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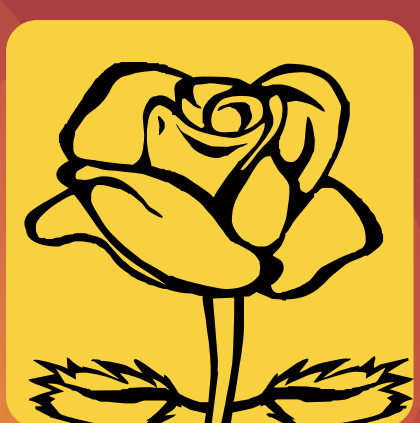

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Research Opinion

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Decoding of chemical communication in insect pests and its manipulation for their management in citrus (*Citrus* spp.)

Anjitha George[1] and C.N. Rao[2]

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ICAR- Central Citrus Research Institute, Nagpur, Maharashtra 440 033, India

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ABSTRACT

The semio-chemicals in general have environmental benefits associated with their use, in contrast to conventional insecticides. These semio-chemicals are inherently different from synthetic insecticides in terms of their mode of action and subsequent impact on the environment and human health. Although a number of outstanding successes have proved the potential of pheromone technology, the use of semio-chemicals is still in its early stages in India. It can be safely predicted that, as farming practices, the demand for semio-chemical technology will increase steadily which requires continuous and equal efforts of researchers, industry and farmers. Development of semio-chemical based push pull strategies using pheromones, repellents of insect pests and attractants of bio-agents for the management of insect pests in citrus (*Citrus* spp.) and citrus based farming systems needs immediate attention as these are known to be eco-friendly insect pest management strategies.

Key Words: Decoding, Chemical communication, Semio-chemicals, Phenomones, Kairomones, Citrus.

Chemical communication plays an important and essential role in the survival of insects, which enable them to appraise immediate environment through modification of their behaviour. Semio-chemicals (signaling chemicals) are such chemical compounds emitted by one organism that modify the behaviour of an organism receiving the signal (Tinsworth, 1990). Rodriguez and Niemeyer (2005) defined semio-chemicals as molecules involved in chemical communication within and between insect species and employed for pest control. Insects use semio-chemicals to locate mate, host or food source, avoid competition, escape natural enemies and overcome natural defence systems of their hosts. If communication is between the same species (intra-specific), they are called pheromones and on the other hand if the communication is between two different species (inter-specific), they are called kairomones.

Semio-chemicals have the capacity to cause changes in behaviour of insects such as pest attraction (Del Socorro *et al.*, 2003, Del Socorro and Gregg, 2004; Grundy *et al.*, 2006), attraction of beneficial insects (Mensah, 2002), aggregation or mating disruption, oviposition deterrence of adult insects (Mensah, 1996, 2000), feeding deterrence of larvae and nymphs of pests (Mensah, 2000) and lure and kill by association of attractive semio-chemicals with chemical pesticides (Pyke *et al.*, 1987; El-Sayed *et al.*, 2009; Mensah and Macpherson, 2010).

Fig. 1. Courtesy: Webster, B.2009

* Corresponding author :
[1] Scientist
[2] Principal Scientist

Since pheromones and kairomones cause behavioural changes in receiving individuals they are also termed as Behaviour Modifying Chemicals (BMC). Application of pheromones in crop protection may be indirect as monitoring agents and direct as tools in mass trapping, lure and kill and mating disruption techniques. Semio-chemicals could also be used to enhance the activity of the natural enemies by direct application of synthetic kairomones or by using crude extracts from host plants and host insects. Exploitation of semio-chemicals as pest control agents have proved them as invaluable tools in modern IPM programmes.

Citrus (*Citrus* spp.) is one such group of horticultural crops where there is immense scope of exploitation of semio-chemicals towards management of insect pests. Of the 250 species of insect pests and mites attacking citrus in India, about a dozen of them play a major role invading citrus groves regularly right from nursery stage to the harvest, posing a serious threat to citrus across the country. Most common method followed by farmers to control these insect pests is use of insecticides. However, indiscriminate use of chemical insecticides not only lead to the development of insecticide resistance, pest resurgence and secondary pest infestation but also poses a serious threat to environment by way of pollution and creating ecological imbalance in nature by eliminating the natural enemies of insect pest (Rao *et al.,* 2018).

USES OF PHEROMONES IN IPM

Detection and monitoring

The principle use of insect sex pheromones is to attract insects to traps for detection and determination of temporal distribution. In most instances, it is the males who are responders to female-produced sex pheromones. Trap baits, therefore, are designed to closely reproduce the ratio of chemical components and emission rate of calling females. The information from trap catches can be very useful for decision making on insecticide applications or other control measures. Careful monitoring and experience in interpreting collected data are important for success. Traps may also be placed with the objective of destroying males for population control.

Mating disruption

The mating disruption may be accomplished in two principle ways: false trail following or confusion. False trail following results from placing many more point sources of pheromone (hollow fibers, flakes or other point sources) per acre than the anticipated number of females in the crop. The odds of males finding females at the end of pheromone trail must be greatly reduced. Emission of pheromone is relatively low from each source such that a downwind trail is created and not lost in a background of released pheromone. Males following these trails are thought to spend their mating energies in pursuit of artificial pheromone sources. The greater the amount of pheromone applied and the greater the release rate, the more likely males are to be confused in the fog of ambient pheromone.

SEMIO-CHEMICALS IN MANAGEMENT OF CITRUS PESTS

Citrus leaf miner

The citrus leaf-miner (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) is a worldwide pest of citrus crops and is responsible for proliferation of citrus bacterial canker, *Xanthomonas axonopodis* (Hasse) pv. citri (Gamma Proteobacteria: Xanthomonadaceae). Sex pheromone of *P. citrella* was reported by a host of researchers (Leal *et al.,* 2006; Moreira *et al.,* 2006) and a 3:1 blend of (Z,Z,E)-7,11,13-hexadecatrienal ($Z_7Z_{11}E_{13}$-16 Ald) and (Z,Z)-7,11-hexadecadienal (Z_7Z_{11}-16 Ald) was found highly attractive to males. Further, effective monitoring protocols using this pheromone have been developed (Conti *et al.,* 1997; Lapointe *et al.,* 2006; Stelinski and Rogers, 2008) and the potential for mating disruption of *P. citrella* has been investigated (Stelinski *et al.,* 2008).

Traps baited with the sex attractant (7Z, 11Z)- 7, 11-hexadecadienal caught an average of 103.9 adults / day over a 6-day period and traps containing 1 mg attractants were effective over a distance of 280 metres and for 20 days in China (Du *et al.,* 1989). Each individual component was effective at disrupting orientation in field trials, but (Z,Z,E)-7,11,13-hexadecatrienal was approximately 13 times more effective, at the same concentration, compared with (Z,Z)-7,11-hexadecadienal alone (Lapointe *et al.,* 2006). A commercially available pheromone lure (Citralure, ISCA Technologies, USA) was highly effective in attracting male *P. citrella* to traps. Pherocon VI Delta (Trece Inc., USA) traps baited with citralure captured more male *P. citrella* than identically baited Pherocon IC Wing traps (Tre´ce´ Inc.) (Stelinski and Rogers, 2008).

The doses of 10 and 100 µg of the synthetic sex pheromone - a 3:1 blend of (Z,Z,E)-7,11,13-hexadecatrienal and (Z,Z)-7,11-hexadecadienal - attracted the greatest number of *P. citrella* males (Parra-Pedrazzoli *et al.,* 2009). A dose of 5 mg of synthetic sex pheromone placed at mid-canopy (1.55 m) height was found to attract the highest number of *P. citrella* males in <5 year-old *Citrus aurantifolia* (Christm) Swingle (acid lime) groves and further reported that pheromone baited traps @ 10, 15 and 20 mg / lure in <5-year-old orchards of acid lime recorded significant maximum

trap catch in orchards with 20 mg lure / 0.3 ha (Rao *et al.*, 2017). Thus, behavioural modification tools that are both effective and economical are required for management of *P. citrella*.

Stelinsk and Czokajlo (2010) developed and evaluated an attracticide formulation containing 0.016% *P. citrella* pheromone [3:1 blend of (Z,Z,E)-7,11,13-hexadecatrienal and (Z,Z)-7,11-hexadecadienal] and 6% permethrin, termed MalEx, for control of *P. citrella*. Although 4500 droplets / ha did not result in statistically better efficacy than 3 000 droplets / ha, there was a noticeable trend for higher efficacy as droplet density increased. Solid elastomer dispensers (DCEPT CLM™, ISCA Technologies, Inc.) loaded with a 3:1 blend of (Z,Z,E)-7,11,13-hexadecatrienal and (Z,Z)-7,11-hexadecadienal, major components of the *P. citrella* sex pheromone, provided disruption of trap catch in commercial citrus orchards for periods exceeding 30 wk (Lapointe *et al.*, 2015). Apart from above, congeneric leaf miner native to Florida, *P. insignis* (Frey & Boll), was observed in sticky traps baited with *P. citrella* lures loaded with the 3:1 blend (Keathley *et al.* 2013).

Citrus Psylla

Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera:Liviidae), is one of the most serious pests of citrus worldwide because it vectors the bacterial pathogen causing huanglongbing (HLB) disease. The *D. citri* generally rely on olfaction and vision for detection of host cues (Wenninger *et al.*, 2009). The presence of a visual cue typically enhanced attractiveness of olfactory cues. In the absence of visual cues, mated females and males showed evidence of attraction only to odors from sour orange and navel orange, respectively. Psyllids exhibited anemotactic responses when assayed with plant odors alone but showed strong evidence of attraction only when olfactory and visual cues were combined, suggesting that olfactory cues facilitate orientation to host plants but may be insufficient alone. Antennal responses to citrus volatiles were confirmed by electroantennogram. *D. citri* uses olfactory and visual cues in orientation to host plants and suggest the possibility of using plant volatiles in monitoring and management of this pest (Wenninger *et al.*, 2009).

A degradation product of lignoceryl acetate (24Ac) probably acetic acid was found in the airborne volatile collections from lures matured under field conditions and detected in higher amounts in volatiles collected from citrus psyllid females at the peak of mating activity than in male samples. Acetic acid elicited dose-dependent electroantennographic responses and attracted ACP males, but not females, in Y-type and 4-way olfactometers. Field tests showed that acetic acid-baited traps captured signifcantly more males than control traps. Surprisingly, captures of females in acetic acid-baited traps were also higher than in control traps, possibly because of physical stimuli emitted by captured males (Zanardi *et al.*, 2018). Further, traps baited with acetic acid (1 µg per trap) captured significantly more ACP adults than control traps captured suggesting that acetic acid is an aggregation-sex pheromone, *i.e.*, a semiochemical produced by one of the sexes that attracts both sexes for mate procurement. This may be a breakthrough for the purpose of monitoring as well as mass trapping of psyllids in the near future.

Plants in family Alliaceae also have been shown to produce sulfur compounds known to repel arthropods (Amarawardana *et al.*, 2007) in various crops. Chemicals from *Allium sativum* (L.) have been reported to repel cotton bollworms (Gurusubramanian and Krishna, 1996), codling moth (Landolt *et al.*, 1999), aphids (Assis *et al.*, 2007), whiteflies (Salas, 2001). Inter-planting guava, *Psidium guajava* (L.) has been reported to reduce *D. citri* populations in citrus orchards in Vietnam, possibly due to volatile chemicals (Zaka *et al.*, 2010). Recently, Rouseff *et al.* (2008) identified dimethyl disulfide (DMDS) from guava as a possible defensive volatile that may explain guava's repellency to *D. citri*. Guava leaf volatiles inhibit the response of *D. citri* to citrus host plant volatiles and suggest that the induced compound, DMDS, may be partially responsible for this effect (Onagbola *et al.*, 2011). Thus, *Allium* spp. or the tri- and di-sulphides could be integrated into management programmes for *D. citri* without affecting natural enemies (Mann *et al.*, 2010).

Citrus mealy bug

Citrus mealy bug attacks various parts of citrus including fruits at stem end portion, which later on causes fruit drop. Synthetic pheromone [(1R-cis)- 2, 2-dimethyl -3-(1-methylethenyl) cyclo butyl methyl acetate] at doses of up to 19 m g / 108 cm^3 on discs of filter paper in petri dishes elicited positive responses from males, but higher doses resulted in reduced response. The half-life of synthetic sex pheromone of *P. citri* in the field was about 2 weeks with the maximal male catches by the doses of 400-700 mg (Hefetz and Tauber, 1990).

Fruit flies

Fruit fly is a serious pest of citrus fruits especially in cooler subtropical regions. On hatching, the maggots of fruit fly bore the ripening fruit and feed on soft pulp. The infested fruits show depressions with dark greenish punctures, get deformed and due to bacterial and fungal activity, fruits rot and fall down. Commercially available sex attractants of fruit flies are listed in Table 1 (Shivankar and Singh, 2000).

Table 1. Commercially available sex attractants for fruit flies

Sex attractant	Species attracted	Other species attracted
Methyl eugenol	Oriental fruit fly *(Bactrocera dorsalis)*	*(Bactrocera umbrosus)*
Anisyl acetone	Melon fly *(Bactrocera cucurbitae*)	Queensland fruit fly *(B. tryoni, B. ochrosiae)*
Sig lure	Mediterranean fruit fly *(Ceratitis capitata)*	Walnut husk fly *(Rhagoletis completa)*
Med lure	Mediterranean fruit fly *(Ceratitis capitata)*	Walnut husk fly *(Rhagoletis completa)*
Trimed lure	Mediterranean fruit fly *(Ceratitis capitata)*	Walnut husk fly *(Rhagoletis completa)*

Fruit sucking moths

Plant oils, *viz*. jatropa, citronella, poppy, thevetia, neem and pongamia along with neem seed kernel extract were effective in repelling *Eudocima materna* (L.) from feeding on the treated guava and pomegranate fruits (Jayanthi *et al.,* 2010). Repellents can be either taste repellents or odour repellents. Since odour is initial attractant for getting moths to host sight, control methods using repellent sprays focus on odour repellents (Bosch, 1971).

