2025
DOI: 10.5958/2455-7560.2025.00013.9
Received: 14 March 2024; Accepted 19 September 2024

Farmer producers' organizations in Karnataka with respect to neera production in coconut (*Cocos nucifera*)–a case study

Prabhat Kumar, Hanumanthe Gowda B and Leenamol MA

Coconut Development Board, Kera Bhavan, SRV Road, Kochi, Kerala, India

Abstract

The study investigated the success rate of Kalparasa [a fresh, unfermented, nutritious health drink obtained from the inflorescence of coconut (*Cocos nucifera* L)], which emerged as an innovative method to generate income from coconut palms. The company, Kalparasa Coconut and All Spices Producers Company Limited, was established and has benefited a large number of coconut growers in Karnataka, as well as other states like Jharkhand, Odisha, and Assam. In the current financial year, each palm yielded 400-600 liters of Kalparasa, with the participation of 6,800 farmers as shareholders and 19 farmers specifically involved in neera collection. The company has increased its turnover from Rupees 6.18 lakhs in 2021–22 to Rupees 22.69 lakhs in 2022–23.

Key words: Kalparasa, Neera, Tapping, Udupi, Farmers Producers' organizations

Coconut (*Cocos nucifera* L), also known as "Kalpavriksha", is a tropical plant that thrives well under hot, wet, and humid conditions at a temperature of 27±5°C. In fact, every part of the coconut tree can be utilized, ensuring that nothing goes to waste. Coconut cultivation has been found to be very successful along the Malabar and Coromandel coasts of India. The southern states of India, such as Kerala, Karnataka, and Tamil Nadu, extensively cultivate coconut and reap large amounts of income from it.

The Udupi district of Karnataka, situated between the Arabian Sea to the west and the Western Ghats to the east, is one of the major coconut-growing areas in southern India. Coconut is one of the major crops cultivated in Udupi district, covering 22,226 ha, with a production of 3,026.57 lakh nuts (2021–22). It ranks 8th in area and 6th in production among the coconut-growing districts of the state. The productivity of coconut in the district is 13,617 nuts per hectare.

Even though the farmers of Karnataka had a good number of productive coconut palms, they were unable to reap significant profits from the crop due to various challenges, such as monkey menace, peacocks, and other wild animals. To address this issue and ensure better profits for farmers, Satyanarayan Udupa, District Secretary of a farmers' organization, in association with CPCRI (Central Plantation Crops Research Institute), established a "Neera" (a fresh, unfermented, nutritious health drink obtained from the inflorescence of coconut) production company—Udupi Kalparasa Coconut and All Spices Producers' Company Limited—under the brand name Kalparasa, in Japthi village of Kundapura taluka in Udupi district, Karnataka.

*Corresponding author : prabhatflori@gmail.com

MATERIALS AND METHODS

The study was undertaken in the Udupi district of Karnataka. Devastated by the reduction in coconut productivity, Shri Satyanarayan Udupa, after discussions with the Horticulture Officer of Karnataka, found a solution to the issue through the production of neera (Kalparasa). It was ensured that the quality of neera would not deteriorate. To achieve this, any produce with a pH below 5.5 is converted into other products such as jaggery (sharkara), honey (madhu), vinegar, chocolate, and ice cream.

Neera production technology was acquired from CPCRI, Kasaragod, in 2019 (Fig. 1), and a total of 68 farmers were trained in hygienic neera tapping. Of these, 48 farmers were from Karnataka, and the rest were from other states such as Jharkhand, Odisha, and Assam. Payments for tappers were made on a per-liter basis, with a wage of ₹400. The tappers were insured under the Kera Suraksha Insurance Scheme of the Coconut Development Board, and a mediclaim coverage of ₹6 lakh was provided.

Shri Satyanarayan Udupa linked 6,800 farmers through 73 coconut farmer societies, and shares were collected from the farmers, with ten directors as assured shareholders. A license for the production and marketing of neera was obtained from the Excise Department of the state in March 2020 for tapping and extraction of neera. In December 2021, permission was also granted for its sale. After obtaining the license, eight trees were selected from each farmer for neera extraction, ensuring that the maximum number of farmers could be involved.

Fig.1. Coconut sap chillers used by farmers for collection of neera

RESULTS AND DISCUSSION

As per the studies and the current trends, it indicates that 64 farmers have benefited from neera tapping, with an average farmer earning around eighty thousand to one lakh rupees per annum from tapping eight coconut palms. The company provides employment to various tappers from the state as well as from other states such as Jharkhand, Odisha, and Assam.

It has been observed that a tree can produce 400-600 of kalparasa per annum, and the farmers are paid twenty rupees per litre if the company provides all the arrangements. However, if the farmer makes all arrangements, the company pays them seventy rupees per litre.

It is clear that the monthly production of kalparasa and the company's turnover have also increased. During 2023-24, a monthly production of 2200 litres with the involvement of nineteen farmers and a turnover of thirty-six lakhs is anticipated. In 2022-23, the monthly production of kalparasa from thirty-two farmers was one thousand eight hundred litres, yielding a turnover of twenty-two lakhs sixty-nine thousand and two hundred six rupees. Prior to that, in the financial year 2021-22(Table 1), the company's turnover was six lakhs eighteen thousand seven hundred and sixty-two rupees with a monthly production of one thousand two hundred litres of kalparasa. It was also found that neera can be converted into several other products such as jaggery, sharkara (crystallized jaggery), honey, vinegar, chocolate, and ice cream.

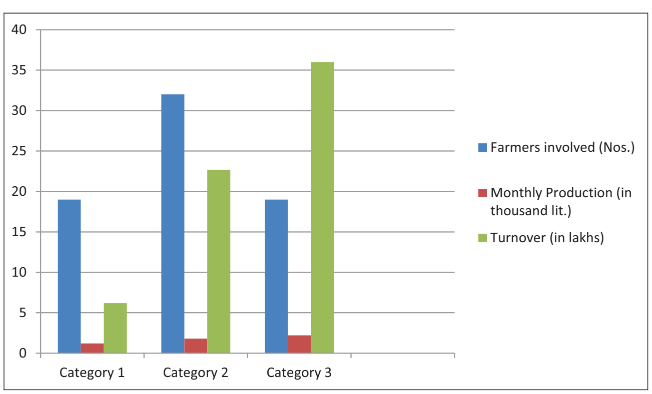

Fig.2. Monthly production and turnover of Udupi Kalparasa Coconut and All Spices Producers' Company Limited

Table 1. Production and turnover of Udupi Kalparasa Coconut and All Spices Producers' Company Limited

Year	No. of farmers involved	Monthly production (lt.)	Turnover (in lakh)
2021-22	19	1,200	6.18
2022-23	32	1,800	22.69
2023-24	19	2,200	36.00

The present findings indicate that neera can be converted into several products coincide with those of Chinnamma *et al.*, (2019) who also studied various value-added products of coconut. Sudha *et al.* (2019) studied various uses of coconut inflorescence sap and found that products like coconut sugar, jaggery, and honey can be produced from the sap. Yarin *et al.* (2019) reported that a coconut palm produces an average of eighty-six litres and eleven ml of neera, which is close to the range found in the current studies in the Udupi district.

REFERENCES

Beegum, S., Thamban, C., Subramanian, P., Mathew, A. C., and Ananth, P. N. (2022). Coconut cultivation and coconut based enterprises in Lakshadweep-Changing scenario and need for revitalizing coconut sector.

Chinnamma, M., Bhasker, S., Binitha Hari, M., Sreekumar, D., and Madhav, H. (2019). Coconut neera—a vital health beverage from coconut palms: harvesting, processing and quality analysis. *Beverages* **5**(1): 22.

Kowsalya, P., Kamalapreetha, B., Anbarasan, R. *et al.* (2023) Processing of Coconut Neera to Produce Sugar Granules and Study on its Properties. *Sugar Tech* **25**: 603–609.

Pandiselvam, R., Sathyanath, S., Manikantan, M.R. *et al.* (2024). Physicochemical properties of coconut inflorescence sap (neera) under double wall open heating system. Food Measure

Ramesh, S.V., Pandiselvam, R., Shameena Beegum, P.P., Manikantan, M.R., Gopal, M and Hebbar, K.B. (2024).

Coconut Inflorescence Sap (Neera): Nutritive Potential and Health Conferring Products.

Rangaswami, G. (1977). Palm tree crops in India. *Outlook on Agriculture* **9**(4): 167-73.

Sudha, R., Niral, V., Hebbar, K. B., and Samsudeen, K. (2019). Coconut inflorescence sap. *Current Science* **116**(11), 1809–1817.

Swamy. S.G.M 2013 Coconut neera production and processing in Karnataka. *Indian Coconut Journal*: 31-33

Thamban, C., Jayasekhar, S., Chandran, K. P., and Rajesh, M. K. *(2020)*. Sustainability of Farmer Producer Organisations-The case of producer organisations involved in the production and marketing of 'neera'in the coconut sector in Kerala, India.