Semio-chemicals in attraction of bioagents

Semio-chemicals play an important role in host-parasitoid relationship, which was categorized by (Rutledge, 1996) into three stages: habitat-location, host-location and host-acceptance, and oviposition. Herbivore induced plant volatiles by phytophagous insects, especially volatile fractions such as caryo-phyllene, hexanoic, tetradecanoic and pentadecanoic acid emanated from larval frass and cuticle resulting from feeding on different plant sources attract natural enemies (Ananthakrishnan and Senrayan, 1992). EAG assays showed that response of *Aphidius ervi* to herbivore induced and released plant volatiles was much higher than volatiles normally released by plant (Du-Yong *et al.,* 1998).

Green lacewings are considered to be one of the most effective generalist predators and they feed on Lepidoptera eggs and young larvae, aphids, spider mites, scales, psylla, mealy bugs, whiteflies, thrips, leaf hoppers and other soft-bodied prey. Chrysopid predator, *M. desjardinsi* was the most abundant neuropteran collected in our survey and therefore, it may be playing a part in the natural control of spider mites in citrus (George *et al.,* 2019; George *et al.,* 2016). Release of chrysopids has been recommended against various insect pests. Several methods have been suggested for increasing their field efficiency by manipulating their behaviour using different attractants. Odors from eggplant, okra, and peppers are attractive to Chrysoperla carnea (Reddy, 2002). L-tryptophan which is one of the components of artificial honey dew (Hagen *et al.,* 1976) was highly attractive to *C. carnea*. Further studies are required to find out slow hydrolyzing agents or oxidizing agents which can augment slow release of the breakdown product over a period of time without much deterioration in the quality of the volatile.

Molleman *et al.* (1997) reported that green lacewing *C. carnea* was attracted by methyl salicylate emitted by herbivore infested pear tree. In field trapping tests, the catch of *Chrysoperla carnea* (Neuroptera: Chrysopidae) increased when acetic acid was added to lures with phenyl acetaldehyde. The addition of methyl salicylate to the binary mixture of phenyl acetaldehyde plus acetic acid increased catches even further. The ternary blend proved to be more attractive than β-caryophyllene, 2-phenylethanol, or 3-methyl eugenol (compounds previously described as attractants for chrysopids) on their own, and no influence on catches was recorded when these compounds were added as fourth components to the ternary blend (Miklos *et al.,* 2009).

Ladybird beetles (Coleoptera: Coccinellidae) have been used widely as biological control agents for aphids and other homopteran pests. Coccinellid responses to semiochemicals from aphids and to aphid honeydew and related microorganisms have been reported (Majerus, 1994). The key component in alarm pheromone of many aphids, (E)-farnesene, is behaviorally active against seven spotted ladybird but its effect is modified by caryophyllene (Al Abassi *et al.,* 2000). The larvae and adults of coccinellids are known to detect their prey either by olfactory or visual stimuli (Stubbs, 1980). *Cryptolaemus montrouzieri* are able to respond positively to kairomones produced by their prey (Stubbs 1980). Garcia and Ribeiro (1983) reported significant attraction of *Coccinella septempunctata* to host

plant with aphids than to the host plant alone. Adults showed significantly higher response to the odours of their own individuals than to the odours of prey's host-plants and control. Sengonca and Liu (1994) have reported that some percentage of *C. septempunctata* was attracted to odours of their own individuals which tendency they attributed to the predators cues from their own individuals who have reached the source before.

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Research Review

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Analysis of India-China mushroom gap— a review

T Janakiram[1], V P Sharma[2] and Anupam Barh[3]

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Horticultural Science Division, ICAR, KAB-II, New Delhi, India

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ABSTRACT

China is a global leader in mushroom production. The mushrooms are grown in China since ancient times. In changing scenario, is cultivation shifted from traditional mushroom towards specialty mushroom during last few decades. More consumption and export demands are responsible for this shift. Nevertheless, Indiais also picking pace in mushroom with lukewarm response. Awareness and other social constraints prevailing in India might be one of the reasons responsible for that. Moreover during last 4 decades, extensive research on mushroom has promoted mushroom in India. With five major and few exotic mushrooms, India slowly is increasing its market share. To be successful in both domestic and export markets, it is essential for Indian growers to produce quality mushrooms and mushroom-fortified value-added products at competitive rates without any agro-chemical residues.

Key Words: China, India, Mushroom, Export, Health, Traditional mushroom, Chemical residues

The journey of mushroom cultivation and the related research in India started during mid-60s and the recent production in country has now reached to 130,000 tonnes. In India, there are five mushroom species, *viz.* white button mushroom *(Agaricus bisporus)*, oyster (*Pleurotus* spp.), paddy straw *(Volvariella volvacea)*, milky *(Calocybe indica)* and shiitake *(Lentinula edodes)* are in commercial cultivation (Fig. 1 excluding f).

In China, cultivation of black ear mushroom *(Auricularia auricula)* was started in 600 AD. The current world leading mushroom, shiitake (Royse *et al.*, 2017) have been cultivated for the first time in China between 1,000 and 1,100 AD (Chang 2000). The Sung Dynasty (960-1127 AD) particularly, Wu San Kwung in South Western part of Zhejiang Province started wood log cultivation of shiitake. Similarly, *Pleurotus ostreatus* was first cultivated in the USA in 1900 and later in 1940s the cultivation also started in India. Globally, production of cultivated, edible mushrooms have taken pace and increased more than 30-fold since 1978 (from about 1 billion kg) to 2013 (34 billion kg). The increase in per capita consumption of mushrooms now exceeds 4.7 kg annually (Royse *et al.*, 2017). It is being practised in more than 100 countries and its production is increasing at an annual rate of 6-7%. Compared to other outdoor horticultural crops, it is the crop with high cropping intensity with superior profits.

In India, mushrooms have gained momentum during last 3 decades. The recent production data (official data of ICAR-DMR, Solan) shows that, the share of button mushroom in India is maximum, amounting to 73%, followed by oyster mushroom which contributes about 16%. In India, growers are growing white button mushroom round the year under controlled conditions and in winter season in north-

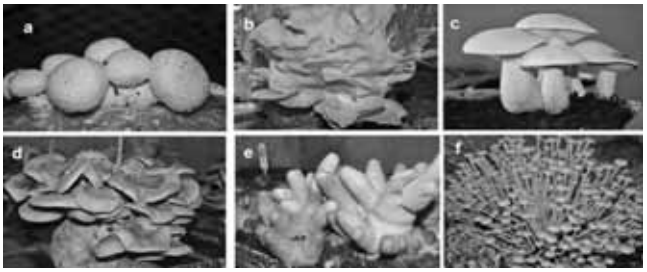

Fig. 1. Important mushrooms (**a:** button mushroom; **b:** oyster mushroom; **c:** milky mushroom; **d:** shiitake mushroom; **e:** paddy straw mushroom; **f:** enokitake mushroom).

* Corresponding author : tolety07@gmail.com

[1] Assistant Director-General, Horticultural Science Division, ICAR, KAB-II, New Delhi, India

[2] Director, ICAR-Directorate of Mushroom Research, Chambaghat, Solan 173 213, India

[3] Scientist, ICAR-Directorate of Mushroom Research, Chambaghat, Solan 173 213, India

western part of India. The total white button mushroom produced in India from both seasonal and high tech cultivation units is estimated at 94,676 tonnes. If we compare with china the mushroom production is around 30 billion kg in 2013 (CEFA, 2014). This huge gap is due to many reasons which include, food preference, awareness, availability of quality spawn, mechanization *etc*.

GLOBAL INNOVATION IN MUSHROOM INDUSTRY

From 1960s world experienced a rapid growth in cultivated mushroom production. From 1969 to 2009, the world mushroom production has increased almost ten times. The most notable increases occurred in China, the USA, the Netherlands, India and Vietnam, according to the FAO (Zhang *et al.*, 2014). This increase is due increasing research and interest of growers and buyers in global market. The increased research leads to different exotic species cultivation in both China and India.

Bionic Morel Cultivation in China

Researches on *Morchella* cultivation in china have started since 1980 in Mianyang Edible Fungi Research Institute of Sichuan. This research institute began work on morel artificial cultivation in 1985, and scientists there achieved their first morel fruiting bodies in 1992. By 2012, their production techniques became popular in fields throughout China. In 2016, cultivated area of morels in China is currently 23,400 acres. Morel cultivation regions are located in more than twenty Chinese provinces. Sichuan province accounts for 44 per cent of total morel cultivation. In India, morel cultivation is still under progress, this is mainly due to less research prioritization towards this mushroom. Still, the economic viability of morel cultivation is less in China, the studies suggested that due to inconsistent production, farmers are losing money in morel cultivation (Anonymous 2017).

Bottle Cultivation

Glass bottle cultivation of *Lentinula edodes* (Shiitake) and *Flammulina velutipes* (Enokitake, winter mushroom) using sawdust was developed around 1928 by a Japanese *Agaricus* grower, H. Morimoto in Kyoto. This cultivation has taken up pace in commercial cultivation and later specialty mushroom" production in China taken a higher industrial growth. In Japan, it was estimated that 93% of edible mushrooms was grown in plastic bottles and bags. The *F. velutipes*, *Hypsizygus marmoreus* (Buna-shimeji), and *Pleurotus eryngii* (King Oyster) are popularly-grown mushrooms in plastic bottles in China, Korea, and Thailand (Yamanaka, 2017).

Fig. 2: Bottle and bag cultivation of *Flammulina*

The king oyster mushrooms are mailnly grown in Japan, China, Korea and Italy using this technology. In China it increased from 21,000 to 114,000 tons between 2001 and 2003 (Gyenge *et al.*, 2016). In India, *Flammulina* production is at very juvenile phase. The production technology till now is present is wheat straw and saw dust which is present with ICAR-DMR but bottle technology in commercial scale is still lacking. Although for food processing industry, winter mushroom possess a tremendous scope but still low research and extension activities are required for this mushroom. ICAR-DMR (Solan, also has strains Table 1).

Table 1. Flammulina stains collected form the Indian Himalayas

Strain	Latitude	Longitude	Altitude(m)
DMRX-166	31° 6'17.33"N	77°10'24.25"E	2169.871
DMRX-767	30°54'16.36"N	77° 5'48.51"E	1506.322
DMRX-768	30°54'16.36"N	77° 5'48.51"E	1506.322
DMRX-769	30°54'16.36"N	77° 5'48.51"E	1506.322
DMRX-897	30°58'12.77"N	77° 6'19.32"E	1417.32
DMRX-1446	23°34'0.00"N	92°22'0.00"E	366
DMRX-1618	30°54'16.36"N	77° 5'48.51"E	1506.322

Ready-to-be-grown Mushroom Kits

These are another new concept were a bag of kit is given to buyer for having a growing experience in mushroom. This cost of bag ranges from ₹ 400 to 2000. This bag is popular in China and other countries. In India, ICAR-IIHR, Bengaluru and ICAR-DMR, Solan, have prepared such cheap kits for urban and periurban areas.

Areas of production in China

Out of 22 provinces in China, 18 provinces are producing mushrooms.Fujian and Zhejiang were highest in production during 1980s but gradually, in late 1990s Henan in the northern China, and Hubei, Hunan and Sichun in the central south started the production in huge quantity. After year 2000 province Jilin and Heilongjiang also started mushroom

production with higher production. All the 18 provinces are producing values exceeding 2 billion RMB Yuan in 2008 (Zhang *et al.*, 2014). The Indian scenario look very different were Punjab, Odisha, Haryana and Maharastra, the leading producers of mushroom. The central part of India is mainly focused on oyster mushroom that includes the areas of Bihar, Chhattisgarh and Madhya pradesh.

Export gap

The mushroom industry globally deals with caned mushroom, frozen mushroom, dried mushroom and fresh mushroom. Besides that the other commodity is mushroom spawn and mother culture that take part in export and import. China is one of major exporter of tinned mushrooms. However, quantity of export is rapidly decreasing, from 600,000 to 450,000 tonnes in less than ten years. (Fresh Plaza, 2017). The India is also becoming major exporters in mushrooms. The major exporter of button mushroom is Poland and China share seventh position while India at 46th position in fresh button mushroom export (around 321 tonnes). Major export from india goes to Germany, Kuwait *etc.* (Table 2). While mushroom production other than Button mushroom China is number 1 while India is having 66th position, producing around 234 tonnes of mushrooms in 2016 (Table 3).

Table 2. Flammulina stains collected form the Indian Himalayas

Export	2017-18 Value in Rs Quantity in Kg	
Country	Qty	Value
Germany	15,000.00	24,88,206.00
Kuwait	372.00	16,512.00
Liberia	10.00	5,545.00
Qatar	25.00	5,060.00
Korea Rp	24.00	3,649.00
Nepal	104.00	2,240.00
U Arab Emts	0.00	675.00
Hong Kong	5.00	450.00
Page Total	15,540.00	25,22,337.00

Source: DGCIS Annual Export

Table 3. Export of mushroom other than button mushroom in world

Rank	Exporting Country	Quantity	Value	Share (%)
1	China P RP	51,855.00	1,41,137.00	19.34
2	Poland	37,917.00	85,138.00	11.66
3	Netherlands	22,384.00	68,669.00	9.41
4	Italy	3,279.00	41,724.00	5.72
5	Russia	8,080.00	38,371.00	5.26
6	Korea RP	14,228.00	37,967.00	5.20
7	Romania	3,799.00	33,916.00	4.65
8	Spain	3,636.00	27,207.00	3.73
9	Belarus	7,133.00	25,506.00	3.49
10	Lithuania	4,387.00	24,504.00	3.36
11	France	2,085.00	20,468.00	2.80
12	Bulgaria	1,897.00	17,558.00	2.41
13	Canada	1,079.00	13,988.00	1.92
14	Belgium	4,257.00	12,752.00	1.75
15	U S A	1,214.00	12,685.00	1.74
16	Germany	2,438.00	11,154.00	1.53
17	Serbia	1,461.00	8,918.00	1.22
18	Hungary	3,208.00	8,319.00	1.14
19	Ireland	3,631.00	7,770.00	1.06
20	Iran	1,187.00	7,584.00	1.04
21	Macedonia	906.00	6,979.00	0.96
22	Malaysia	3,144.00	6,528.00	0.89
23	Morocco	785.00	6,091.00	0.83
24	Slovenia	680.00	5,673.00	0.78
25	Japan	1,515.00	5,205.00	0.71
26	Turkey	636.00	5,125.00	0.70
27	Ukraine	596.00	4,836.00	0.66
28	Portugal	471.00	4,359.00	0.60
29	Australia	24.00	3,704.00	0.51
30	Austria	1,097.00	3,585.00	0.49
31	Algeria	314.00	3,218.00	0.44
32	Thailand	1,014.00	2,919.00	0.40
33	Other Asia, nes	847.00	2,737.00	0.37
34	Bosnia-hrzgovin	380.00	2,594.00	0.36
35	Czech Republic	853.00	2,291.00	0.31
36	South Africa	329.00	1,776.00	0.24
37	Other Europe, nes	11.00	1,631.00	0.22
38	Croatia	239.00	1,614.00	0.22
39	Sweden	155.00	1,392.00	0.19
40	Latvia	223.00	1,042.00	0.14
41	U K	408.00	886.00	0.12
42	Korea DP RP	59.00	861.00	0.12
43	Finland	84.00	850.00	0.12
44	Libya	127.00	762.00	0.10
45	Slovak Rep	88.00	729.00	0.10
46	Syria	64.00	636.00	0.09
47	UAE	249.00	515.00	0.07
48	Areas, nes	220.00	491.00	0.07
49	Montenegro	65.00	463.00	0.06
50	Saudi Arabia	252.00	417.00	0.06
51	Mexico	9.00	416.00	0.06
52	Montserrat	47.00	389.00	0.05
53	Vietnam Soc Rep	130.00	380.00	0.05
54	Cyprus	101.00	360.00	0.05
55	Estonia	40.00	291.00	0.04
56	Denmark	62.00	278.00	0.04
57	New Zealand	31.00	253.00	0.03
58	Bhutan	3.00	211.00	0.03
59	Netherland	98.00	195.00	0.03
60	Tunisia	13.00	172.00	0.02
61	Switzerland	17.00	161.00	0.02
62	Egypt	63.00	144.00	0.02

63	Singapore	15.00	137.00	0.02
64	Greece	24.00	131.00	0.02
65	Albania	16.00	121.00	0.02
66	**India**	**234.00**	**101.00**	**0.01**
67	Azerbaijan	17.00	100.00	0.01
68	Oman	10.00	62.00	0.01
69	Hong Kong	10.00	58.00	0.01

The spawn from India is also exported to various counries Nepal, Singapore, Pakistan etc. (very meger) (Table 4).

Table 4. Spawn export by India

	2017-18	
Country	Quantity (kg)	Value (₹)
Nepal	24,600.00	8,58,000.00
Singapore	338.00	2,69,898.00
Pakistan Ir	750.00	1,23,311.00
Kuwait	458.00	1,13,706.00
Netherland	75.00	1,13,520.00
Japan	78.00	1,06,425.00
Total	26,299.00	15,84,860.00

Source: DGCIS Annual Export

CHALLENGES OF MUSHROOM PRODUCTION IN INDIA

Technological Constraints and Awareness

The mushroom cultivation in India requires extensive research and more research institutes/ organizations that solely work on mushrooms. Since mushroom contain various species that are unique need more scientific manpower and unrevealing the potential mushroom. Worldwide, an estimated 1,069 species of mushroom have been reported that are being used for food purposes (Boa, 2004). To deal with research of each mushroom increase funding is required in mushroom for research and extension.

Area-based Mushroom Promotion

The production systems selection depends upon local conditions and resources available. The species such as oyster, milky and paddy straw mushrooms can be successfully cultivated by small and marginal farmers with limited land and resources with lower risk taking ability. The integration of mushroom in farming system is also help in assured income in regular basis. Only thin requiring is knowledge of array of mushroom that can be grown in various agroclimate of India without requirement of huge investment and available market. The tropical mushroom like milky and paddy straw should be promoted at warmer climate while some species of oyster is well suited for subtropical climate. This kind of promotion of mushroom helps the growers to gain financial stability in present cropping system.

Marketing and Cold Storage Facilities

Marketing is major concern of mushroom growers in India. Unlike button mushroom whose market is more stable other mushroom market require some serious efforts. The development of mushroom, local traders, markets, intermediaries, regional wholesalers, local restaurants, shops and farmer cooperatives is important for mushroom growers and farmers. Cold storage facilities are required in countries for mushroom so that stock can be kept for 1-2 days by farmers to avoid forced selling.

Availability of Quality Spawn

Quality spawn is one of major constraints for mushroom production. The spawn availability hinders the growers for consistent production more over poor spawn reduce the quality of produce and sometimes crop failure.

Social Constraints

In ancient China, one mushroom called Ganoderma , (Ling-zhi) was regarded as a magic herb called xian-cao. These were also regarded as symbol of good luck and happiness. (Li *et al.,* 2016) In contrast, it is regarded as non vegetarian and hence not accepted in many communities in India. This is also one of major constraints of promotion of mushroom in India.

CONCLUSION

India is gifted with human resource. The human resources is fully potent of both has a good combination of technical and non-technical skills required for mushroom growing activities. The prediction of mushroom trade is showing significant opportunities. The high labour cost in western countries make India a better place for competitive market in mushroom production. With a domestic population of more than 1.2 billion, India itself is a large market for mushrooms. The development of rapid infrastructural facilities and well-organized distribution network provides the greater scope for marketing of perishable products in order to meet domestic consumer demands. To be successful in both domestic and export market it is essential to produce quality fresh mushrooms and mushroom fortified value-added products at competitive rates without any agro-chemical residues. Efforts should also be made to exploit the commercial utilization of mushroom substrate left after cultivation for preparation of organic manure, vermicompost, briquettes, *etc.*

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Research Review

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Onion storage in tropical region — a review

P.C. Tripathi* and K.E. Lawande

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

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ABSTRACT

Onion (*Allium cepa* L.) is one of the most widely cultivated vegetable in the world. It is used daily in culinary preparations. Onion is produced mainly in the season in temperate region and one or two or three seasons in tropical region as per the climatic conditions. Thus, a sizable quantity of onion is stored all over the world to fulfill the daily requirements of onion. Onion is generally stored at two temperature and humidity regimes, *i.e.* 0-2°C and 65-70% RH and 25-30°C and 65-70% RH. In tropical region onion, is stored at ambient conditions in different types of structures. The storage losses in tropical region are very high (30-40%) due to improper pre-and post-harvest management and poor storage environment coupled with climatic conditions. Lot of research works have been carried out in all tropical onion-growing countries on various aspects of storage. The varieties, nutrient management, time, quality and quality of irrigation, time and methods of harvesting, field and shade curing are some important pre-harvest factors effecting storability. Post-harvest treatments such as irradiation, fumigation and storage environment such as type of structure, ventilation pattern, type of construction material, design, stake dimensions, temperature and humidity regime, packing material, season of storage are post-harvest factors effecting storability. The use of recommended varieties, production technologies, curing, ventilated well-designed permanent structure and irradiation may reduce these losses up to 20-25% with economic feasibility. The research works carried out in tropical onion-growing countries is summarized in this review.

Key Words: Onion, Storage, Tropical region, Pre-harvest, Past-harvest, Climatic conditions, Storability

Onion (*Allium cepa* L) is one of the most widely cultivated vegetable in the world. The storage losses in onion in tropical regions are high. A lot of attempts have been made to reduce the losses. Several research findings have shown that losses can be reduced. But the storage conditions, climatic conditions, cost of storage, poor adoption of research findings are main impediments. There is still a need to develop cost-effective technologies for onion storage in tropical regions. It is used as vegetables in most parts of the world. Onion is believed to be originated in central Asia. According to ancient records it was used in India, China, Egypt, Persia thousands year ago. Although, it is originated in temperate region but it is widely adopted in tropical climate. Presently, it is cultivated in more than 170 countries of the world. The area under onion in the world increased continuously during the last three decades. World production of onion has increased significantly from 7.5 million tonnes in 1960 to 51.9 million tonnes in 2002 and 92.64 million tonnes in 2015. China, India, USA and Turkey are major onion-growing countries in the world. Other major producers are Russian federation, Japan, Spain, Pakistan and Egypt. These eight countries account for over 60 per cent of the total world production of onion. India ranks first in area (1.19 million ha), but production is highest (23.93

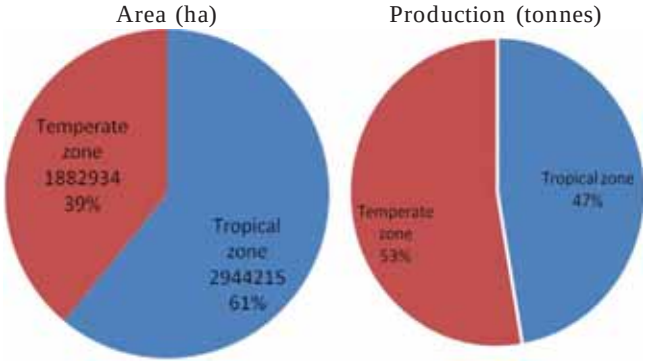

Fig. 1. Area and production of onion in temperate and tropical regions (FAO ,2016)

*Corresponding author : prakaashtripathii2000@yahoo.co.in
Principal scientist& Head(i/c) , Division of PGR, ICAR-IIHR, Bengaluru

Table 1. Onion production 2016 (FAO data book) in tropical countries

Country	Area (ha)	Production	Productivity (kg / ha)
Algeria	49896	1525987	305834
Argentina	24000	600000	25000
Bangladesh	177492	1735334	97770
Brazil	57464	1657441	288431
Cameroon	25075	303781	121149
Colombia	19973	484321	242491
Democratic Republic of the Congo	10551	56617	53659
Egypt	84878	3115482	367054
Ethiopia	33603	327475	97454
India	1199850	19415425	161815
Indonesia	149635	1446869	96693
Mexico	51504	1635049	317458
Morocco	25089	685647	273286
Myanmar	69962	1123084	160528
Niger	33288	1011577	303885
Nigeria	466277	1004153	21536
Pakistan	135912	1739054	127955
Peru	18093	705633	390012
Philippines	12988	122594	94392
Senegal	14016	416217	296964
Sri Lanka	10205	145262	142348
Sudan	87696	1583900	180613
Viet Nam	36719	16388	352884
Yemen	16388	241872	147587

million tonnes) in China. The productivity is highest in Korea (65 tonnes / ha).

More than 70 tropical countries cultivates onion either for domestic consumption or export. The tropical counties contribute 61% of total area and 47% of total global production of onion (Fig. 1, Table 1; FAO 2016). The productivity of onion was lower in tropical region as compared to temperate regions. Contrary to temperate region, where onion is grown in one season, it is grown more than one season in most of the tropical countries. Despite of cultivation in more than one season, onion is stored for 1-6 months to fulfill market requirements. The global export of onion is 64,29,147 tonnes. The major onion-growing tropical countries are India, Pakistan, Indonesia, Bangladesh, Niger, Ethiopia *etc*. These countries contribute more than 70% of the total onion export. These countries are major supplier of onions to temperate countries during critical gap (Table 2). There are two distinct storage temperature and humidity regimes for onion, *i.e.* 0-2°C and 70% RH and 25-30°C and 70% RH. The second condition prevails in tropical countries which encourage more storage losses. More-over onion is stored under ambient conditions in tropical regions as the low temperature storage facilities are rarely available (Brice *et al.*, 1997).

POST-HARVEST LOSSES

Onion is stored at ambient storage condition in most of the tropical countries where the storage losses

Table 2. Export of onion (2016)

Quantity (tonnes); value (US$ million)

Country	Quantity	Value
Netherlands	9,89,687.00	412.00
Mexico	3,98,135.00	398.00
India	12,66,678.00	354.00
China P Rp	5,11,664.00	214.00
Spain	3,96,695.00	187.00
USA	2,98,337.00	166.00
Egypt A Rp	2,79,239.00	130.00
Egypt	2,40,108.00	125.00
New Zealand	1,73,778.00	106.00
Peru	2,20,302.00	93.00
Total	64,29,147.00	2,819.00

Source: COMTRADE, United Nations

are very high. About 40-50% of the stored onion never reaches to consumers because of various types of losses. Steppe (1976) estimated that 16-35% of onions were lost as post-harvest spoilage. In tropical countries, such losses may be higher than the estimates (Salunkhe and Desai, 1984). These losses comprises physiological loss in weight (PLW), i.e. moisture losses and shrinkage (30-40%), rotting (10-12%) and sprouting (8-10%). The higher storage losses were due to physiological loss of weight, occurring during drier months when mean temperatures are high with lower humidity. The rotting losses are high in high humid months. The sprouting of onion starts in later part of storage when bulb dormancy is over and temperature dips below 20°C.

Physiological loss in weight (PLW)

Onion bulbs contain 85-90% water. Being and a active stage, it produces and loose water due to respiration and transpiration. The storage condition influences the rate of water loss. The storage condition is governed by temperature, relative humidity, air movement and atmospheric pressure (Ryall and Lipton, 1979). The injuries increase the rate of respiration and accelerate weight loss. The weight loss may be 5-6% per month of storage in ambient storage conditions in tropical conditions. The storage losses increase with duration of storage due to increase in rotting and sprouting. Tripathi and Lawande (2006) reported 23% weight under in onions stored under ambient temperature was compared to 4.0 % in onions stored at low temperature (0- 2°C) for 4 months. The weight loss in onions increases with increased storage period and also affected by the time of storage due to variation in temperature, relative humidity and rainfall (Abu-Goukh *et al.*, 2001).

The storage influence the storage as it is more in *kharif* (rainy) season crop as as compared to late *kharif* (late rainy) and *rabi* (winter) crop. The physiological weight loss was 19.29-20.87 and 6.14-4.97% at ambient stored onions and cold stored onions with Hessian cloth bags and Nylon net bags respectively. The PLW was much higher at ambient stored onions compared to cold stored onions with maleic hydrazide (MH-40) and gamma irradiation (60 Gy from cobalt - 60 source) treated onion (Tripathi and Lawande, 2007). The total storage losses reduced to 39.23% in ventilated bamboo structures compared to conventional storage structure (53%) after five months of storage of onion bulbs (Subbaram *et al.*, 1990). Tripathi and Lawande (2008, 2015) observed that total losses of onion bulbs was 35.17 and 44.96% stored in low-cost bottom ventilated structure and recommended bottom ventilated structure respectively. The PLW was 4.6, 5.1, and 6.2% for the Renate onion bulbs when stored in the cold room at 0, 2 and 5°C respectively for 186 days of storage (Adamicki, 2005).