Yarin. T., Bandyopadhyay. A and Ghosh. D.K., (2019). Sustainable approach towards conversion of unproductive coconut paslms into productive one through neera production. *Journal of Crop and Weed,* **15**(3): 12-18.

Yuvarani. R., Shoba. N., Senthamizh Selvi. B and Vennilla. P (2020) Studies on development of neera powder from coconut (*Cocos nucifera* L.) neera by using spray dryer.

Current Horticulture **13**(1): 75–79, January–March 2025
DOI: 10.5958/2455-7560.2025.00014.5
Received: 03 November 2023; Accepted: 11 December 2024

Effect of transplanting dates on incidence of brinjal (*Solanum melongena*) shoot-and fruit-borer [*Leucinodes orbonalis* (Guenee)]

Chiranjiv, S M Haldhar, K I Singh, L N K Singh, Pranita Roy and S L Choudhary

Department of Entomology, College of Agriculture, CAU, Imphal, Manipur, India

Abstract

The field experiment was conducted to study the incidence of brinjal (*Solanum melongena* L.) shoot-and fruit-borer [*Leucinodes orbonalis* (Guenee)] on different transplanting dates at the College of Agriculture, CAU, Imphal, during 2021-22. The incidence of *L. orbonalis* on brinjal was noticed on different dates. The third transplanted crop recorded relatively higher shoot damage with a mean of (25.9 per cent), followed by the second, fourth and first transplanted crop with a mean of, 20.7, 16.5 and 11.7 per cent, respectively. Similarly, third transplanted crop recorded highest mean fruit damage (25.0 per cent on a number basis and 23.40 per cent on a weight basis), followed by second, fourth and first transplanted crop recorded with mean fruit damage (21.7 per cent on a number basis and 20.8 per cent on weight basis, 18.0 per cent on number basis and 16.7 per cent on weight basis and 12.2 per cent on number basis and 11.9 per cent on a weight basis).

Key words: Transplanting dates, Shoot infestation, Fruit infestation, Incidence, Shoot-and fruit-borer

Brinjal (*Solanum melongena* L.) is infected by 26 different types of insects and mites (Vevai, 1970). In Manipur, brinjal cultivation is done in 129 hectares of land with a production of 1641 tonnes (Anonymous, 2021). Different insect pests attack brinjal right from the seedling stage to the final harvesting stage. Some important insect pests of brinjal, which cause enormous damage to this crop are brinjal shoot-and fruit-borer (*L. orbonalis*), hadda beetle (*Epilachna* spp), jassid (*Amrasca bigutella bigutella*), aphid (*Aphis gossyppii*) and white fly (*Bemisia tabaci*) (Latif *et al.* 2009). Among these, brinjal shoot-and fruit-borer, *L. orbonalis* is considered to be the most destructive pest of brinjal (Saimander and Gopal 2012, Choudhary *et al.* 2024) and is found in all brinjal- growing countries (Dutta *et al.,* 2011; Tomar and Saha, 2018). Brinjal shoot-and fruit-borer *L. orbonalis* (Guenee) is responsible for crop losses of 20-90 per cent in different regions of the country (Raju *et al.,* 2007; Haldhar and Maheshwari, 2018 and 2021; Chiranjiv *et al.,* 2023; Halder *et al.,* 2023).

This pest is active during rainy and summer seasons and has a distinct feeding pattern. The larva bores into shoots during early stages of crop growth, causing drooping, withering, and drying of affected shoots due to disruption of the vascular system and translocation of food materials. The larvae bore through the calyx and later into the flower buds and fruits at later stages of plant growth, and the bored holes are invariably plugged with excreta (Haldhar *et al.,* 2013; Haldhar and Deshwal, 2017).

***Corresponding author :** haldhar80@gmail.com

The time of transplanting is an important cultural practice having a bearing on the population build-up of the associated pest complex in brinjal. Pest attacks can be suppressed or escaped by altering the transplanting dates. In this way, the most vulnerable period of crop growth may not synchronize with the peak activity of the pest organism. Thus, manipulation of the date of transplanting of this crop may reduce the incidence of this pest and indirectly it may lessen the number of spray applications for its management. Keeping in view the economic importance of the crop, and the quantum of damage caused by the shoot and fruit borer, the study was carried out.

MATERIALS AND METHODS

The experiment was conducted at the College of Agriculture, CAU (24°45' N latitude and 93°56' E longitudes), Imphal, which is located at an altitude of 790 MSL. The climate of Imphal is subtropical, tempered by altitude, with mild, dry winters from November to February and a long, hot and rainy period from April to October 2022. For the seasonal incidence of shoot-and fruit-borer, four different transplanting planting dates (2 September, 12 September, 22 September and 2 October during 2022) were taken during 2022-2023. The soil at the experiment site had a clay loam texture and was acidic in response, with a pH of 5.5. One month before transplanting, experimental field was ploughed extensively with a tractor, followed by three crossing ploughings with a power tiller. After that, the soil was pulverized and the plot was appropriately levelled. Before transplanting, the soil was completely integrated with well-decomposed farmyard manure (FYM) at a rate of 20 tonnes per hectare, Urea, single superphosphate, and murate of potash were used to apply N, P_2O_5 and KO to the experimental crop at 80:40:60 kg/ha, respectively. On the day of the last harrowing of the field, the complete dose of P_2O, and KO, as well as one-third dose of N, were applied uniformly to all plots as a basal dose. After one month of transplanting and at the start of the flowering stage, the remaining N was split into two halves and applied as a side dressing.

The total field area of 144 m^2 was laid out in uniformly sized plots measuring 2m × 2.5 m (5m²) with twenty plots for the experiment with different dates of the transplanted crop. With five replications, the experiment was set up in Randomized Block Design (RBD). The crop was planted (variety: Pusa Purple Long) on four different dates, at ten days intervals. The plot area was 2m x 2.5m in size, with (60 cm x 45 cm) spacing. The shoot/ fruits were split open wherever necessary to note the pinkish-coloured larvae. The crop was left for natural infestation of *L. orbonalis*.

The observations were recorded on shoot infestation at weekly intervals and fruit infestation at each picking. For fruit infestation, a total number of fruits and infested fruits were recorded per plot during each harvesting from each replication. The meteorological parameters (maximum, minimum and mean temperatures, morning, evening and mean relative humidity and rainfall) were taken from the meteorological observatory, ICAR complex, Imphal for computing. Simple correlations between shoot and fruit infestations and weather parameters (maximum, minimum and mean temperatures, morning, evening and mean relative humidity, rainfall) were computed.

$$\text{Yield Loss (\%)} = \frac{\text{Average damaged fruit yield}}{\text{Average total matured fruit yield}} \times 100$$

$$\text{Percentage Damaged Parts} = \frac{\text{Number of damaged plant}}{\text{Total number of plants of served}} \times 100$$

The per cent age of infested shoot/fruit was recorded and data recorded were analyzed by using OPSTAT online software and two factor ANOVA was performed in Randomised Block Design to compute CD value. The treatments with a significant difference were also separated using Tukey's honestly significant difference post Hoc test using IBM SPSS software.

RESULTS AND DISCUSSION

Effects of transplanting on infestation

Among the four different transplanting dates, first transplanting showed owest shoot-and fruit-borer infestation, while third transplanting recorded highest shoot and fruit infestation (Table 1). In the first transplanting (2 September 2022), shoot infestation started from 39th SMW and persisted up to the 48th SMW and infestation varied from 2.39 to 24.03%. The peak shoot infestation (24.03%) was observed in the 43rd SMW. In fruit infestation (at each picking) on a number basis, infestation started from 42nd SMW and sustained up to the 50th SMW, which varied from 4 to 24.08%. The peak fruit infestation (24.08%) was noticed in 46th SMW. The fruit infestation (weight basis) started from 42nd SMW and sustained up to 50th SMW and the infestation varied from 3.52 to 26.07%.

The peak fruit infestation (26.07%) was noticed in 46th SMW. In third transplanting (22 September 2022), shoot infestation started from 43rd SMW and it remains up to the 52nd SMW. Infestation varied from 9.26 to 43.65% with a peak of 43.65% in the 47th SMW. Fruit infestation (number basis) started from the 46th SMW and persisted up to the 2nd SMW and infestation varied from 7.33 to 41.55%. The highest fruit infestation (41.55%) was observed in the 50th SMW. The fruit infestation (weight basis) started from 46th SMW and sustained up to second SMW and infestation varied from 7.04 to 39.56%. The peak fruit infestation (39.56%) was noticed in 50th SMW.