Sprouting

The storage condition does not cause sprouting, but only affect its rate ((TDRI, 1986; Ryall and Lipton, 1979). Onion varieties varied significantly in percentage of sprouted bulbs during storage and sprouting increases with increase in storage period (Abu-Goukh *et al.*, 2001). Wright *et al.* (1935) studied the influence of storage temperature and humidity on keeping quality of onions. They concluded that extent of sprouting in stored onions was generally influenced little by humidity, but it increased with an increase in temperature (over the range of 0 to 10°C).

Abu-Goukh *et al.* (2001) reported that increase in sprouting percentages towards the end of storage period could be due to decrease in temperature or due to loss of dormancy in bulbs. Many workers indicated that if duration of storage is extended into winter season and temperature dropped to intermediate levels, sprouting is rapidly encouraged (Abdalla and Mann, 1963; Musa *et al.*, 1973). The lower sprouting of onion bulbs in low cost bottom ventilated structure was observed by Tripathi and Lawande (2004c). Adamicki (2005) studied the sprouting of onion bulbs during shelf-life at 18-20°C.

Rotting

Ryall and Lipton (1979) described that bacterial soft rot (Erwinia caratovora), black mold rot (Aspergillus niger), Fusarium bulb rot (Botrytis spp) as common storage diseases. These are most destructive post - harvest diseases of onion bulbs. The rotting was recorded around 50.8% for 'Rumba' onion bulbs stored for 252 days of storage at atmosphere storage conditions (Adamicki, 2005). Tripathi and Lawande (2007) and Tripathi *et al.* (2008) studied rotting of onion bulbs stored during cold storage and post-cold storage with sprout suppressant and packaging materials at ambient conditions. There was no rotting of bulbs in cold stored onions after four months of storage. Rotting was higher at ambient storage than cold storage even after four months of post-storage at room temperature. The rotting was 4.44 % and 16.04% in cold stored onions during four months of post-cold storage and ambient stored onions respectively. Higher rotting was recorded in leno bags as compared to hessian cloth bags under ambient storage conditions (Tripathi and Lawande, 2013).

Root growth and other disorders

High relative humidity and insufficient ventilation is main reason cause of root growth. Kaufman *et al.*

(1953) found that under humid and high temperature conditions, roots grew within a few days. The rooting of bulbs is generally low. The exposure of onions to direct sun light results in greening of bulbs. It is more observed in especially in white onions. The outer fleshy scales of bulb become light to dark green and these may have undesirable flavour (Salunkhe and Desai, 1984).

FACTORS EFFECTING STORAGE LIFE OF ONION

The storability of onion is influenced by genetical, cultural and post-harvest management factors. The genetically controlled factors, which may influence the storage performance, include dry matter content, pungency number of scales and dormancy period of variety. The cultural practices which influence the storability include manures, fertilizers, quality and quantity of irrigation water etc. The time and method of harvesting, curing and storage environment, packing materials also have considerable effect on storage life of the onion.

Genetic factors

The inherited qualities, which lead to give good storage life of onion, are high dry matter content, high pungency and long dormancy. Long-storing onions often have high dry-matter content, high total soluble solids high pungency and long dormancy (Bruce *et al.*, 1997; TDRI, 1986). Although the linkage between long st*orabi*lity and high dry matter content is not fully stabilized but varieties having several layers of dry skin have better chance of performing well during storage. The locally adopted short day onion varieties tend to have better storage quality than the imported short day varieties. The poor keeping varieties have low TSS, low dry matter content, high relative loss of water in the period immediately after harvest and poor skin retention with only one number of scales. Locally adapted onion varieties, selected over many years within the tropics, tend to store better than the short day varieties introduced from temperate countries. Patil and Kale (1998) recorded the total soluble solids of onion (TSS) and observed that it increased from 10.6 to 11.9% during six months period of storage. It was found that higher content of total soluble solids was associated with better keeping quality. Abu-Goukh *et al.* (2001) studied quality and st*orabi*lity of 20 onion varieties in Sudan including 5 local, 4 Indian, 6 American and 5 hybrids. The local varieties had the best keeping quality and stored well at ambient conditions for six months compared to the American and hybrid varieties.

The colour of outer scale is correlated with storability of onion. The red coloured varieties have the highest storage potential, followed by yellow skinned varieties and the white ones had the lowest storage potential (Abu-Goukh *et al.*, 2001; Saxena *et al.*, 1974). Krishnamurthy et al (1987) observed the pyruvic acid for the Bangalore rose onion, Nasik red onion and Bellary Red onion as 1.17, 0.96 and 0.98 mg/g, respectively after harvest.

The onion bulbs with high pyruvic acid content had the better storage quality. Bajaj *et al.* (1979) reported that the red onion varieties had higher phenolic compounds than white varieties, which protect them against pathogenic infection, and thus had a better keeping quality. The varieties suitable for storage have more number of outer dry scales. These outer layers help to create an effective vapour barrier around bulb, thereby minimizing moister loss (Brice *et al.*, 1997). These layers also act as physical and chemical barrier to the entry of pathogens. Tripathi and Lawande (2010) found that lower respiration rate was recorded in light red coloured onion cv. N-2-4-1 while comparatively higher respiration rate was found in dark red colour and white colour varieties. The Q10 coefficient was found higher at low temperature range but low at higher temperature ranges.

Cultural practices

Seed treatment : The treatment of onion seed with fungicides prior to sowing significantly reduce the neck rot caused by *Botrytis allii* during storage. The seed treatment with bavistin or benomyl @ 2g/kg seed before sowing reduces the neck rot disease. It was found that dipping of seeds in benomyl solution for two minutes before sowing was found more effective compared to procymidone in Gizar variety of onion (Ahmed *et al.*, 1991).

Manures and fertilizers : Onion crop removes 85 kg nitrogen, 36 kg phosphorus and 68 kg potassium/ha from soil for production of 30 tones of onion. Therefore sufficient quantity of Nitrogen, phosphorus and potassium fertilizers should be applied to soil. A sizable quantity of organic manures should also be applied. The excessive nitrogen application has been found to increase the rotting in storage. High nitrogen is associated with thick neck in onion, which are more prone to storage losses (Kunkel, 1947). Although application of nitrogen in early stages is important for vigorous vegetative growth, excessive nitrogen towards harvest time can lead to increased levels of fungal and bacterial rots and promotion of early sprouting. High nitrogen or choice of ill-adapted varieties may result in a large proportion of thick-necked or bolted bulbs (Bhalekar *et al.*, 1988). Bulbs which fail to mature completely may retain open necks which allow the entry of pathogens.

The time of application of nitrogen application is also an important factor. The application of higher doses

of nitrogen particular in the later stage off growth should be avoided. There must not any application to nitrogenous fertilizer after 60 days of transplanting. The application of additional quantity of potassium (30 kg / ha) found to increase storage life. The application of sulfur (50 kg / ha) also found to increase storage life in onion cv. N-2-4-1. (Aziz Qureshi et al, 2003). The application of organic manures has been found beneficial in increasing storage life. The storage life of onion cultivated with only farmyard manure (25 tonnes / ha) was found better than chemical fertilizers but losses were higher with poultry manure (10 tonnes / ha) (Tripathi, 2006).

Irrigation : The method and time of irrigation has also closely associated with storage losses. The choice of overhead irrigation rather than furrow or drip irrigation can also increase the incidence of diseases. The storage losses in drip irrigation were found lower than others methods. Tripathi *et al.* (2010, 2017) found that total storage losses after three months of storage were lowest in drip irrigation (13.38%) and surface irrigation (17.15 %). While higher losses were found in micro-sprinkler irrigation (22.58%) and big sprinkler irrigation (32.25%) systems. Similarly, these losses were 32.72 and 36.18 % in drip and surface irrigation, respectively in comparison to 46.18% in micro-sprinkler and 57.73% in big sprinkler after 6 months of storage. The rotting losses were significantly higher in both types of sprinklers than drip and surface irrigation. Brice *et al.* (1997) reported higher storage losses in overhead irrigation.

The reason may be due to the fact that the overhead irrigation allows the entry of disease causing micro-organisms in the later stage of bulb maturity. The late irrigation results in higher level of neck rot. It is generally recommended that irrigation should be stopped 2-3 weeks before harvesting. The quality of water should be good if overhead irrigation system is used for irrigation. The regulation of quantity of water in overhead irrigation is also important. It is generally recommended that irrigation should be stopped 2-3 weeks before harvest.

Season : In Some tropical countries, onion is grown in more than one season, apart from varietal characteristics, seasons of planting also influences the storage life of bulbs. The assessment of storage in three seasons, i.e. *kharif*, late-*kharif* and *rabi* season revealed that *kharif* season onions have higher percent of sprouting and almost 30% of the bulbs sprouted within four month of storage. The occurrence of rotting was also high in *kharif* season onion. In late-*kharif* season (January-February harvested onion), sprouting and rotting were less during first 4 months of storage. In April-May harvested (*rabi* season) onion, storage losses were less as compared to other seasons. The bulbs remain good up to September-October (Tripathi, 2008).

Pre-harvest treatments

Fungicides and other chemicals : The foliar application of fungicides 10-15 days before harvesting helps in reduction of pathogens load and helps in reduction of diseases in storage. The mature crop sprayed with fungicide such as Bavistin (0.2%) 15 days prior to harvesting. Spraying of benomyl and procymidone (0.2%) four weeks before harvesting decreased the per cent infection of onion neck rot. Combined application of bavistin (0.1%) and streptocyclin (0.05%) was found effective in reducing decay loss in onion (Gupta,1992). Among 18 fungicides evaluated Bavistin (0.1%) and Benomyl (0.1%) were found most effective when used as pre-harvest spray treatments prior to harvesting (Omveen *et al.*, 1987). The most effective control of *Aspergillus niger* was achieved by pre-harvest spray of Bavistin (0.1%) followed by difoliton, Blitox and Dithane-M-45 in onion cv. Hisar-2 after two months storage (Maheswari *et al.*, 1988). The lowest rotting loss (1.20%), physiological weight loss (9.33%) and total loss(10.52%) were found with Carbendazim at 0.1% as pre-harvest spray at 100 and110 days after planting of onion cv. Agrifound Dark Red (Singh and Sharma, 2002).

Pre-harvest sprays of borax and copper oxychloride (2.5 g / l) increased skin thickness, decreased weight loss and enhanced colour. Dark red skin varieties had a better response to pre-harvest treatments in relation to light skin varieties. The firmness of bulbs was not affected by pre-harvest treatments (Ferreira and Minami, 2000). The lowest losses of onion bulbs due to decay (24.88%) after five months of storage was observed with 0.1% Carbendazim spraying at 30, 20 and 10 days before harvest (Srivastava *et al.*, 1996). Tripathi (2008) used several fungicides, chemicals to reduce the storage losses in onion but pre harvest application of plant growth regulators, micronutrients, metallic salts, weedicides, fungicides etc. was found ineffective in control of storage losses except application of Bavistin which help in reduction of rotting. Some of the metallic salts helped in retention of bulbs colour.

Sprout suppressants : Several sprout suppressants have been evaluated in onion to reduce sprouting of bulbs during storage. The use of sprout suppressants such as maleic hydrazide (1500-2500 ppm) 2-4 week before harvesting have been found successful in control of sprouting in storage. Many studies have been reported on the inhibiting action of maleic hydrazide on sprouting of onions in storage (Wittwer and Sharma, 1950; Wittwer and Patterson, 1951). Paterson and Wittwer (1953) obtained 61% marketable bulbs in 2,500

ppm maleic hydrazide treatments as compared to 38% in control after 6 months of storage. Application of maleic hydrazide was carried out when one-third of tops (foliage)had fallen down, this being two weeks before harvest.

Wittwer and Paterson (1951) pointed out that maleic hydrazide should be applied to the plants with nearly mature bulbs and yet with green foliage, because too early application produced puffy or spongy bulbs and because green leaves were required for absorption and translocation of maleic hydrazide. The application of maleic hydrazide 7 weeks before harvesting produced 9.5-62% spongy bulbs, and that spraying with maleic hydrazide 4 weeks before harvest increased internal break down other than sprouting (Paterson and Wittwer, 1953).

Isenberg (1969) noticed that effects of maleic hydrazide was delicately depend on plant maturity. Pandey *et al.* (1994), Kulwal *et al.* (1991) and Bhalekar *et al.* (1988) found significant effect of maleic hydrazide in sprouting inhibition in onion. Ray *et al.* (1996) found that maleic hydrazide was most effective treatment in reducing loss in weight, rotting and sprouting for onion bulbs stored in wooden baskets at ambient temperature for eight months storage. Maleic hydrazide sprayed at 2000 ppm, 15 days prior to harvest was found to be comparatively more effective than aureofungin (150 ppm) and streptocycline (150 ppm) for reducing sprouting and rotting losses during storage of onion cvs. Baswant-780 and Agrifound Dark Red (Waskar *et al.*, 2004). The use of sprout suppressants such as maleic hydrazide (1500-2500 ppm) 2-4 week before harvesting have been found successful in control of sprouting in storage. The sprout suppressants should be applied when there are 5 - 8 green leaves per bulb to absorb and translocate the sprout inhibitor. The early application of maleic hydrazide leads to high proportion killed brown shoots and spongy bulbs. Maleic hydrazide is less effective when temperatures exceed 26°C as crystallize on leaf surfaces. Tripathi and Lawande (2007) did not found significant of maleic hydrazide on sprouting in onion in *rabi* season onion cv. N-2-4-1. The probable reason may be the associated with higher temperature.

Harvesting time and method : The timing of harvest is influenced by several factors such as market demands, risks from changing weather patterns, or risks of theft from the field. Harvesting date is, therefore, often a compromised between yield and subsequent storage quality, and it must be matched to suit the cultivar, ambient conditions, husbandry practice and method of storage. Timing of harvest is important yield maximization and quality production. The yield is maximum, if bulbs are left in the field until all the leaves have completed dried. But under relativity wet soil conditions complete drying of leaves seldom occurs. Further, delayed harvesting may result in reduction in skin quality, sprouting, rooting and reduction in firmness, weight loss, and incidence of watery scales and storage rots of bulbs (Brice *et al.*,1997; Bottcher, 1999). Thus it is generally recommended that onion should be harvested when 50% plants show neck fall.

Ali and El Yamani (1977) found that delaying harvest until 50% of the leaves had fallen resulted in fewer storage losses when compared to harvesting at 25% fall-over. In recently developed mechanized production systems in Europe, onion leaves are mechanically cut or 'topped' and the bulbs harvested before outer skins have started to dry; this usually corresponds to approximately 50-70% leaf fall-over. However, such a system only works efficiently if bulbs are dried under controlled conditions immediately after they arrive in store to avoid a rapid subsequent deterioration in quality.