The present findings are partially in agreement with reports of Singh *et al.* (2017) that the maximum incidence of shoot borer was recorded after 2 months of crop growth; among the 4 different dates of transplanting, 3rd date of transplanting recorded maximum shoot borer incidence; whereas, the crop transplanted on the 1st date recorded lowest infestation. Singh *et al.* (2011) observed that the infestation of *L. orbonalis* on the brinjal crop started from the early vegetative stage and continued up to the crop maturity. The first infestation appeared on shoots from

Table 1. Effect of different transplanting dates on the incidence of shoot and fruit borer

Treatment	Date of transplanting	Shoot infestation	Fruit infestation (No. basis)	Fruit infestation (Wt. basis)
T_1	2 September 2022	0.117	0.122	0.119
T_2	12 September 2022	0.207	0.217	0.208
T_3	22 September 2022	0.259	0.250	0.234
T_4	2 October 2022	0.165	0.180	0.167
	S.E(m)	0.0024	0.0048	0.0065
	CD(p=0.05)	0.0073	0.0148	0.0199

the first week of October and peaked in the first week of November.

The investigations conformed with the findings of (Meena, 2014) who reported that the infestation of shoot borer on shoots of brinjal crop, commenced in the last week of August *i.e.*, two weeks after transplanting which gradually increased and reached its peak in the last week of September. Thereafter, it started declining and persisted up to the second week of October and the incidence was found to be a positive significant relationship with RH and a negative non-significant relationship with temperature and rainfall.

Effects of weather on its incidence of shoot and fruit borer of brinjal

Shoot infestation in first transplanting date revealed a positive relationship: all weather parameters (maximum temperature, minimum temperature, mean temperature, evening relative humidity, and rainfall). Morning relative humidity and mean relative humidity showed a negative relationship. In the case of fruit infestation (both number and weight basis) showed a negative relationship with minimum temperature, mean temperature, morning relative humidity, evening relative humidity, mean relative humidity and rainfall whereas maximum temperature showed a positive relationship with fruit infestation (Table 2). Shoot infestation in second date of transplanting revealed that minimum temperature, mean temperature, morning relative humidity, evening relative humidity and mean relative humidity showed a negative relationship, whereas maximum temperature and rainfall showed a positive relationship.

In fruit infestation (both number and weight basis), maximum temperature, minimum temperature, mean temperature, morning relative humidity and mean relative humidity showed a positive relationship and other factor showed a negative relationship. In third date of transplanting, the minimum temperature, evening relative humidity, mean relative humidity and rainfall showed a negative relationship and maximum temperature, mean temperature and morning relative humidity showed a positive relationship with shoot infestation.

In fruit infestation (on number basis) the maximum temperature, minimum temperature, mean temperature, evening relative humidity, mean relative humidity showed a positive relationship and morning relative humidity, rainfall showed a negative relationship with fruit infestation. In the case of fruit infestation (on weight basis) the morning relative humidity showed a negative relationship and other all factors showed a positive

Table 2. Correlation coefficient (r) between shoot-and fruit-borer infestation and weather parameters

BSFB Infestation	Temperature(°C)			Relative humidity (%)			Rainfall (mm)
	Maximum	Minimum	Mean	Morning	Evening	Mean	
First date of transplanting							
Shoot infestation	0.082	0.091	0.093	-0.564	0.018	-0.169	0.046
Fruit infestation (no. basis)	0.071	-0.244	-0.143	-0.058	-0.412	-0.396	-0.148
Fruit infestation (wt. basis)	0.122	-0.171	-0.076	-0.188	-0.384	-0.446	-0.117
Second date of transplanting							
Shoot infestation	0.086	-0.191	-0.106	-0.370	-0.441	-0.612	0.075
Fruit infestation (no. basis)	0.380	0.192	0.293	0.299	-0.203	0.044	-0.549
Fruit infestation (wt. basis)	0.420	0.287	0.364	0.246	-0.142	0.051	-0.506
Third date of transplanting							
Shoot infestation	0.421	-0.018	0.186	0.135	-0.546	-0.358	-0.559
Fruit infestation (no. basis)	0.367	0.502	0.467	-0.084	0.180	0.128	-0.188
Fruit infestation (wt. basis)	0.332	0.509	0.453	-0.076	0.226	0.169	0.140
Fourth date of transplanting							
Shoot infestation	0.319	0.428	0.399	0.119	0.250	0.246	-0.219
Fruit infestation (no. basis)	-0.618	-0.143	-0.367	0.814*	0.557	0.661	0.640
Fruit infestation (wt. basis)	-0.572	-0.136	-0.342	0.779*	0.500	0.605	0.552

relationship with fruit infestation. In the fourth date of transplanting, all the factors were showed a positive relationship except the rainfall with shoot infestation. Fruit infestation (both number and weight basis), morning relative humidity showed a positive significant relationship and evening relative humidity, mean relative humidity, rainfall showed a positive relationship and other factors negatively related with fruit infestation.

The result is in the line of Naqvi *et al.* (2009), who reported that relative humidity showed a positive significant effect on the shoot and fruit borer, but rainfall showed a negative relationship with shoot and fruit. The maximum shoot borer infestation (33.31%) was recorded in present experiment as compared to 75.02 per cent (Patnaik 2000), 38.01 per cent (Singh *et al.*, 2017), 26.18 per cent (Jat *et al.*, 2002) in different regions of the country. The present investigations are in conformity with the findings of Singh *et al.* (2009) who reported that shoot infestation occurred during fourth week of August and the incidence was found to be non-significant relationship with temperature, relative humidity and rainfall.

Singh *et al.* (2011) reported that the peak infestation of this pest on shoots was observed in the first week of June and fourth week of May while the peak incidence on fruits was observed during the second week of June and third week of June in two successive cropping seasons, respectively. Nandi *et al.* (2017) and Kumar *et al.* (2017) have also reported positive correlation of brinjal shoot and fruit infestation with temperature. They have also reported positive correlation between relative humidity and pest infestation on harvestable fruit while Yadav *et al.* (2015) reported a negative correlation which is only observed between flower and squares infestation in the present study.

Conclusion

The shoot-and fruit-borer infestation peaked on the initial transplanting in 43rd and 46th SMW, respectively. All meteorological factors during that time, with the exception of maximum temperature, showed a negative link with infestation. Fruit infestation was positively connected with highest temperature. Shoot-and fruits-borer infestation on shoots and fruit peaked in the 45th and 48th SMW after the second transplanting. The 47th and 50th SMW of the third transplanting saw highest shoot and fruit borer infestation levels on shoot and fruit.

REFERENCES

Anonymous. 2021. Retrieved September 5, 2022, from http://www.agrimanipur.gov.in.

Chiranjiv, Haldhar SM, Singh KI, Singh NG, Ibrar SM and Mishra O P. 2023. Biology and morphometric of shoot and fruit borer (*Leucinodes orbonalis* Guenee) on brinjal crop under laboratory conditions. *Journal of Agriculture and Ecology*, **16**: 67-72.

Choudhary BR, Ram H, Haldhar SM and Chet Ram. 2024. Evaluation of high temperature tolerant longmelon (*Cucumis melo*) cultivar. *Current Horticulture* **12** (2): 53–55.

Dutta P, Singha AK, Das P and Kalita S. 2011. Management of brinjal fruit and shoot borer, *Leucinodes orbonalis* in agro-ecological conditions of West Tripura. *Scholarly Journal of Agricultural Sciences* **1**: 16-19.

Halder J, Srivastava K and Rai A B. 2023. Irrigation, a potential tool for insect pest management in horticultural crops-a review. *Current Horticulture* **11**(1): 3–7.

Haldhar SM and Deshwal HL. 2017. Fundamentals of agriculture entomology. *New Vishal publication, New Delhi; pp: 1-452.*

Haldhar SM and Maheshwari SK. 2018. Insect-pests management in arid and semi-arid horticultural crops. Technical Bulletin, No: 64, ICAR-CIAH, Bikaner, pp 1-42.

Haldhar SM and Maheshwari SK. 2021. Pest management in dryland horticultural crops. Biotech Books, pp-473; ISBN: 978-81-7622-491-8.

Haldhar SM, Sharma SK, Choudhary BR, Bhargava R, Samadia DK and Meena SR. 2013. Insect pests of arid vegetable crops: practical manual for field identification and damage symptoms. CIAH/ Tech./ Pub. No. 43 pp 1-54.

Jat KL, Pareek BL and Singh S. 2002. Seasonal incidence of shoot and fruit borer (*Leucinodes orbonalis* Guen.) on eggplant (*Solanum melongena* L.) in Rajasthan. *Ann. Biol.*, **18**: 165-69.

Kumar KR, Singh NN, Raju SVS and Mishra VK. 2017. Influence of abiotic factors on seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. Varanasi region. *Int. J. Curr. Microbiol. appl. Sci.*, **6**: 1513-1518.

Latif MA, Rahmah MM, Islam MR and Nuruddin M. 2009. Survey of arthropod biodiversity in the brinjal field. *Journal of Entomology* **6**: 28-34.

Meena A K. 2014. Seasonal incidence of shoot and fruit borer (*Leucinodes orbonalis Guen*) On brinjal in relation to weather parameters in hyper arid region of Rajasthan. 340-343.

Nandi C, Gangadhar N, Sanjeev J and Prafulkumar MV. 2017. Seasonal Incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guene, (Lepidoptera: Crambidae) during Kharif season. *Int. J. Curr. Microbiol. appl. Sci.* **6**: 1088-1093.

Naqvi A R, Pareek B L and Mitharwal B S. 2009. Seasonal incidence of shoot and fruit borer, *Leucinodes orbonalis* Guenee infesting brinjal in hyper-arid region of

Rajasthan. *J. Insect Sci. (Ludhiana)* **22** (2): 195-198.

Patnaik HP. 2000. Flower and fruit infestation by brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. - damage potential vs. weather. *Veg. Sci.* **27**: 82-83.

Raju S V S, Bar U K, Shankar and Kumar S. 2007. Scenario of infestation and management of eggplant shoot and fruit borer, *Leucinodes orbonalis* (L.) Guen. in India. *Resistant Pest Management Newsletter* **16** (2):14-16.

Saimandir J and Gopal M. 2012. Evaluation of synthetic and natural insecticides for the management of insect pest control of eggplant (*Solanum melongena* L.) and pesticide residue dissipation pattern. *American Journal of Plant Sciences* **3**(2): 214-227.

Singh B, Rana B S, Kumar R. and Prasad B. 2017. Effect of different dates of transplanting on the incidence of brinjal shoot and fruit borer **5** (5): 564-573

Singh D K, Singh R, Datta SD and Singh SK. 2009. Seasonal incidence and insecticidal management of shoot and fruit borer (*Leucinodus orbonalis* L.) in brinjal. *Annals of Horticulture* **2**(2): 187-190.

Singh RKR, Singh JK and Shah MAS. 2011. Population incidence of brinjal, (Lepidoptera; Pyralidae) in Manipur. *J Exp Zool.* **4**(1): 229-232.

Singh S P N and Kumar N. 2011. Insecticidal evaluation against *Leucinodes orbonalis* Guen. on brinjal. *Pestic. Res. J.* **23**(2): 227-229.

Tomar B S and Saha P. 2018. Parthenocarpic brinjal (Solanum melongena): a review. *Current Horticulture* **6** (2): 3–6.

Vevai E J. 1970. Know your crop, its pest problems and control: Brinjal. *Pesticides* **4**: 26-33.

Yadav A, Raghuraman M and Sandeep C. 2015. Impact of abiotic factors on population dynamics of fruit and shoot borer in brinjal. *J. exp. Zool.* **18**: 765-68.

Current Horticulture **13**(1): 80–82, January–March 2025
DOI: 10.5958/2455-7560.2025.00015.1
Received: 18 October 2023; Acceptd: 04 July 2024

Inter-correlation and path co-efficient analysis for agro-morphological and yield traits in bottle gourd (*Lagenaria siceraria*)

Sneha Rathore, Arjun Lal Ola, Anita Choudhary, Shivam, Kalpna and Saroj Bishnoi

[1]*Department of Horticulture, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India*

Abstract

The study was carried on Inter-correlation and path co-efficient analysis of bottle gourd (*Lagenaria siceraria*) at Vegetable Research Farm, RLBCAU, Jhansi, Uttar Pradesh during *kharif 2022*. A total of 30 genotypes were sown in a randomized block design with three replications. Observations were recorded on 15 characters. Higher magnitude of GCV and PCV was recorded for fruit length (cm), fruit width (cm) and yield/plant (Kg/plant). The insignificant difference between GCV and PCV was recorded for most of the traits indicated that traits were less impacted by the environment. The inter-character association at phenotypic and genotypic correlation coefficients suggested that yield/plant recorded highly positive significant correlation with fruit width, average fruit weight and number of fruits/plant at both genotypic and phenotypic levels. Path coefficient analysis revealed highly positive direct contribution towards yield/plant with number of fruits/plant, fruit width and average fruit weight at both genotypic and phenotypic level. On the other hand, vine length, days to first flowering bud, days to first fruit setting, days to first fruit picking and fruit length showed negative direct effect on fruit yield/pant.

Key words: Genotypes, Correlation, Path, Genotypic correlation, Phenotypic correlation

Bottle gourd (*Lagenaria siceraria* L.); 2n= 2x=22 belonging to family Cucurbitaceae is most significant vegetable in India. It is widely grown in the tropics and sub-Tropics, primarily for its fruit. It is a monoecious, diploid, annual and climbing or prostrate plant with delicate pubescence (Singh and Kumarnag, 2023). The correlation coefficient would indicate the relationship among independent and dependent variables without specifying cause and effect (Akinnola, 2012). The genetic improvement in dependent parameters can be achieved by applying strong selection to a character which is genetically correlated with dependent parameters (Al-Jibouri *et al.*, 1958). Selection for yield and quality traits can be achieved to best possible extent if information about correlation between such traits is available followed by better understanding of association between the relevant characters provided by path coefficient analysis (Muralidharan *et al.,* 2017).

MATERIALS AND METHODS

The study was undertaken during *kharif* 2022 at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh. Total 30 genotypes were collected from different sources like State Agricultural universities, ICAR-Institutions, local collections and private companies. The genotypes are laid out in 3 m × 3 m plot size with a spacing of 0.6 m between each 5 plants in a plot. The observations were recorded from 3 randomly selected plants from each genotype for 15 different characters. Correlation coefficient analysis reveals the association of characters, i.e. a change in one character brought about by a change in other character. Phenotypic and genotypic correlation coefficients between different variables were calculated by using the covariance technique (Al-Jibouri *et al.* 1958). Path coefficient analysis term coined by Wright (1921) and explained by Dewey and Lu (1959) was executed separately to know the direct and indirect effects of the important component traits on yield per plant.

***Corresponding author :** arjunola11@gmail.com

RESULTS AND DISCUSSION

Fruit width showed positively significant correlation with average fruit weight and yield/ plant revealing that these characters may be given importance in the selection of high-yielding genotypes. It also showed negatively significant association with fruit length at both genotypic and phenotypic levels, indicating that these traits would be eliminated during selection (Muralidhara *et al.* 2017). Ascorbic acid content recorded highly positive significant association with days to first fruit setting, first fruit picking and vine length and highly significant negative association with protein content at phenotypic level. Whereas, total soluble solid, protein content and ascorbic acid content at both genotypic and phenotypic level showed non-significant association with yield/plant (Table 1).

So, it can be inferred that simultaneous selection for fruit yield/plant and quality may not be possible and balanced selection criteria must be worked out to find out acceptable level of characters under improvement. Chandrashekhar *et al.* (2018), Rehan *et al.* (2020), Ahmad *et al.* (2019) and Rambabu *et al.* (2017) also reported similar findings. The node number to first female flower appearance, average fruit weight, number of fruits/plant and fruit length recorded highest positive direct effect on fruit yield/plant followed by days to first flowering and vine length indicating that simultaneous improvement in fruit yield/plant is possible though manifestation of this trait. Node number to first male flower appearance, days to first fruit picking, days to first fruit setting, total soluble solids, protein content and ascorbic acid content recorded negative direct effect on yield/plant suggesting that this can be nullified by selecting positive indirect effects during the selection (Table 2). These results are similar to those of Panigrahi *et al.* (2018), Muralidharan *et al.* (2017), Husna *et al.* (2011) and Janaranjani and Kanthaswamy (2019).