Onion is harvested manually by hand uprooting in most of the tropical regions. But in hard soil, hand hoe is used for harvesting. The use of mechanical harvester is very limited in tropical regions because of smaller land holdings, cheaper labour availability and some wet foot conditions (Tripathi *et al.*, 2005).

Field curing and removal of leaves : Curing is a surface drying process carried out to remove excess moisture from the outer skins, roots and neck tissue of harvested onion bulbs. It improves the keeping quality of onion bulbs and reduces the chance of infection by disease-causing organisms in storage. Curing can be achieved in the field or by artificially with forced heated air. Curing is complete when the neck of the onion is tight and the outer scales are dry and rustle when handled (Wright and Grant, 1997). In tropical conditions, field curing is practiced in most of the regions. Rainy (*kharif* season) onion, curing is some time avoided due to rains but it is invariably practiced in other seasons.

The field curing allows drying of leaves and translocation of growth inhibiting hormones to bulbs which enhances the dormancy of the bulbs (Brice *et al.*, 1997). The onion should be dried with intact leaves for 3-4 days after harvesting. while cutting the leaves, 2-3 cm long neck should be kept along with the bulbs. These bulbs should be kept under shade for 2 to 3 weeks for proper drying of bulbs Before contemplating storage it is imperative to ensure that the onion bulbs are of good quality and that they have been properly dried and cured. The drying process allows the formation of strong, intact outer protective skins, and the closure of the neck of the onion. Drying and curing often take place simultaneously in the tropics (Brice *et al.*, 1997).

Onions can be cured in the field, where the bulbs are undercut; hand pulled, and allowed to dry for 5 to 10 days (depending on ambient temperatures) before topping. Curing may be done in windrows with tops of one row covering the bulbs of the next row to prevent sunburn of bulbs (Tripathi and Lawande,2004b). Bhattarai and Subedi (1998) found that seven days curing before storage was recorded as minimum loss in weight (31.9 %) than without curing (43.9%) after 120 days of storage. Bhonde and Bhadauria (1995) reported that bulbs of onion cv. Bangalore Rose recorded the lowest (13%) and highest (16.11%) of physiological losses in weight when cured in shade and non-cured bulbs respectively, after two months of storage.

Kale *et al.* (1992b) found that the curing of onion bulbs for four days in the field by windrow method followed by curing in shed for 21 days before storage recorded the minimum storage losses (38.70%) compared to non-cured bulbs (47.80%). Singhal (2000) studied the field curing by windrow method for three to five days, shade curing with tops for 10 - 12 days. Wright *et al.* (2001) found that onions are lifted at 60-80% top down, the bulbs are field-cured, and the foliage is removed after curing, is the simplest method and best compromise to ensure postharvest onion quality and successful storage. Tripathi (2008) found that curing of bulbs under poly tunnels in *kharif* season was found effective in reduction of losses.

The removal of leaves is generally done 3-4 days of field curing. The removal of leaves facilitates easy grading, packing and marketing. It has been found that untopped bulbs remains in the store for longer period but presence of top in bulb is undesirable due to many seasons, but the top should be removed after complete drying of leaves. The bulbs of *rabi* season onion cv. N-2-4-1 having different neck length *i.e.* 0 cm, < 2 cm, 2-4 cm and intact leaves were stored under ambient condition (Tripathi, 2008). The physiological weight loss in intact leaves onions were lower than topped onion. The sprouting and rotting losses were also lower in intact leaves onions. But black mould infection was higher in intact leaves onions. The similar effect was observed in *Rabi* onion but the storage losses were less.

Shade curing : Shade curing in shade helps in development of colour and more number of scales. In India, the shade curing is done in shade or below tree with 1-2 fit thick heaps of onion. These heaps are turn-up at regular intervals for proper drying. Some farmer practices shade curing in field by covering the heaps of onions with dried leaves of onion (Tripathi *et al.*, 2003). Excessive exposure to sunlight causes sloughing off of outer scales (baldness), sunburn and excessive shrinkage of the onion. Tripathi (2008) found that curing of bulbs in pits and heaps in *rabi* season was found effective in reduction of losses.

Size of bulbs : The size of bulbs and storage losses are correlated. Karmarker and Joshi (1941), Kapour *et al.* (1953) and Stow (1975) reported that size of onion bulbs affected both sprouting and water loss during storage. They found that large bulbs sprouted at faster rate than small ones in storage but that small onions lost weight more rapidly. Kunkel (1947) did not found any statistically significant differences in storage losses attributed to size of stored bulbs. Small and Chandler (1990) indicated that large bulbs appears to be more susceptible to spoilage than medium or small bulbs, they found that smaller bulbs within the variety tend to have a higher dry matter content.

The smallest bulbs sprout first and produce roots, and the largest bulbs were the last, but these differences diminished with time in storage. As far the size of bulbs is concerned, medium-sized (50-60 mm diameter) and thin necked onion performed better storage than bigger and smaller onions. Tripathi (2008) stored onion bulbs of different size, *i.e.* 25-40 mm, 40-50 mm, 50-60 mm and more than 60 mm under ambient conditions. The results revealed that physiological weight loss was higher in small-sized bulbs, while it was less in medium and bigger bulbs. The rotting was not found associated with bulbs size but sprouting was higher in either smaller or bigger bulbs as compared to medium size bulbs.

Neck thickness of bulbs : The thickness of bulbs influences the storage of onion bulbs. The thick neck bulbs shows more decay and sprouting. Saimabha and Randhawa (1983) and Patil *et al.*, (1987) did not find any significant difference in storage losses of different sizes of bulbs. The storage of onion bulbs of different neck thickness, *i.e.* < 3 mm, 3-6 mm and more 6 mm under ambient conditions revealed that there was no effect of neck thickness on physiological weight loss but rotting was less in those bulbs having less than 3 mm neck thickness (Tripathi, 2008).

POST-HARVEST TREATMENTS

Fumigation

The fumigation of bulbs with sulphur before storage decreases the infection of moulds. Onion bulbs cv. N-2-4-1 were given sulfur fumigation (50g / m^3) for 1-5 hours to reduce the disease infection. There was on effects of sulphur fumigation on weight loss rotting and sprouting. But the black mould infection was 2-3% less in all fumigation treatments as compared to control (Tripathi, 2008).

Irradiation

Sprouting is a major source of wastage of stored

onions. It is primarily temperature dependent. Irradiation at low doses is commonly used for sprouting inhibition. Several workers have reported the efficacy of the irradiation in onion bulbs under different storage and irradiation conditions (Dallyn and Sawyer, 1959; Lewis & Mathur, 1963; Salem, 1974, Bonginwar and Shirsat, 2000). Gamma irradiation was found effective in preventing the sprouting losses in all onion varieties irrespective of colour (Iglesias-Enriquez *et al.* (2001) A dose of 5 - 15 krd of gamma irradiation shortly after harvest effectively inhibited sprouting of onions (Gonzales *et al.*, 1969). Matsuyama (1972) reported that sprouting could be effectively controlled when onions were irradiated with 3-7 krd during their dormant period. Tripathi and Lawande (2010) stored gamma irradiated *rabi* Onion cv N-2-4-1 was stored under ambient condition and low temperature conditions (0-2°C and 65-70% RH) from May to October. The results revealed that total losses in cold stored onions at the time of taking out were only 6.41% as compared to 33.35% in onions stored under modified bottom ventilated storage structure.

The irradiation before cold storage completely eliminated the post cold storage sprouting and there was only 4.7% sprouting in irradiated cold-stored onion even after four months of taking it out from the cold store. The onion of *kharif* and late *kharif* season showed similar results with slightly higher weight loss. Tripathi and Lawande (2013) reported that different onion varieties were irradiated with gamma rays and stored under ambient condition for 5 months from June to November. The result revealed that gamma irradiation effectively checked sprouting in all onion varieties irrespective of season and colour. In general , rotting was not increased by the irradiation barring few *kharif* season varieties. There was no significant effect of irradiation on PLW and black mould infection. But black mould infection was higher in white colour varieties. It was concluded that treatment of well cured onions with 60 Gy to 90 Gy gamma irradiation within one month of harvesting completely eliminated the problem of sprouting of onion during storage.

Packing

Packaging 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 onion is generally packed in Hessian cloth bags of various sizes for marketing. Now the use of netlon bag and consumers pack (1-5 kg) is also going popularly. Tripathi *et al.* (2005) found that most of the farmers in Maharashtra, Gujarat and Karnataka are not using any packing material for onion. The common practice is that farmers use to carry their produce in tractor trolley or bullock carts etc. and sell in nearby market. Only 1.44 per cent farmers in Maharashtra and 30.99% farmers in Gujarat were found to use hessian cloth bags as packing material. Pandey *et al.* (2000) reported that cured onion cv. Agrifound Dark Red bulbs can be stored under ambient conditions for four months in bamboo baskets with lowest percentage total loss.

The onion bulbs cv. Red Creole which were cured through sun-drying stored at 0°C in wooden crates retarded bulb rot incidence and post harvest losses (Eligio *et al.*, 2002). Different packaging materials, *viz.* hessian cloth bags or gunny bags, netlon bags and plastic crates were used for packing of onion cv. N-2-4-1. The results revealed that lowest over all losses was 31.1% which were found in Hessian cloth bags and plastic crates kept in control forced ventilated compartments after five month of storage. Tripathi and Lawande (2007) observed the physiological loss in weight of cv. N-2-4-1onion bulb in cold storage for hessian cloth bag and netlon bag as 5.55 and 5.91% respectively after four months of storage. Higher rotting was recorded in netlon bags as compared to hessian cloth bags under ambient storage conditions. Tripathi (2008) and Tripathi and Lawande (2013) found that among various type of packing materials used, plastic Crates were found most effective in reduction of losses but net profit for four month storage was highest in stakes and lowest in plastic crates.

STORAGE ENVIRONMENT AND METHODS

Storage environment

The storage of onion on large scale from trading point of view was not a major concept. However, with increased domestic as well as export, storage became essential. There are two distinct temperature regimes where losses are minimum. One is high temperature regime, where storage temperature is 25-30°C and another is low temperature regime, where temperature is maintained 0-2°C. Best results under both the temperature regimes are obtained when humidity is maintained at 65 - 70%. The storage losses in high temperature conditions (25-30°C) are high (30-35%) but storage cost is low. While in low temperature conditions (0-2°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°C) in ambient storage structures lead to higher weight loss while lower temperatures (less than 10°C) enhance sprouting losses. Higher humidity (more than 70%) coupled with higher

temperature enhance storage diseases, while lower humidity enhance weight loss. Every farmer used to store these commodities in small scale for their home consumption. Anything in excess used to be sold in weekly bazaars in bigger villages and towns. Slowly storing of onion during monsoon season and selling during lean period in the country or export to gulf countries started by traders might have compelled farmers and traders to hold the stock for some time till prices rise. Initially storage conditions and structures were very primitive and mostly unscientific. Maintaining the bulbs within the store at suitable temperatures and humidity is a vital consideration in achieving successful storage of onions.

If storage temperature or humidity is too high or too low, rapid deterioration followed by high or total losses is likely to occur. Storage conditions affect sprouting, rooting, loss of weight, respiration rate, incidence and severity of rots, and many other quality aspects of stored bulbs (Brice *et al.*, 1997). Sprouting in onions is a result of normal physiological changes in stored bulbs, which, as biennials, develop reproductive shoots in the second year. The storage conditions thus do not cause sprouting, but only affect its rate (Ryall and Lipton, 1979). Bulbs are naturally dormant at maturity and the length of this dormant period varies with cultivar and conditions (Thompson *et al.*, 1972). Aoba (1955) found that the actual rest period in onions is about one month, but it may be followed by one or two months before sprouting occurs. Wright *et al.* (1935) studied the influence of storage temperature and humidity on the keeping quality of onions. They concluded that the extent of sprouting in stored onions was generally influenced little by the humidity, but it increased with an increase in temperature, over the range of 0-10°C. The decrease in temperature to intermediate levels encourage rapidly sprouting (Abu-Goukh *et al.*, 2001; Abdalla and Mann, 1963; Musa *et al.*, 1973). According to Wright *et al.* (1935), root growth of onions in storage increased with humidity and it was little influenced by temperature. Onion roots emerge from the base of shortened stem, growing several centimeters in length during storage. High relative humidity (above 85%) with insufficient ventilation is primary cause of root growth. Kaufman *et al.* (1951) showed that under humid and high-temperature conditions, roots grew within a few days. The loss in weight of bulbs increased with an increase in storage temperature from 0-10°C, a further increase being observed at still higher temperatures.

This effect was partly attributed to increased sprouting and root growth occurring at 5-20°C and 0-10°C, respectively (Karmarker and Joshi, 1941). A marked reduction in weight loss of onion bulbs at higher relative humidity was observed by Wright *et al.* (1935). Kapour *et al.* (1953) reported that root growth of onions increased as storage temperatures increased from 0 to 10°C. Karmarker and Joshi (1941) reported that during storage of onions above 30°C, the percentage of total sugars did not alter, but the percentage reducing sugars decreased. The temperature and relative humidity are the prime important factors associated with storage of onion.

A high relative humidity (more than 75%) is the biggest enemy of onion storage as it promotes root growth and development of storage diseases. In contrast the humidity (less than 65%) leads to excessive moisture loss from the bulbs, resulting shriveling and loss of weight. The dormancy of bulbs, which inhibits sprouting, is primary temperature dependent. Sprouting is high between 5°C-20°C. As far as the weight losses are concerned it is less at 0-2°C or moderately lower at 25-30°C. The temperature of 5-25° and more than 30° increases the weight loss. Thus there are two distant temperature conditions and one defined humidity range suitable for storage of onions. The onion storage structure should be planned and designed storage in such a manner that it can achieve and maintain the desired storage conditions in lowest possible cost within available resources.

Storage methods

The survey of onion storage structures in major onion growing states of India, *i.e.* Maharashtra, Gujarat and Karnataka revealed that temporary, semi-permanent and permanent storage structure are used for the storage of onion. Out of 270 structures of farmers in three states, 34.4% structures were permanent, 30.74% were semi-permanent and 38.52% were temporary. Over all, only 22.96% structures were bottom ventilated. Fifty six per cent permanent structures were bottom ventilated, while only 8.43% semi-permanent structures and mere 0.2% temporary structures were bottom ventilated. As far as capacity is concerned, majority of temporary structures were less than 10 tonnes capacity, while majority of permanent structures were more than 30 tonnes capacity. The temporary structures were made of wooden logs with thatched roof and thatched roof with polyethylene covers.