Table 1. Estimation of genotypic correlation coefficients for different characters

Trait	DFFB	FMFEN	FFFEN	FFS	FFP	FL	FW	FWt	NFPP	VL	TSS	PC	AAC	YPP
DFFB	1													
FMFEN	-0.098	1												
FFFEN	0.065	0.950 **	1											
FFS	0.842 **	-0.171	0.062	1										
FFP	0.854 **	-0.199	0.017	0.995 **	1									
FL	-0.277	0.126	-0.016	-0.139	-0.110	1								
FW	0.164	0.056	0.100	0.022	-0.014	-0.840 **	1							
FWt	0.007	0.129	0.057	0.048	0.010	-0.177	0.533 **	1						
NFPP	-0.060	-0.059	-0.031	-0.083	-0.135	0.107	0.130	0.312	1					
VL	0.308	-0.189	-0.097	0.290	0.269	-0.090	-0.022	-0.283	0.023	1				
TSS	-0.062	0.061	0.020	-0.198	-0.209	0.002	0.069	0.004	-0.100	-0.143	1			
PC	0.016	0.498 **	0.507 **	-0.081	-0.081	0.078	0.089	0.051	0.013	-0.145	0.177	1		
AAC	0.185	-0.302	-0.272	0.323	0.316	0.135	-0.045	-0.036	0.022	0.255	-0.021	-0.325	1	
YPP	-0.069	0.033	-0.006	-0.050	-0.106	-0.035	0.396 *	0.817 **	0.799 **	-0.172	-0.055	0.032	-0.019	1

*Significance at 5% level, **Significance at 1% level

Table 2. Direct (diagonal) and indirect diagonal (above and below diagonal) genotypic path effects of different characters towards yield

Trait	DFFB	FMFEN	FFFEN	FFS	FFP	FL	FW	FWt	NFPP	VL	TSS	PC	AAC	YPP
DFFB	**0.08591**	0.03781	0.02245	-0.00366	-0.16009	-0.02772	0.00211	0.0052	-0.03252	0.00058	0.0013	-0.00026	-0.00073	-0.0696
FMFEN	-0.00842	**-0.38564**	0.32654	0.00075	0.03744	0.01265	0.00072	0.09008	-0.03162	-0.00036	-0.00128	-0.00814	0.00119	0.0339
FFFEN	0.00561	-0.36652	**0.34358**	-0.00027	-0.0032	-0.00165	0.00129	0.0401	-0.01708	-0.00018	-0.00042	-0.00829	0.00107	-0.006
FFS	0.07237	0.06611	0.02159	**-0.00435**	-0.18663	-0.01389	0.00029	0.03387	-0.04493	0.00055	0.0041	0.00133	-0.00127	-0.0509
FFP	0.07337	0.07703	0.00586	-0.00433	**-0.18746**	-0.011	-0.00019	0.00755	-0.07265	0.00051	0.00435	0.00133	-0.00125	-0.1069
FL	-0.02384	-0.04886	-0.00569	0.00061	0.02065	**0.09988**	-0.0108	-0.12286	0.05772	-0.00017	-0.00004	-0.00129	-0.00053	-0.0352
FW	0.0141	-0.02162	0.03458	-0.0001	0.00276	-0.08394	**0.01285**	0.37045	0.06999	-0.00004	-0.00143	-0.00147	0.00018	0.3963 *
FWt	0.00064	-0.05005	0.01985	-0.00021	-0.00204	-0.01768	0.00686	**0.69408**	0.1676	-0.00054	-0.00009	-0.00085	0.00014	0.8177 **
NFPP	-0.00521	0.02274	-0.01094	0.00036	0.0254	0.01075	0.00168	0.21693	**0.53626**	0.00004	0.00209	-0.00023	-0.00009	0.7998 **
VL	0.02648	0.07322	-0.03349	-0.00126	-0.05054	-0.00906	-0.00028	-0.19649	0.01246	**0.0019**	0.00297	0.00237	-0.00101	-0.1727
TSS	-0.00539	-0.02376	0.00689	0.00086	0.03935	0.00021	0.00089	0.00292	-0.05408	-0.00027	**-0.0207**	-0.0029	0.00009	-0.0559
PC	0.00137	-0.19219	0.17433	0.00035	0.01531	0.00787	0.00115	0.03601	0.00739	-0.00028	-0.00368	**-0.01634**	0.00128	0.0326
AAC	0.01597	0.11659	-0.09361	-0.00141	-0.05941	0.01353	-0.00058	-0.02535	0.01211	0.00048	0.00045	0.00532	**-0.00393**	-0.0198

Residual effect - 0.0024

The DFFB, days to first flowering bud, FMFEN, first male flower at early node, FFFEN, first female flower at early node, FFS, days to first fruit setting, FFP, days to first fruit picking, FL, fruit length (cm), FW, fruit width (cm), F Wt, average fruit weight (g), NFPP, number of fruits per plant, YPP, yield per (kg/plant), YPH, yield per (q/ha), VL, vine length (cm), TSS, total Soluble Solid (°Brix), PC, protein content (mg/100g), ACC and ascorbic acid content (mg/100g)

REFERENCES

Ahmad, M., B. Singh, M.K. Singh and M. Kumar, 2019. Study of genetic variability, heritability and genetic advance among the characters of bottle gourd. *Progressive Agriculture* **19**(2): 217-19.

Akinnola, A. 2012. Path analysis step by step using excel. *Journal of Technical Science and Technologies* **1**(1): 9-15.

Al-Jibouri, H.A., P.A. Muller and H.F. Robinson, 1958. Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. *Agronomy Journal* **50**(1): 633-36.

Chopra, M. L., Kumar, K., Vikas, M. A., Jat, P. K., and Prasad, H., 2024. Variability assessment in fruits of seedling origin guava (Psidium guajava). *Current Horticulture* **12**(1): 72-75.

Chandrashekhar, T., M. Vijaya, P. Saidaiah, V. Joshi, and S.R. Pandravada, 2018. Genetic variability, heritability and genetic advance for yield and yield attributes in bottle gourd (*Lagenaria siceraria* (Mol) Standl.) Germplasm. *Journal of Pharmacognosy and Phytochemistry* **7**(6): 2085-88.

Dewey, D.R. and K.H. Lu, 1959. A correlation and path analysis of the components of crested wheat grass seed production. *Agronomy Journal* **51**: 515-18.

Ghorpade, S.B., V.S. Jagtap, S.J. Ban, and S.P. Chaudhari, 2019. Genetic variability studies for qualitative attributes in bottle gourd (*Lagenaria siceraria* L.). *Journal of Pharmacognosy and Phytochemistry* **8**(5): 1911-13.

Gurcan, K., A. Say, H. Yetisir and N. Denli, 2015. A study of genetic diversity in bottle gourd [*Lagenaria siceraria* (Molina) Standl.] Population, and implication for the historical origins on bottle gourds in Turkey. *Genetic Resources and Crop Evolution* 62: 321-33.

Husna, A., F. Mahmud, M.R. Islam, M.A.A. Mahmud and M. Ratna, 2011. Genetic variability, correlation and path co-efficient analysis in bottle gourd (*Lagenaria siceraria* L.). *Advances in Biological Research* **5**(6): 323-27.

Janaranjani, K.G., and V. Kanthaswamy, 2015. Correlation studies and path analysis in bottle gourd. *Journal of Horticulture* **2**(1): 1-4.

Kandasamy, R., E. Arivazhagan and S.S. Bharathi, 2019. Variability and heritability studies in bottle gourd (Lagenaria siceraria (Mol.) Standl.). *Plant Archives* **19**(2): 3263-66.

Muralidhara, B. M., Venugopalan, R., Sakthivel, T., Karunakaran, G., Honnabyraiah, M. K., and Savadi, S., 2024. Correlation studies in avocado (*Persea americana*) accessions for morphological and biochemical characters. *Current Horticulture* **12**(1): 46-49.

Muralidharan, B., V. Kanthaswamy and K.G. Janaranjani, 2017. Correlation and path analysis for quantitative and qualitative traits in bottle gourd [*Lagenaria siceraria* (Molina) standl]. *Journal of Pharmacognosy and Phytochemistry* **6**(5): 2280-83.

Panigrahi, I., D.S. Duhan, V.P.S. Panghal, S.K. Tehlan and A.C. Yadav, 2018. Correlation coefficient analysis between yield defining traits of cultivated genotypes of bottle gourd (*Lagenaria siceraria* (Mol.) Stdl.). *Journal of Pharmacognosy and Phytochemistry* **7**(2): 1378-80.

Rambabu, E., A.R. Mandal, P. Hazra, B.K. Senapati and U. Thapa, 2020. Genetic divergence studies in Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *International Journal of Chemical Studies* **8**(3): 2304-06.

Rehan, M. Singh, M. Kumar, V. Kumar, S. Malik and A. Singh 2020. Assessment of the genetic diversity in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *International Journal of Current Microbiology and Applied Sciences* **9**(10): 1003–10.

Parle, M., and S. Kaur, 2011. Is bottle gourd a natural gourd. *International Research Journal of Pharmacy* **2**(6): 13-17.

Singh, B., and Kumarnag, K. M., 2023. Pollination management in horticultural crops under protected conditions: a review. *Current Horticulture* **11**(2), 3-8.

Singh, R. K., Rai, M., Kumar, A., Dwivedi, S. V., and Kumar, M., 2023. Genetic variability and divergence in okra (*Abelmoschus esculentus*). *Current Horticulture* **11**(2): 39-43.

Wright, S., 1921. Correlation and causation. *Journal of Agricultural Research* **20**(7): 557- 85.

Current Horticulture **13**(1): 83–88, January–March 2025
DOI: 10.5958/2455-7560.2025.00016.8
Received: 03 November 2023; Accepted: 11 December 2024

Selection of promising genotypes of faba bean (*Vicia faba*) by deciphering genetic variability and trait association

Vijaypal Singh Thakur, Yash Kumar Singh, Neha Thomas and VP Sahi
Department of Genetics and Plant Breeding, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Abstract

Twenty-five genotypes of faba beans were evaluated for selection of promising genotypes by deciphering genetic variability and trait association. The experiment was conducted in a Randomized Block Design with three replications at Department of Genetics and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Prayagraj during *rabi* season of 2023. The plant-to-plant distance was 20 cm and row-to-row distance of 30 cm. The data were recorded from randomly selected five plants for each genotypes for each replications for nineteen characters *viz.* days to first flowering; days to 50% flowering; plant height (cm); number of branches/plant; number of nodes on main branch; number of flowers/plant; leaflet length (cm); leaflet width (cm); days to pod initiation; number of pods/plant; pod length (cm); pod width (cm); days to maturity; number of seeds/pod; seed index (gm); harvest index (%); biological yield (gm); seed yield; seed yield/hectare (tonnes/ha). Analysis of variance showed significant variation among different genotypes for all characters studied. Moderate GCV and PCV was recorded for number of branches/plant, number of pods/plant, pod width, number of seeds/pod, seed index, biological yield and seed yield per hectare. High estimate of heritability coupled with high genetic advance as percent of mean and moderate GCV was recorded for number of branches/plant, number of pods/plant, pod width, number of seed/pod, seed index, biological yield and seed yield. This indicates closeness of respective σ^2p and σ^2g value thereby low environmental effect on expression of these characters. Positive and significant correlation were observed for number of branches/plant, number of nodes in main branch, number of flowers/plant, number of pods/plant, pod length, days to maturity, plant height, leaflet length, number of seeds/pod, biological yield, days to first flowering, seed index and seed yield with seed yield (per plant) at genotypic level. While rest of the characters showed non-significant association with seed yield. Significant positive association of these above attributes indicated that these attributes were mainly influencing the seed yield in faba bean.

Key words: GCV, PCV, Variability, Heritability, Correlation coefficient, Genetic parameters

Faba beans, *Vicia faba* (L.), belongs to the Leguminosae family, sub-family Fabiodeae. It is a diploid, self-pollinated species with *Vicia narbonensis* (L.) and *V. galilaea* Plitmann & Zohary, wild species are taxonomically similar to cultivated species, but they have 2n=2x= 14 chromosomes, while cultivated field beans (*V. faba* L.) have a chromosome number of 2n=2x=12 chromosomes. At most of the occasions crossing between them is generally unsuccessful (Bond *et al.,* 1985). Faba bean is assigned to the Central Asian, Mediterranean, and South American centres of Diversity and believe to be a native to North Africa and southwest Asia, and extensively cultivated elsewhere (Harlan, 1969; Zohary and Hopf, 2000). Omima *et al.* (2018) suggested that having information on the magnitude of genetic variability is number one criterion for successful breeding. Genetic variability is a key for the success of a plant breeding program since it provides an opportunity to breeders to make the selection for desirable superior individuals from a genetically diverse base population (Partap *et al.* 2019). Understanding the level of genetic variability might support plant breeders' decision on the selection of parental genotypes with a broad genetic base for further genetic improvement and amenities in development of breeding strategy (Omima *et al.* 2018). The lack of adequate variability has been considered as one of the major bottlenecks in crop improvement and the success of its improvement needs use of wide genetic variability in respect of important economic characters present in the population (Bhanu *et al.,* 2016). The estimation of heritability along with genetic advance is more applicable than the heritability value alone (Johnson *et al.* 1955). Therefore, study was designed to evaluate genetic variability and correlation coefficients in faba beans genotypes for eastern zone of Uttar Pradesh.

***Corresponding author :** vijaypalthakur1998@gmail.com

MATERIALS AND METHODS

The present study was carried out at the Experimental Research Centre, Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, during *rabi* season of 2023. The data were recorded from randomly selected five plants for each genotypes for each replications for nineteen characters *viz.* days to first flowering; days to 50% flowering; plant height (cm); number of branches/plant; number of nodes on main branch; number of flowers/plant; leaflet length (cm);

leaflet width (cm); days to pod initiation; number of pods/ plant; pod length (cm); pod width (cm); days to maturity; number of seeds/pod; seed index (gm); harvest index (%); biological yield (gm); seed yield (g/plant); seed yield (tons/ha). The experiment was set up using a randomized block design. The Fisher and Yates, 1963 method was used to statistically analyse the data. Johnson *et al.*,(1955); formulae was used to calculate GCV and PCV. Heritability (in broad sense) was eliminated by the formula Burton and Devane (1953). Correlation was calculated using methods suggested by Al-Jibouri *et al.* (1958).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance showed highly significant differences (α=0.05) among 25 genotypes for all characters studied indicating the presence of considerable amount of genetic variability among germplasms (Table 1). Based on data on character values and analysis of variance, significant genotype differences were found for all 19 characters, indicating that the material has enough genetic variability to support a breeding programme aimed at increasing the yield of faba beans seeds. The results are in line with those of Dubey *et al.* (2022) and Ertiro *et al.* (2023).

Genetic parameters

In general, estimates of phenotypic coefficient of variation (PCV) was found higher than their corresponding genotypic coefficient of variation (GCV) indicating the influence of environment on expression of these characters (table 2). Phenotypic coefficient of variation (PCV) ranged from 0.58% for days to maturity to 18.37% for pod width. Genotypic coefficient of variation (GCV) ranged from 0.48% for days to maturity to 17.43% for pod width. Both moderate GCV and PCV were recorded for number of branches/plant, number of pods/plant, pod width, number of seeds/pod, seed index, biological yield and seed yield in comparison to other characters indicating the presence of high amount of genetic variability for these characters. This also suggests that improvement in these characters might be gained to a reasonable extent therefore, selection for these characters would be effective because the response to selection is directly proportional to variability present. While both low GCV and PCV were recorded for days to first flowering, days to 50% flowering, number of nodes on main branch, leaflet length and leaflet width, days to pod initiation, pod length, days to maturity and harvest index. Rest characters observed to have comparably significant and more difference between GCV

Table 1. Analysis of Variance (ANOVA) for 17 characters in faba bean

ANOVA Summary			
Mean Sum of Squares (MSS)			
Degree of freedom	**Replication (df=2)**	**Genotype (df=24)**	**Error (df=48)**
Days of first flowering	3.04	3.36**	1.53
Days of 50% flowering	1.35	5.37**	1.07
Plant height	2.84	243.11*	18.37
Number of branches/plant	0.01	0.92**	0.03
No. of nodes on main branch	0.16	4.04**	0.74
Number of flowers/plant	0.36	12.58*	1.41
Leaflet length	0.01	0.32**	0.08
Leaflet width	0.01	0.04**	0.01
Days to pod initiation	6.01	8.91**	4.02
Number of pods/plant	0.17	13.16*	1.11
Pod length	0.04	0.26**	0.09
Pod width	00.01	0.09**	0.01
Days to maturity	0.40	0.97**	0.13
Number of seeds/pod	0.01	0.61**	0.05
Seed index	0.02	48.52*	4.63
Harvest Index	7.87	46.06**	16.55
Biological yield	0.39	47.24**	7.69
Seed yield (per plant)	0.08	10.06**	2.30
Seed yield	0.01	0.10**	0.01

** and * at 1% and 5% level of significance

Table 2. Genetic Parameters for 17 characters of 25 Faba beans genotype.

Genetic Parameter	GCV (%)	PCV (%)	Heritability (%) [broad sense]	Genetic advance	Genetic advance as per cent of Mean
Days of first flowering	1.30	2.44	28.59	0.86	1.44
Days of 50% flowering	1.85	2.44	57.19	1.86	2.88
Plant height	9.90	11.05	80.31	15.98	18.27
Number of branches/plant	16.66	17.55	90.18	1.07	32.59
No. of nodes on main branch	6.37	8.23	59.90	1.67	10.15
Number of flowers/plant	9.92	11.65	72.52	3.38	17.40
Leaflet length	5.38	7.50	51.50	0.42	7.95
Leaflet width	4.34	6.52	44.22	0.13	5.94
Days to pod initiation	1.73	3.22	28.91	1.42	1.92
Number of pods/plant	14.40	16.27	78.37	3.66	26.26
Pod length	4.89	7.91	38.21	0.30	6.23
Pod width	17.43	18.37	90.01	0.34	34.06
Days to maturity	0.48	0.58	67.95	0.90	0.81
Number of seeds/pod	13.91	15.78	77.78	0.78	25.28
Seed index	13.33	15.30	75.94	6.87	23.94
Harvest Index	5.56	9.11	37.27	3.94	7.00
Biological yield	12.38	15.58	63.15	5.94	20.27
Seed yield (per plant)	9.77	13.43	52.89	2.41	14.64
Seed yield	11.04	11.30	95.53	0.37	22.23

Table 3. Correlation coefficient between yield and its attributing traits in 25 faba beans genotypes at phenotypic level