The sidewalls of temporary structures were made with pigeon pea stalks or wheat straw. The floor of these structures was *kuchcha* but raised, in many cases. Semi-permanent structures were made with wooden logs or galvanized iron pipes / angles. Most of semi-permanent structures were built on raised platform, which is either *kuchcha* or filled with coarse sand. The side walls of these structures were made of pigeon pea stalks, wooden bantams and bamboos. The roof majority

of the semi-permanent structures was made with Mangalore tiles. The permanent structures were constructed with galvanized iron pipes / angles, RCC pillars. The roof of these structures was made of galvanized iron sheet or asbestos sheets. The sidewalls were made of wooden bantam, chain link and Bamboo.

As far as the storage capacity of the structure is concerned, most of the temporary structure and 40% semi-permanent structure were of less than 10 tonnes capacity. Contrary to this, 90% of the permanent structures were of more than 10 tones capacity. The total losses in the permanent structures were less despite of longer period of storage. The percentage of recommended bottom ventilated type structure was less than 35 in permanent type while in semi permanent it was less 10%. (Tripathi *et al.*, 2003; 2004). In other tropical countries, the onion is mostly stored in temporary storage structures made of thatch, wooden longs *etc.* (Bruce *et al.*, 1997).

Reduction in losses by modification in storage environment

Traditionally cured bulbs were tied into bunches with leaves. These bunches are tied around the pole. Bunches were arranged in such a way that bulbs acquired maximum aeration. The inspection of bulbs is easy way but this method can be used only for limited quantity. Various types of structures are used for storage of onion. Most of these structures are traditional type. Several modified onion storage structures have been design and tested (Skultab and Thompson, 1972, Krishnamurthy *et al.*, 1988; Subbaram *et al.*, 1990a, 199b; Kale *et al.*, 1992a, Shukla and Gupta 1994; Bhonde *et al.*, 1996, Maini *et al.*, 1997, warade *et al.*, 1997, Tripathi and Lawande, 2004). These structures help in reduction of storage losses. The Nasik type storage structure was an improvement over the local thatched type of bamboo structure. The total storage loss at the end of five months was 21% of cv. Bellary Red onion (Krishnamurthy *et al.*, 1988). Two perforated concentric type storage structures were fabricated by Shukla and Gupta (1994). It consists of 25 mm × 25 mm × 25 mm welded wire mesh, each having capacity of one tonne.

One of the structures was used for natural ventilation at outside the shed. Another one was attached to a blower to circulate air and also inside the shed. Quality of onion bulbs was recorded as 10% loss and 5-8% loss in natural air ventilation type structure and forced-air circulation structures respectively after three months storage. Maini *et al.*, (1997) reported that two tier systems was better than single or bamboo storage structure for minimizing physiological loss in weight and storage point of view. The traditional single tier storage structure top made of corrugated cement roof or with RCC ceiling. Windward sides were made from bamboo splits in single tier structure. The loading height was 1.5-2 m at all places, enough ventilation through windows in the walls and also raised flooring were provided.

The physiological weight in losses of these structures varied from 30-50%. (Tripathi and Lawande, 2004 a, b, c 2015) designed and seven storage structures, *i.e.* traditional double row storage structure, Modified bottom ventilated storage structure, top and bottom ventilated storage structure with mud-plastered walls, Modified bottom ventilated storage structure with chain linked side walls, traditional single row storage structure, Modified bottom ventilated single row storage structure, Bottom ventilated single row low cost thatched roof storage structure, at NRC for Onion and Garlic, Rajgurunagar. It was found that the bottom-ventilated structures were found better than the traditional storage, without bottom ventilated storage structures with respect to reduction of physiological weight loss (PLW) and rotting.

The storage losses were lower in single row structures than the double row structures. Over all, among double row structure top and bottom ventilated storage structure with mud-plastered walls was found best with 23.82% quantitative losses and 13.75% qualitative losses as compared to 46.11% quantitative losses and 5.21% qualitative losses in traditional double row storage structure after 5 month of storage. While among the single row structures, Bottom ventilated single row low cost thatched roof structure was found best with 28.66% quantitative losses and 3.46% qualitative losses as compared to 38.88% quantitative losses and 7.89% qualitative loses in traditional single row storage structure. The net profit was highest (₹ 33892/-) in Top and bottom ventilated storage structure with mud-plastered walls while net profit per tonne was highest (₹ 1207/-) in Bottom ventilated single row thatched roof structure. Out of these, low cost bottom ventilated storage structure for small and marginal farmers and top and bottom ventilated mud plastered structures for hot and humid areas and modified bottom ventilated structure with extended roof have found promising.

The low cost bottom ventilated storage structure is constructed with bamboo and has thatched roof. The life span of this structure is 3-5 years. This suites well to small and marginal farmers . The top and bottom ventilated structures is constructed with iron frame work and asbestos roof. The sidewalls of this structure is constructed with bamboo plastered with mud. The life span of this structure is more than 20 years. This structure has control flaps, which can open or closed as per requirement. This structure sited well for hot and

humid conditions. Modified bottom ventilated structure with extended roof is improvement over bottom ventilated structure. It has extended roof to protect from rain splashes. The life span of this structure is more than 20 years. Many state government / central government organizations are providing subsidy for construction of modern type of storage structures.

Cold storage

The onion can be stored under cold storage at 0-2°C and 65-70% humidity with very minute losses. But cost of storage and the problem of sprouting in post cold storage in onion is main problem. This problem of sprouting can be minimized by gamma irradiation treatment. The cold storage of onion is successful if combined with r-irradiation techniques (Tripathi and Lawande, 2006). At temperature of about 25°C most varieties do not sprout but the high levels of desiccation and rotting which can occurs means that it would be uneconomic to store them at these temperatures for long periods. Onion can be stored at 0°C and 70-80% RH for up to 8-9 months. At higher temperatures the storage life progressively decreases (Ramangkura, 1986).

Storage studies of onion bulbs were conducted in low temperature structure by Mondal and Pramanik (1992). Onion bulbs stored in low temperature structure (<15°C and 50-70%) prolonged the storage life and minimizes the storage losses. Mulabagalaiah (1997) verified the storage characteristics in cold storage of potatoes. The minimum sprouting, sprout length and weight loss were recorded when stored in cold storage followed by storing in zero energy cool chamber compared to that in gunny bag storage. Benkeblia and Shiomi (2004) conducted studies by storing onion bulbs cv. Rouge Amposta at 0ºC in the dark for four weeks and then transferred in dark to 20ºC and 65% relative humidity condition. The total breakage of dormancy of cold treated onion bulbs was observed after 8 weeks. The 50% breakage of dormancy was noted between the fourth and fifth week. Cold treatment at 0ºC induced breakage of dormancy of onion bulbs. Cold storage behavior of onion bulbs were studied by Tripathi and Lawande (2007). The temperature and relative humidity was 0-2°C and 65-75%, respectively. The losses in cold storage were very low (5-6%) as compared to ambient storage (20-25%). There was no rotting, sprouting and black mould infection in cold storage.

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Research Review

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Doubling oil palm yield through technological interventions — a review

Manorama K*, R K Mathur, M V Prasad, K Suresh, K Ramachandrudu and B N Rao

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ICAR-Indian Institute of Oil Palm Research, Pedavegi 534450, Andhra Pradesh, India

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ABSTRACT

India's vegetable oil demand is growing at a faster pace and by 2030 it is expected to be around 34 million tonnes. Palm oil is the most viable option to meet the edible oil demand of the country. India is the only country which grows this crop under irrigated conditions because, it is a water-loving crop and is the only option to lessen the gap between vegetable oil demand and production in India. Its theoretical yield potential is up to 18 tonnes of oil per hectare. Till now, its potential has not been fully exploited in terms of FFB production as most of the farmers are new to this crop and also it requires judicious management of resources like water and nutrients. Further, FFB yield levels at present are highly variable in different states and there is a large scope for enhancing the productivity by adopting recommended management practices. If proper management is provided, its crop could do wonders with very good yields under irrigated conditions. For reaping higher economic benefits from this crop, oil palm farmers should resort to good management, intercropping, inclusion of other components of farming like cattle, goats and poultry etc. Farmers also have to be made aware of different options of waste utilization for productive purposes through value-addition. In addition, with good R&D support, right policy back up from GOI, the income of oil palm farmers is expected to grow rapidly while meeting the edible oil demand of the country. Oil palm was introduced to India during 1970s and at present it occupies nearly 0.316 million ha of area in our country. This is most suitable crop to meet the vegetable oil demands in our country, contributing very high oil yield on unit area basis. The Government of India is emphasizing its expansion even to non-traditional areas because of its high yield potential. At present, average fresh fruit bunch yields are around 4.3-6.1 tonnes/ha at national level. By adopting suitable practices detailed in this discussion, the yield levels could be improved substantially.

Key Words: Doubling, Oil palm, Potential area, Systems approach, Crop insurance

Oil palm starts yielding after three years of planting in the main field. Accordingly, the average FFB yields have been calculated from the area planted before three years and the overall productivity of India is very low at 5.24 tonnes/ha. There is steady improvement of average yield from 4.31 to 5.24 tonnes during last seven years. Dr.M S Swminathan pointed out that the two major factors that influence oil palm farmers are market and monsoon. If we could manage both efficiently, majority of our farmers do enjoy farming. In oil palm, there are well structured market facilities mainly because of its perishable nature and also involvement of processing procedures. So, major emphasis lies on monsoon and management. Unlike in other countries, *viz.* Malaysia and Indonesia where oil palm is grown in very large areas, it is grown as small holders' crop in India. Moreover, more than 90 per cent of Indian oil palm is grown as irrigated crop. Therefore, strategies for enhancing the income of farmers in India are definitely different from other countries.

The national average FFB production during last seven years hovered around 4.31-6.12 tonnes/ha which is very low compared with other countries. But there are huge differences between states with respect to FFB yield (Table 1).

Reasons for low yield levels

Oil palm being a hardy crop, can adapt to most of the adverse conditions. Being humid tropical in nature it requires higher quantities of water, temperature and humidity. The factors which influence productivity are almost similar in all the states and the site specific

*Corresponding author : kmano1000@yahoo.com

Table 1. Average fresh fruit bunch yield (t/ha) of different states (DES, 2017)

State	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Andhra Pradesh	6.26	7.30	9.17	9.97	9.55	9.56	8.71
Karnataka	0.58	0.57	0.51	0.44	0.48	0.51	0.38
Tamil Nadu	0.21	0.31	0.31	0.29	0.32	0.36	0.32
Gujarat	0.02	0.05	0.05	0.05	0.12	0.14	0.20
Odisha	1.52	2.91	0.67	0.49	0.34	0.32	0.31
Goa	2.16	0.26	2.34	2.32	2.50	3.65	5.43
Kerala	7.73	7.97	7.51	6.85	7.22	7.14	5.96
Mizoram	0.05	0.11	0.17	0.16	0.18	0.24	0.24
Telangana	3.93	5.72	4.72	5.94	5.12	5.64	5.98
All India	4.31	5.05	5.85	6.12	5.81	5.80	5.24

problems may be there with respect to water availability, pollinator survival, harvesting, soil pH, low temperature, poor water quality etc. The planting material used in different parts of the country consists of both indigenous and imported teneras and there is no much variation in yields of these two sources. When we look at the average yields in different states, Andhra Pradesh, Kerala, Telangana and Goa performed consistently better whereas, the other states could not do well in terms of total state average. The main reasons for lower yields in different states are:

Improper water management

Oil palm requires very large quantities of water to meet its evapotranspirational demands. In India, it is grown as irrigated crop and continuous irrigation throughout the year is difficult in most of the states. *For example:* In Andhra Pradesh, the districts like West Godavari, East Godavari, Srikakulam and Krishna which gets rainfall for about 5-6 months and with good ground water potential could support the irrigation requirement whereas, other districts like Visakhapatnam, Nellore and Anantapur could not support the same. In Nellore District of Andhra Pradesh, dry winds prevail during summer months causing pollination weevil to disappear. Similarly in Maharashtra, West Coast region gets rainfall for seven months and the remaining 5 months are very dry. In Mizoram, dry spell exists between November to March. In many parts of Andhra Pradesh, Karnataka and Tamil Nadu enough water is not available for continuous irrigation. These are the reasons for poor yields in those areas. In Karnataka, erratic monsoon causing drying of borewells makes farmers fail to irrigate the oil palm gardens. Water stress at floral primordial initiation decides the sex ratio and thereby FFB yield. In some of the gardens, there are also problems of rodents, elephants and wild boar.

Imprudent nutrient management

Although there are recommended nutrient schedules for different regions, most of the farmers are not adopting them. Moreover, right method of application also is not being followed in most of the farms. The DRIS (Diagnosis and Recommendation Integrated System) norms have been formulated for the states of Goa, AP, Mizoram, Karnataka, Gujarat and Tamil Nadu and identified the most deficient nutrients. In addition, micronutrient deficiencies prevalent in different states also contribute to yield reduction. In some of the places, imbalanced fertilization also noticed which leads to N:K imbalance in many gardens. Boron deficiency is a very common problem in many locations. Potassium and magnesium deficiencies are noticed in majority of the gardens. Soil salinity is also another problem which affects the FFB yields badly (Rao *et al.*, 2017).

Climatic variability

The performance of oil palm is better in high temperature (Up to 40-45° C) areas with higher relative humidity. The areas with lower minimum temperature are likely to harvest little lower yields. But still, the site potential itself is far away from the actual yields in most of the states which indicates that there is a great scope for improvement in this direction. In certain pockets of Eastern India, higher temperatures prevail for 3-4 months and low temperatures do exist in Eastern and North-Eastern parts of India which badly affects the oil palm growth and development. Low temperatures are expected to influence the floral initiation thereby affecting yield. In Andhra Pradesh, there is large variation in average yields of different districts and with in a district also between different Mandals. In Nellore District of Andhra Pradesh, very poor yields are recorded because of insufficient

irrigation and dry westerly winds during summer months. In some of the villages, there are huge differences between side by side farms mainly because of difference in management practices (Manorama and Saravanan, 2014).