Phenotypic correlation matrix																		
Characters	**DF50**	**PH**	**NPB**	**NNMB**	**NFPP**	**LL**	**LW**	**DPI**	**NPPP**	**PL**	**PW**	**DM**	**NSPP**	**SI**	**HI**	**BY**	**SYPH**	**SYPP**
DFF	0.268*	-0.0097	0.158	0.0439	0.224	0.228*	0.084	-0.2233	0.251*	0.0627	-0.490**	0.0212	-0.0566	0.426**	-0.1405	0.1062	0.1408	0.1465
DF50	1.000	0.244*	-0.340*	0.1372	0.0768	0.0646	-0.1964	-0.1532	0.0854	0.1886	-0.1609	0.0438	0.0767	0.277*	0.0216	0.0327	0.0011	0.0205
PH		1.000	-0.496**	0.391**	0.1246	0.1748	-0.1457	0.256*	0.1491	0.372*	0.1605	0.252*	-0.1203	0.1043	0.1385	0.351*	0.403**	0.341*
NPB			1.000	0.0529	0.396**	-0.0864	0.274*	-0.095	0.429**	-0.0815	-0.2211	0.1378	0.0494	0.1505	-0.373**	0.297*	0.270*	0.2127
NNMB				1.000	0.366*	-0.2037	-0.0271	0.1808	0.327*	0.1865	-0.0139	-0.0147	-0.2019	-0.0554	-0.0287	0.341*	0.265*	0.1789
NFPP					1.000	0.1585	0.228*	0.0426	0.809**	-0.0053	-0.1868	0.349*	-0.0056	0.451**	-0.1926	0.498**	0.620**	0.442**
LL						1.000	0.289*	-0.005	0.1952	0.1172	-0.0549	0.376**	0.1541	0.466**	-0.0192	0.08	0.271*	0.253*
LW							1.000	-0.119	0.234*	-0.2025	-0.1324	0.356*	0.0879	0.217	-0.0258	-0.0072	0.0849	0.0888
DPI								1.000	-0.0874	0.128	0.2248	-0.0445	-0.2	-0.354*	0.0677	-0.0306	0.058	0.0157
NPPP									1.000	0.0132	-0.2254	0.325*	0.091	0.462**	-0.2017	0.590**	0.723**	0.629**
PL										1.000	-0.0052	0.0673	0.1099	0.0075	0.230*	0.300*	0.356*	0.344*
PW											1.000	0.0696	-0.1222	-0.357*	0.0345	-0.0761	-0.0571	-0.0648
DM												1.000	0.1396	0.367*	-0.1109	0.334*	0.395**	0.285*
NSPP													1.000	0.0974	0.1241	0.1191	0.259*	0.2092
SI														1.000	-0.1505	0.229*	0.376**	0.341*
HI															1.000	-0.236*	0.011	0.021
BY																1.000	0.744**	0.635**
SYPH																	1.000	0.907**

and PCV value depicting greater influence of environment on expression of character. Hiywotu *et al.* (2022), Kebede *et al.* (2022) and Kumar *et al.* (2023) gave similar conclusions. The characters that showed lesser effect of environment on expression should be selected for breeding programme.

In the study, heritability (broad sense) ranged from 28.91% for days to pod initiation to 95.53% for seed yield (95.53%) [table 2]. High heritability (broad sense) estimates (60% and above) had been observed for plant height, number branches/plant, number of flowers/plant, number of pods/plant, pod width, days to maturity, number of seeds/pod, seed index, biological yield, and seed yield. Therefore, these characters are predominantly governed by additive gene action and could be improved through individual plant selection owing to their high heritability values. Such characters, according to Panse and Sukhatme (1957), are primarily controlled by additive gene action and, because of their high heritability values, could be enhanced by individual plant selection. Similar results for high heritability for plant height, number branches/plant, number of pods/plant, pod width, days to maturity, biological yield was reported earlier by Kumar *et al.* (2020) and Mishra *et al.* (2022). High heritability was found earlier by Singh *et al.* (2013), Chaurasia *et al.* (2022), for the number of seeds/pod, seed index, biological yield. Shift in gene frequencies towards superior side under some selection pressure is termed as genetic advance and is generally expressed as percentage of mean (genetic gain) to compare the advance of different characters having different units of measurements.

High estimate of heritability coupled with high genetic advance as percent of mean and moderate GCV was recorded for number of branches/plant, number of pods/plant, pod width, number of seeds/pod, seed index, biological yield and seed yield. This indicates closeness of respective σ^2p and σ^2g value thereby low environmental effect on expression of these characters. Such values may be attributed to the additive gene effects and direct selection for these traits would be fruitful. Thus, phenotypic selection may be effective for these characters with high to moderate GCV along with high heritability coupled with high genetic advance as percent of mean. This also pointed out the fact that these characters have appreciable genetic potential and are comparably less influenced by environment, hence desirable for simple selection in breeding programmes. Al-Barri and Shtaya (2013), Mishra *et al.* (2022), and Ertiro *et al.* (2023) all reported similar results for the harvest index.

Correlation coefficient analysis

Our results revealed that there was a comparative higher degree of genotypic correlation coefficients than

Table 4. Correlation coefficient between yield and its attributing traits in 25 faba beans genotypes at genotypic level

	Genotypic correlation matrix																	
Characters	**DF50**	**PH**	**NPB**	**NNMB**	**NFPP**	**LL**	**LW**	**DPI**	**NPPP**	**PL**	**PW**	**DM**	**NSPP**	**SI**	**HI**	**BY**	**SYPH**	**SYPP**
DFF	0.575**	-0.073	0.389**	0.206	0.372*	0.1751	0.278*	-0.369*	0.308*	0.326*	-0.758**	0.0225	0.0721	0.728**	0.0308	0.267*	0.239*	0.241*
DF50	1.000	0.282*	-0.446**	0.228*	0.0953	0.1966	-0.341*	-0.282*	0.0587	0.2238	-0.244*	-0.0093	0.1714	0.356*	0.0925	0.0776	0.0045	-0.013
PH		1.000	-0.561**	0.544**	0.1696	0.262*	-0.240*	0.569**	0.1189	0.711**	0.2258	0.361*	-0.1124	0.0576	0.330*	0.441**	0.449**	0.501**
NPB			1.000	0.1134	0.492**	-0.1609	0.540**	-0.308*	0.506**	-0.105	-0.273*	0.1479	0.0454	0.1967	-0.587**	0.385**	0.298*	0.350*
NNMB				1.000	0.428**	-0.246*	-0.2265	0.514**	0.379**	0.585**	-0.011	0.0114	-0.274*	-0.0418	-0.1274	0.514**	0.391**	0.478**
NFPP					1.000	0.271*	0.323*	-0.1168	0.1233	0.1281	-0.286*	0.490**	0.0894	0.589**	-0.381**	0.874**	0.802**	0.972**
LL						1.000	0.631**	-0.322*	0.2203	0.315*	-0.0676	0.695**	0.324*	0.746**	0.389**	0.284*	0.365*	0.390**
LW							1.000	-0.1868	0.320*	-0.1675	-0.2072	0.493**	-0.0159	0.366*	0.0946	-0.0442	0.1249	0.1286
DPI								1.000	-0.0508	0.514**	0.416**	-0.280*	-0.312*	-0.620**	0.485**	0.327*	0.1412	0.1961
NPPP									1.000	0.123	-0.279*	0.475**	0.1305	0.590**	-0.279*	0.826**	0.820**	0.913**
PL										1.000	0.0404	0.268*	0.327*	0.1068	0.058	0.699**	0.566**	0.585**
PW											1.000	0.077	-0.143	-0.434**	0.1043	-0.0351	-0.0542	-0.0551
DM												1.000	0.238*	0.488**	0.0203	0.419**	0.522**	0.628**
NSPP													1.000	0.1854	0.145	0.1078	0.309*	0.353*
SI														1.000	-0.1325	0.388**	0.422**	0.462**
HI															1.000	-0.588**	0.0041	-0.0057
BY																1.000	0.942**	0.843**
SYPH																	1.000	0.543**

NPB: No. of primary branches; **NN:** No. of nodes on main branch; **NFPP:** No. of flowers per plant; **NPPP:** No. of pods per plant; **PL:** Pod length; **PW:** Pod width; **HI:** Harvest index; **DM:** Days to maturity; **PH:** Plant height; **LL:** Leaflet length; **LW:** Leaflet width; **NSPP:** No. of seeds per pod; **BY:** Biological yield; **DFF:** Days to first flowering; **DF50:** Days to 50% flowering; **SI:** Seed index; **SYPH:** Seed yield per hectare; **SYPP:** Seed yield per plant their phenotypic counterparts in most of the characters (Table 3 and 4). This indicated that there was a higher degree of association between two characters of genotypic association, their phenotypic association was lessened due to the influence of environment. Positive and significant correlation was observed for number of flowers/plant (0.442**), number of pods/plant (0.629**), pod length (0.344*), days to maturity (0.285*), plant height (0.341*), leaflet length (0.253*), biological yield (0.635**), seed index (0.341*) and seed yield (0.907**) with seed yield per plant at phenotypic level. While rest of the characters showed non-significant association with seed yield.