STRATEGIES TO IMPROVE YIELD

Resource management

In oil palm cultivation, water and nutrients are the two most important inputs for achieving higher economic yields. Though the crop requires 150-300 litres of water depending upon the season, some growers are applying excess water where the ground water levels are high and power supply is not a problem. To be precise, in summer 215-265, in rainy season 100 - 150 and in winter season 160-170 litres of water is enough per day per palm. Higher levels of irrigation does not guarantee any yield improvement rather it is detrimental as excess water leaches out the nutrients off the feeding zone of roots. Adopting drip irrigation system and also utilization of automated technologies to give exactly the required quantity of water can save lot of water which could be diverted for growing other crops. Besides these, mulching of palm basins with organic wastes and trenching across the slope are also recommended for water conservation.

Similarly, nutrient management based on soil and leaf nutrient analysis at periodical intervals enhances the nutrient use efficiency. Application of fertilizers at blanket recommended dose not only accounts for higher cost but also causes imbalance and thereby impeding uptake of certain nutrients. Judicious management of nutrients is highly recommended to safe guard the soil condition. Further, application of fertilizers via micro-irrigation system (fertigation) helps not only in better nutrient use but also to reduce the cost of production. Therefore, periodical testing of soil and leaf samples is advocated along with fertigation to supply required quantities of nutrients at precise rates.

Systems approach

When oil palm was introduced in India, the conditions were different with respect to wages, labour availability and government policies on imports. But today, the wages have increased and labour is not available for harvesting in tall trees. Under these circumstances, the net profit from oil palm cultivation is expected to be low. Ramachandrudu *et al.* (2018) report that if a farmer has got one hectare of land with oil palm and he harvests 20 tonnes of FFB per year from that piece of land, he gets only ₹ 5000 per month which is even lower than daily wages of a labourer. So, monocropping of oil palm is not much profitable unless it is combined with intercropping and also dairy component. For feeding the cattle, grass can be grown in between oil palm rows as intercrop and the milk can fetch him good profits. Diversifying and intensifying the oil palm cultivation through suitable component crops and other components like dairy, poultry birds or goats etc would definitely enhance the income.

Growing of intercrops adds a lot of organics to soil, changes micro climate and thereby shows synergistic effect on oil palm production. Canopy cover calls for differences in light interception in juvenile and mature gardens leading to changed preferences of inter crops. In juvenile plantations, growing of banana and colocasia contributed to higher net benefits of ₹ 81,405 and 61,053 respectively (Table 2) (Reddy *et al.,* 2004). In adult plantations oil palm + bush pepper could result in a net return of ₹ 1,56,985 in comparison to ₹ 53,453 in sole crop of oil palm. Oil palm intercropped with cocoa could give net returns of ₹ 1,24,864 (Table 3) (Ramachandrudu *et al.,* 2018).

Table 2. Economics of intercrops in juvenile phase of oil palm (Reddy *et al.*, 2004)

Intercrop	Gross returns (₹/ha)	Net profit (₹/ha)
Banana	129600	81405
Colocasia	116238	61053
Guinea grass	39858	13553
Maize	57960	37732
Tobacco	98000	58298
Chilli	70000	30744
Okra	44444	11095

Table 3. Economics of intercrops in adult oil palm plantations (Ramachandrudu *et al.*, 2018)

Intercrop	Gross returns (₹/ha)	Net profit (₹/ha)
Oil palm sole crop	105430	53430
Oil palm + cocoa	194864	124864
Oil palm + red ginger	184695	113195
Oil palm + heliconia	176140	102140
Oil palm + bush pepper	240695	156695
Oil palm + banana	194550	120550
Oil palm + ornamentals	171690	107690

Successful cropping models standardized at ICAR-IIOP, Pedavegi are (Ramachandrudu *et al.,* 2018)

- Oil palm + cocoa
- Oil palm + banana
- Oil palm + long pepper + bush pepper
- Oil palm + red ginger + heliconia
- Oil palm + long pepper + cut foliage

Suitable cropping system models for Kerala and hilly areas have been standardized as (Varghese and Sunitha, 2005; Jessy Kutty *et al.,* 2005)

Oil palm + cocoa/cinnamon+ black pepper on glyricidia + black pepper on oil palm + anthurium/ kacholam

Oil palm + *Kaempferia galanga*

Value-addition

In oil palm lots of waste is generated both in plantations and also in factories. It may be possible to improve the net income of the farmers if these wastes are utilized by value addition. The fronds and male inflorescences generated from oil palm plantations can be effectively recycled using chaff cutting machinery. In plantations, oil palm produces large quantities of biomass (15-17 t/ha/year on dry weight basis) through fronds and male inflorescences. The biomass in farmers' gardens is either underutilized or unutilized. Nearly 40 per cent of total cost of cultivation goes towards fertilizers in oil palm. By properly recycling this waste biomass, most of the nutrient requirements can be met which gives economical benefits and ecological advantages.

Mushroom cultivation is possible on empty fruit bunches as substrate and it can be encouraged to get additional income. The mesocarp fibre generated as a waste from oil palm industries is also useful as mushroom substrate. Farmers and agricultural labourers also can be trained to make use of this waste material to generate wealth of mushrooms to enhance the net income.

Fish rearing in farm ponds

Majority of oil palm growers do have farm ponds for the purpose of water harvesting in their fields. After the installation of micro-irrigation system, these ponds have become obsolete and are not being used regularly. These ponds can be converted in to fish ponds to rear fishes. From these ponds it is reported to have 3-4 harvests in 8-9 months period, which contributed in a net return ranging between ₹ 37,000 to 62,000 per ha.

Visits to progressive farmers' gardens

To encourage the farmers in oil palm cultivation and to inculcate the habit of adopting recommended practices, oil palm farmers from low yielding states and districts need to be taken to the gardens of progressive farmers who are harvesting higher FFB yields. Within the same village there is a large variation in the yields of different farms and this indicates the importance of management.

Assured market price

Oil palm is grown for 25-30 years economically. Market volatility affects oil palm production greatly because farmers do not show interest to take up new and recommended technologies due to uncertainty in FFB prices which are dependent on international crude palm oil prices. This is the biggest hindrance for oil palm expansion programme also. To encourage farmers towards oil palm cultivation and to follow recommended package, price stabilization is very much required. This can be achieved by creating a Price stabilization fund or similar mechanism. Through that a minimum support price needs to be assured for the farmers by linking the cost of production of FFB. To counter balance the impacts of vagaries of weather, an insurance scheme has to be designed and adopted.

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Research Review

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Exploring potential of bacterial endophytes in disease management of horticultural crops

Popy Bora[1,*], Kakumoni Saikia[2], Hrishikesh Hazarkia[2] and Gavas Ragesh[3]

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Department of Plant Pathology, Assam Agricultural University, Jorhat, Assam, India

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ABSTRACT

The endophytes are facultative or obligate symbiotic microorganisms, living in apparently healthy internal plant tissues, without causing disease in the host. Bacterial endophytes are found in a diverse group of plants including many horticultural crops, *viz*. fruits, flowers and medicinal plants. They harbour diverse group of bacterial endophytes including members of Pseudomonads, Bacillus and Streptomyces, which have been found successful against many phytopathogenic fungi and bacteria. Endophytes can suppress diseases through various mechanisms, *viz*. antibiosis, competion, lysis, siderophore production, enhanced host defense *etc*. Many Actinobacteria produce metabolites with antimicrobial activity which can be explored as a potential alternative to chemical in plant disease management. Moreover, bacterial endophytes have been reported to play a crucial role in bioremediation of organic and inorganic pollutants and promoting plant growth through nutrient enhanced nutrient uptake.

Key Words: Bacterial endophytes, Bioremediation, Disease management, Horticultural crops, Prudent option

Plant pathogens have been posing serious threats for production and productivity of both field and horticultural crops. Chemocentric approaches to deal with these pathogens basically rely on a variety of chemicals. But immoderate use of such chemicals imposes a serious threat to the ecology of our living systems. Worldwide growing concern about the ill effects of chemo centric management practices and burgeoning interest on organically-grown foods have provided a strong impetus for the development of alternative means of sustainable agriculture. At this juncture exploring the plant beneficial microbes as biological control agents, have great practical implications. Rhizospheric microbes like fluorescent Pseudomonads, *Trichoderma* spp., *Bacillus subtilis etc*. are found to be successful against many pathogens of economic significance (Bora *et al.,* 2013; Barman *et al.*, 2016). Recently many microbes residing inside plants have caught researchers' attention due to their ability to suppress plant pathogens. Application of these endophytes as biocontrol agents is an emerging area of research which can potentially reduce the number of chemicals used in agricultural crops. Endophytes are the microorganisms which colonize the living plant tissue without causing any negative effect on plant (Nair and Padmavathy, 2014). Hence endophyte refers to microorganisms that live within plant tissues for all or part of their life cycles and do not cause any deleterious effect on plant's health (Saikkonen *et al.*, 2004). They are mostly dominated by bacteria, fungi and actinomycetes which can be isolated from wild or cultivated crops (Golinska *et al.*, 2015).

*Corresponding author : pbora.sonitpur10@gmail.com

[1] Junior Scientist, Department of Plant Pathology, ICAR - AICRP on Fruits, Assam Agricultural University, Jorhat; pbora.sonitpur10@gmail.com

[2] Ph.D. Scholar, kakusaikia05@gmail.com

[3] Ph.D. Scholar, hhazarika.cronos@gmail.com

[4] Junior Scientist (Nematology), ICAR-AICRP on Fruits, Bananana Research station, Kannara; gavas.ragesh@gmail.com

Plant endophytic bacteria

Wilson (1995) defined endophytic bacteria as prokaryotes that tried to colonise the xylem and phloem vessels of disease-free plants which do not cause any harm to the plant in which they reside. In recent past,

researchers defined endophytes as 'endosymbionts' which inhabit the inner parts of plant tissues and do not damage or inflict diseases which could be isolated through adherence of aseptic methods. Endophytes colonize most plant parts, *viz.* in between the spaces of the cell walls and vascular bundles of plant roots, stems, leaves, flowers, fruits, seeds *etc.* (Compant *et al.*, 2011). Mecardo-Blanco and Lugtenberg (2014) opined that endophytes population are always greater in roots than any other organs of plants. In roots, the average density is 10^5 cfu / g fresh weight, whereas average values of 10^4 and 10^3 are reported for stem and for leaf, respectively.

More than 96% of the total number of endophytic bacteria are distributed among four bacterial phyla (54% Proteobacteria, 20% Actino-bacteria, 16% Firmicutes and 6% Bacteroidetes). Most of the prokaryotic endophytes (26%) could be assigned to the Gammaproteobacteria. Endophytic Gamma-proteobacteria are largely represented by a few genera: *Pseudomonas, Enterobacter, Pantoea, Stenotrophomonas, Acinetobacter* and *Serratia*. Among gram-positive endophytes, the class Actinobacteria (20%) comprises diverse endophytes. Most of the sequences group with the genera *Streptomyces, Microbacterium, Mycobacterium, Arthrobacter* and *Curtobacterium*. The class Bacilli (15%) comprises the genera *Bacillus, Paenibacillus* and *Staphylcoccus* which have more than 100 sequences assigned to them (Hardoim *et al.,* 2015).

An important question arises as to why endophytes are present in the plant. Speculations that the endophytes could be "**influential passengers",** having some effect on plant performance, while some might simply be "**accidental tourists**", with no role on the plant (Vega *et al.,* 2008). How these bacteria enter the plant system is another important question. Numerous literature on penetration process suggests both active and passive entry of endophytic bacteria into the plants. The injury in roots or other plant parts or infection of pathogenic microbe may facilitate their entry in a passive way. James *et al.* (2001) reported the entry of *Gluconacetobacter diazotrophicus* through cracks in sugarcane. The endophytic bacteria have diversified effects and major role is in disease suppression, possible promotion of plant growth, phytoremediation, nitrogen fixation, phosphate solubilization, plant metabolism modulation and enhancement and phytohormone signaling that could open up unexplored dimensions of plant adaptation to various environmental conditions that positively or negatively impact their growth and development (Muthukumar *et al.,* 2017).

Endophytic bacteria in horticultural crops

The horticultural crops including vegetables, fruits and medicinal plants harbor endophytic bacteria and many of them have been reported to possess antimicrobial properties. Compant *et al.* (2011) reported that bacterial genera, *Pseudomonas* and *Bacillus,* have been isolated from the interior of flowers, fruits and seeds of grapevine. The *Bacillus* was also found as the predominant species in fruits, along with *Acinetobacter* and *Enterobacter* species (Shi *et al.,* 2010; Krishnan *et al.,* 2012). Fürnkranz *et al.* (2012) reported that seeds and flowers of Styrian oil pumpkin contain bacteria with antagonistic activity against pumpkin pathogens. Endophytic bacteria are associated with several medicinal plants worldwide. *Bacillus atrophaeus* and *Bacillus mojavensis* isolated from *Glycyrrhiza uralensis* (licorice) showed broad spectrum of antifungal and antibacterial activity (Mohammad *et al.,* 2018).

Disease suppression by bacterial endophytes

Endophytic microorganisms are regarded as competent agents of biocontrol, which provide an effective alternative to chemical control. Endophytic can possibly prevent deleterious effects due to toxins

Table 1. Endophytic bacteria isolated from some horticultural crops

Plant origin	Endophytic bacteria	References
Grape	*Enterobacter* sp.	West *et al.* (2010)
Canola	*Bacillus* sp., *Actinobacteria, Micrococcus* sp.	Germida *et al.* (1998)
Citrus	*Bacillus cereus, B. lentus, B. Pumilis, B. subtilis, B. megaterium*	Araujo *et al.* (2001)
Black pepper	*Bacillus* sp., *Pseudomonas* sp.	Aravind *et al.* (2009)
Onion	*Burkholderia phytofirmans*	Weilharter *et al.* (2011)
Tomato and chilli	*Bacillus* sp., *C. minutissimum, S. delphini, P. vulgaris*	Amaresan *et al.* (2012)
Banana	*Bacillus amyloliquefaciens, Bacillus subtilis subsp subtilis, B. thuringiensis*	Souza *et al.* (2014)
Chilli	*Bacillus* sp.	Amaresan *et al.* (2014)
Pistachio	*Pseudomonas protegens, Bacillus* spp., *Serratia* spp., *Pantoea* spp.	Etminani and Behrouz (2016)

produced by certain pathogenic organisms. The plant disease suppression mechanisms by endophytes include antibiosis, competition, siderophore production, lysis, HCN production, Ammonia production, *etc*.