Positive and significant correlation was observed for number of branches/plant (0.350*), number of nodes in main branch (0.478**), number of flowers/plant (0.972**), number of pods/plant (0.913**), pod length (0.585**), days to maturity (0.628**), plant height (0.501**), leaflet length (0.390**), number of seeds/pod (0.353*), biological yield (0.843**), days to first flowering (0.241*), seed index (0.462**) and seed yield (0.543**) with seed yield/plant at genotypic level. While rest of the characters showed non-significant association with seed yield. Significant positive association of these above attributes indicated that these attributes were mainly influencing the seed yield in faba bean. Thus, selection practiced for improvement in one character will automatically result in the improvement of the other character even if direct selection for improvement has not been made for the yield character.

For phenotypic correlation coefficient, Kumar *et al.* (2020) and Kebede *et al.* (2022) reported significant and positive correlation with seed yield/plant for number of flowers /plant, number of pods/plant, pod length, days to maturity, plant height. Khamassi *et al.* (2021) and Ertiro *et al.* (2023) concluded seed yield to be significantly and positively correlated with number of flowers/plant, number of pods/plant, pod length, days to maturity, plant height, number of seeds/pod, biological yield, days to first flowering, seed index at genotypic level.

CONCLUSION

It is concluded that analysis of variance showed significant variation among different genotypes for all characters studied. Both moderate GCV and PCV was recorded for number of branches/plant, number of pods/plant, pod width, number of seeds/pod, seed index, biological yield and seed yield.

REFERENCES

Al-Barri, T., and Shtaya, M. J. Y. (2013). Phenotypic characterization of faba bean (*Vicia faba* L.) landraces grown in Palestine. *Journal of Agricultural Science* **5**(2): 110.

Al-Jibouri, H. A., Miller, H. A., Robinson, H. F. (1958). Genotypic and environmental variances and co-variances in upland cotton crosses of interspecific origin. *Journal of Agronomy* **50**: 633-36.

Bhanu, A. N., Singh, M. N. and Singh, M. (2016). Genetic Variability, Correlation and Path Coefficient Analysis for Quantitative Traits in Mungbean Genotypes. *Journal of Food Legume.* **29**(3-4): 199-205.

Bond, D. A., Lawes, D. A., Hawtin, G. C., Saxena, M. C. and Stephens J. S. (1985). Faba Bean (*Vicia faba* L.). In: R.J. Summerfield and E.H. Roberts (eds.): Grain Legume Crops. William Collins Sons Co. Ltd. 8 Grafton Street, London, WIX 3LA, UK. 199-265.

Burton, G. W. and Devane, E. M. (1953). Estimation of heritability in tall fescus (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal* **45**: 478-80.

Chaurasia, H., Arya, R. K., Choudhary, R. R., Reenu, and Amit. (2022). Genetic variability, correlation and path analysis in faba bean (*Vicia faba*) for yield and its attributing traits under semi-arid conditions. *The Pharma Innovation Journal* **11**(4): 530-37.

Dubey, P., Shweta, and Mishra, A. (2022). Studies of genetic parameters in exotic collections of fava bean (Vicia fava L.). *International Journal of Current Microbiology and Applied Sciences* **11**(07): 125-36.

Ertiro, T. A., Kebede, G. Y., Assen, K. Y., Haile, G. A., and Gutu, D. T. (2023). Variability and association of some morpho-agronomic traits in advanced faba bean (*Vicia faba* L.) genotypes at potential areas of South-eastern Ethiopia. *Asian Journal of Research in Crop Science* **8**(4): 198-210.

Fisher, R. A. and Yates, F. (1963). Statistical Tables for Biological, Agricultural and Medical Research. *Oliver and Boyd, London*: 143 p.

Harlan, J. R. (1969). Ethiopia: A centre of diversity. Economic Botany **23**:309-14.

Hiywotu, A. M., Abate, A., Worede, F., and Marefia, A. (2022). Genetic variability in Ethiopian faba bean (*Vicia faba* L.) accessions. *Cogent Food* and *Agriculture* **8**: 2132847.

Johnson, H. W., Robinson, H. F. and Comstock, R. E., (1955). Estimates of genetic and environmental variability in soybean. *Agronomy Journal* **47**: 413-18.

Kalia, P., Seed, S., and Singh, Y. (2003). Genetic variability in faba bean (*Vicia faba* L.) for pod yield and its contributing traits. *Indian Journal of Genetics and Plant Breeding* **63**(3): 261-62.

Kebede, G. Y., Haile, G. A., and Abo, T. (2022). Genetic variability and character associations of faba bean (*Vicia faba* L.) genotypes, South-eastern Ethiopia. *Asian Journal of Research in Crop Science* **7**(2): 38-47.

Khamassi, K., Babay, E., Rouissi, M., Dakhlaoui, A., Ben Ayed, R., and Hanana, M. (2021). Genetic variability of Tunisian faba beans (*Vicia faba* L.) based on seeds' morphophysical properties as assessed by statistical analysis. *Journal of Food Quality* **2**(3): 1-10.

Kumar, S., Layek, S., and Upadhyay, A. (2020). Genetic characterization for quantitative and qualitative traits and its relationship in faba bean (*Vicia faba* L.). *Indian Journal of Agricultural Research* **54**(3): 336-42.

Kumar, S., Dwivedi, D. H., Yadav, P., Kumar, V., and Dayal, R. (2023). Evaluation of broad bean (*Vicia faba* L) genotypes for genetic variability, heritability and genetic advance. *International Journal of Environment and Climate Change* **13**(11): 1523-29.

Loss, S. (2006). Faba bean varieties and markets, Department of Agriculture and food, Government of Western Australia.

Mishra, U. K., Tripathi, R. M., Verma, O. P., Singh, A., Maurya, B., and Patel, A. (2021). Studies on genetic variability, heritability and genetic advance for quantitative traits in faba bean (*Vicia faba* L.). *The Pharma Innovation Journal* **10**(7): 1238-40.

Omima, B. H., Ahmed, H. A., Adel, M. F. and Amin, A. S. (2018). Variability Heritability and Genetic Advance of Some Groundnut Genotypes (*Arachis hypogea* L.) Under Saline Sodic Soil. *Annals of Reviews and Research* **1**(1): 1-5.

Partap, B., Kumar, M., Kumar, V. and Kumar, A. (2019). Genetic Variability and Correlation Studies of Seed Yield and Its Components in Black Gram (*Vigna mungo* (L.) Hepper). *Journal of Pharmacognosy and Phytochemistry* **8**(3): 2035-40.

Saran, R., Sharma, P. P., Choudhary, M., and Dalip. (2021). Evaluation of genetic parameters in faba beans [*Vigna mungo* (L.) Hepper] for seed yield and its related traits. *The Pharma Innovation Journal* **10**(7): 364-66.

Singh, A. K., Bharati, R. C., Manibhushan, N. C., and Pedpati, A. (2013). An assessment of faba bean (*Vicia faba* L.) current status and future prospect. *African Journal of Agricultural Research* **8**(50): 6634-641.

Zohary, D. and Hopf, M. (2000). Domestication of plants in the old world: The origin and spread of cultivated plants in West Africa, Europe and the Nile valley. Oxford University Press New York USA.

Current Horticulture is indexed in the...

- AGRINDEX, published by the FAO, Rome; the Science Citation Index and the Current Contents (Agriculture, Biology and Environmental Sciences), published by the Institute of Scientific Information, Philadelphia
- Abstracting journals of the Centre for Agriculture and Biosciences International
- Abstracting Agencies of the International and National repute

Disclaimer

• All disputes are subject to the exclusive jurisdiction of competent courts and forums in Ghaziabad only • The society does not assume any responsibility for opinions offered by the authors in the articles and no material in any form can be reproduced without permission of the society • The society is not responsible for any delay in delivery of the journal to the subscribers due to unforeseen circumstances or postal delay • Readers are recommended to make appropriate enquiries before sending money, incurring expenses or entering into commitments in relation to any advertisement appearing in this journal • The society does not vouch for any claim made by the advertisers of products and services • The publisher and the editors of the publication shall not be held liable for any consequences in the event of such claims not being honoured by the advertisers.

Published by the Society for Horticultural Research and Development, SD-70, Shastri Nagar, Ghaziabad, and printed at M/s Chandu Press, 469, Patparganj Industrial Estate New Delhi, E-mail: chandupress@gmail.com

Editor: Dr Som Dutt