Antibiosis : Antibiosis is a result of the production of antibiotics and various bioactive volatile organic compounds (VOCs). Antibiotics are basically microbial toxins that can poison or kill other microorganisms, at low concentrations. Most microbes as a competitive mechanism secrete one or more compounds with antibiotic activity. The effectivity of antibiotics is feasible only if sufficient quantities are produced near the pathogen, which could result in a biocontrol effect (Pal *et al.,* 2006). Many endophytes produce antibiotics which strongly inhibit the growth of plant pathogens. The endophytic bacterium, *B. amyloliquefaciens*, *B. subtilis* and *B. pumilus* can produce several antibiotics which have a high inhibitory effect to growth of *X. campestris* pv. campestris (Wulff *et al.,* 2002). Volatile bioactive compounds can include acids, alcohols, alkyl pyrones, ketones, lipids, *etc.* (Ownley and Windham, 2007). The production of 2,3-BD by endophytic bacteria *Enterobacter aerogenes* render more resistance in maize plants against Northern corn leaf blight fungus, *Setosphaeria turcica* (Alessandro *et al.,* 2014).

Competition : An active competition exists between plant pathogens and endophytes for sites of colonisation, carbon, nitrogen, and various micro-elements. The primary sites of competition are rhizosphere, phyllosphere or intercellular spaces within the plant system. Successful competition is often a matter of timing, as such, the initial colonizer emerges victorious most of the time (Ownley *et al.,* 2009). Although it is difficult to make any quantitative assessment, some indirect evidence indicates that competition between pathogens and endophytes could limit disease incidence and severity. This implies that abundant nonpathogenic soil microbes will rapidly colonize plant surfaces and utilise the available nutrients, making it difficult for pathogens to grow. Seed treatment, seedling root treatment and soil application of *Pseudomonas fluorescens* can significantly control bacterial wilt of tomato, brinjal and chilli caused by *Ralstonia solanacearum* and rhizome rot complex in ginger (Bora and Bora, 2008; Bora *et al.,* 2016) . Innerebner *et al.,* (2011) demonstrated that treatment of plant foliage with the bacterium, *Sphingomonas* sp., prevented the invasion of the bacterial pathogen, *Pseudomonas syringae*, in tomato.

Siderophore production : Several endophytes can produce siderophores, a mechanism which is highly important for their survival in Fe-deficient environments (Sessitsch *et al.,* 2004). This provides a competitive edge as chelating Fe^{3+} and competitively acquiring of ferric iron can deprive the pathogenic organisms and other competing microbes of this essential element. This ferric-siderophore complex will be unavailable to other deleterious organisms, but siderophore producing microbes can utilize this complex via specialised receptors in its outer-cell membrane (Miethke and Marahiel, 2007). This, in turn, might restrict the growth of deleterious microorganisms. Pseudobactin is an example of siderophore produced by the endophyte, *Pseudomonas fluorescens,* which can restrict the growth of *Erwinia caratovora* in the same Fe-deficient environments (Sayyed *et al.,* 2013).

Lysis : As a mode of defense and competitive specialization, many lytic enzymes are secreted by an array of microorganisms that can hydrolyze a wide variety of polymeric compounds, including cellulose, hemicelluloses, chitin, proteins and nucleic acid. In an attempt to colonise the plant surface, they produce enzymes to hydrolyze plant cell walls. An additional effect of the production of these enzymes is the suppression of activities of plant pathogen by degrading their cell walls. Many kinds of such these enzymes exist, which include chitinases, β -1,3 glucanases, and cellulases. An example is the production of extracellular lytic enzymes chitinase and β 1,3 glucanase by *Pseudomonas fluorescens* which helps in suppression of many pathogenic bacteria and fungi (Bora *et al.,* 2016).

HCN production : HCN produced by some endophytes can effectively block the cytochrome c oxidase pathway and is highly toxic to the plant pathogens. An example of such control is HCN production by *Pseudomonas fluorescens* can effectively control *Macrophomina phaseolina.* (Reetha *et al.,* 2014).

Ammonia production : Some endophytes can produce ammonia that lowers down the pH which can put a stop to the effective working of pathogen's enzymes and proteins. As such, the growth of pathogens is inhibited. Suppression of *Pythium ultimum* induced damping off of cotton by the endophyte *Enterobacter cloacae* by the production of ammonia, is a good example of this process (Heydari and Pessarakli, 2010).

Induction of host defense : Endophytes can increase the plant's ability to cope with phytopathogens by inducing resistance by activation of salicyclic acid and jasmonic acid pathway. Endophytic fungi of some genera isolated from root tissues of tomato can elicit induced systemic resistance against the tomato foliar pathogen *Septoria lycopersici* (Kavroulakis *et al.,* 2007). The first report that endophytic bacteria could elicit ISR dates back to 1991 (Wei *et al.,* 1991). ISR can be induced by some nonpathogenic rhizobacteria, is

mediated by jasmonic acid or ethylene and is not associated with the accumulation of PR proteins (Tripathi *et al.,* 2008). *Pseudomonas fluorescens* have been reported to elicit systemic resistance against Fusarium wilt of radish (Saravanan *et al.,* 2004).

Plant parasitic nematode bio suppression through endophytes

Plant parasitic nematodes (PPN), also known as "hidden enemies" of agricultural crops, cause significant plant damage and yield losses as biotrophs either by their sheer numerical strength in optimum soil environment or as specialized internal root parasites. Endophytic bacteria have shown high potential, to act as biological control agents of plant parasitic nematodes, by systemically colonizing roots and internal host tissues thus making them a valuable tool to improve crop performance. Their distinguishing and amenable characteristics, *viz*. easiness to culture *in vitro*, to be applied as seed treatments, reduction of initial root damage, escaping microbial competition and capability to influence host's response to pathogen attack coupled with zero production of any phytotoxic symptoms but promoting plant growth and dependence on root exudates for multiplication makes them ideal candidate against biotrophs especially PPN (Siddiqui and Shaukat, 2003).

The biocontrol potential of endophytic bacteria for the management of PPN is highly evident in their ability to colonize the same root tissues as sedentary plant-parasitic nematodes like root-knot nematodes (*Meloidogyne* spp.) in vegetables and cyst nematodes in comparison to migratory endoparasites. This is made possible by the association of endophytic bacteria with sedentary endoparasitic nematodes throughout their life cycle within the root. Four selected endophytic bacteria, *viz*. *Pantoea agglomerans* MK-29, *Cedecea davisae* MK-30, *Enterobacter* spp. MK-42 and *Pseudomonas putida* MT-19 significantly reduced early root penetration of *Meloidogyne* juveniles into tomato roots up to 56%, when applied as a root dipping and soil drench. Seed treatment of these endophytic bacteria followed by soil drench application apparently gave a higher reduction in number of galls than single application. (Munif *et al.,* 2013). Similarly, *Pseudomonas aeruginosa* strain IE-6 and its streptomycin- resistant derivative IE-6S+ colonized inner root tissues of tomato and significantly reduced *Meloidogyne javanica* population densities under glasshouse and field conditions (Siddiqui, and Shaukat, 2003).

Future prospects

Endophytes have been proved to be a boon and have a good impact on plants, environment, and also human being in several possible ways. The exploitation of endophyte-plant interactions can result in enhancing plant growth, management of many plant diseases and pests, thereby reducing the number of chemicals used in agriculture. However, a deeper understanding of tritrophic interaction, *i.e.* between host, endophyte and environment needs in-depth study. Studies on role of bacterial endophytes against insect pests also needs further attention. The hidden potential of endophytic bacteria in possible bioremediation, biocontrol, their compatibility study with established BCAs are some other issues to be addressed to develop a effective delivery mechanism that will not only help in disease management but also help in bioremediation.

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Effect of fruit thinning on nut characteristics and leaf mineral nutrient concentration in walnut *(Juglans regia)* cv. Xiangling

Yong-Jie Xu[1*], Qi-Zhu Wang[2], Xian-Zhen Deng[1] and Hua Wang[3]

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Hubei Academy of Forestry, Wuhan, Hubei 430 075, China

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ABSTRACT

The experiment was conducted to find out the effect of fruit thinning in walnut (*Juglans regia* L.) ₹ final nut number, nut weight, kernel rate, nuts mineral nutrients concentration and mineral nutrients concentration within leaves during growing season of 2014 and 2015 at Baoking in Hubai, China. The fruit thinning affected nut uniformity more than final nut number, weight and kernel rate. Fruit thinning showed non-significant effect on macro nutrient (N, P and K) concentrations within kernel, but had significant effect on micronutrient (Fe, Zn and B) concentration. With more fruits been retained, N, K, Fe, B and Zn concentrations within leaves increased significantly during the fruit developing. Thus, fruit thinning management for early-bearing commercial orchard could obtain more commercially valuable nuts and reduce mineral nutrients consuming.

Key Words: Concentrations, Fruit thinning, Leaf mineral nutrient, Nut characteristics

Walnut (*Juglans regia* L.) is most popular nut grown in the world, due to its rich nutrition (Chen *et al.*, 2014). It is widely cultivated in 22 provinces in China. Studies in the past showed that fruit thinning was necessary to obtain high quality fruits (Wertheim, 2000). Thinning fruitlets at petal fall stage affected fruit and vegetative growth in peach (Blanco *et al.*,1995), fruit size, and return bloom in apple (Oummaand Matta, 2002), and macronutrient content in pistachio trees (Baninasab *et al.*, 2007). Whether or not fruit thinning affects nut characteristics have not been reported. In walnut, mineral nutrients concentration in leaves, flowers and fruits varies during different growth seasons (Drossopoulos *et al.*, 1996a; Drossopoulos *et al.*, 1996b; Drossopoulos *et al.*, 1996c; Hu *et al.*, 2011). Presumably, fruit thinning may affect variation of mineral nutrient concentration within leaves and kernels. However, such work has not been done so far. Therefore, an experiment was conducted on Xiangling walnut, one of Chinese early-bearing varieties, is widely cultivated in China. After grafted, its primary fruit stage is at 3 years, while full productive stage at 7 years.

* Corresponding author : 498674563@qq.com

[1] Hubei Academy of Forestry, Wuhan, Hubei 430 075, China

[2] Baokang County Center of Walnut Technology, Xiangyang, Hubei 441 600, China

[3] Key Laboratory of Horticultural Plant Biology, Ministry of Education, College of Horticulture and Forestry Sciences, Huazhong Agricultural University, Wuhan, Hubei 430 070, China.

MATERIALS AND METHODS

Sample trees were collected from a block of 7-year-old walnut cv. Xiangling grafted on *Juglans regia* L. root-stock in a commercial orchard (31°31'N and 110°50'E) in Baokang, Hubei province, China, during 2014-15. Trees were spaced 6 m and 7 m apart within and between the rows respectively. All sample trees were managed in the same soil management within two years. Chemical characteristics of orchard soil in 2014 were shown in Table 1. Trunk diameter at foot (30 cm off the ground) was measured before treatments (Table 2).

After flower full bloom in 2014 and 2015, 12 healthy trees with similar flower densities were selected from the orchard block. The following fruitlets thinning treatments were applied on individual trees 30 days after flower full-blooming (18 May, 2014 and 20 May, 2015).

Level-I: No fruitlet retained on each tree;

Level-II: 200 fruitlets retained on each tree;

Level-III: 400 fruitlets retained on each tree;

Table 1. Some chemical characteristics of soil

Soil depth (cm)	Macro nutrent concentration (g/kg)			Macro nutrent concentration (g/kg)		
	N	P	K	Fe	B	Zn
0-60	49.68	11.9	68.4	4.73	0.29	1.07

Level-IV: 600 fruitlets retained on each tree;

CK: No fruit thinning treatment.

Leaves were sampled every 30 days after flowers full-blooming until leaves fall period. Nuts were harvested on 28 August during 2014 and 1 September during 2015, 130 and 133 days after flower full-blooming respectively. Twenty mature leaves per tree were randomly sampled from crown periphery. All leaves were placed in plastic bags and kept in a large ice box until they were brought to the laboratory, and then washed in a weak detergent solution, rinsed in tap water several times, given a final rinse in distilled water, dried at 60°C for 48 h in a forced-air oven, and ground to pass a 40-mesh sieve for nutrient analyses.

During harvesting season, number of nuts was counted to obtain nuts retained rate. Thirty dried nuts from the same treated trees were randomly collected to assess average nut weight and kernel rate using balance scale (0.01 g). Unshelled nut samples (200 g) removed randomly were dried to constant weight and rapidly grounded into a fine powder to pass the same sieve as that of leaves treatment.

All samples were analyzed for N, P, K, Fe, B and Zn levels. Total N in samples was determined by modified macro-Kjeldahl digestion with the addition of salicylic acid (Weinbaum and Neumann, 1977). To determine other elements, a sub sample was ashed in a muffle furnace at 200°C for 2 h and then at 500°C for an additional 12 h. Ashed samples were dissolved in 0.1 N HNO_3 and then analyzed. The amount of P was determined colorimetrically using blue phospho-molybdate complex at 660 nm and ammonium molybdate and stannous chloride procedure (Oumma and Matta, 2002). Potassium was determined using a flame photometer (Jenway, PFP7). Atomic absorption spectrometry (ZEEnit®700P) was used to determine Fe, B and Zn. Mineral element concentrations were expressed on a dry weight basis.

Since non-significant differences were found within two years, data from both years were pooled together and presented. The experiment was designed with three replications every year. The data were subjected to SAS 8.1 with one-way ANOVA, and the means were compared using the least significant difference (LSD) test at $P<0.05$.

RESULTS AND DISCUSSION

The diameter at foot of treated trees has no significant difference (Table 2), final nut number increased with reduction of fruit thinning strength. Nut retained rate and nut weight were just the opposite. In CK treatment, final nut number was 262.45 nuts per tree, nut retained rate was 31.76%, the weight was 10.08 g per nut. The former was larger, and last two were less than other three level treatments. But there were no significant differences among four level treatments because of internal instability. Previous reports show that fruit trees have fruiting adjustment capacity by varying fruits number early in growing season (Rowe and Johnson,1992; Blanco,1995) or fruit size (Oumma and Matta, 2002). We also observed this capacity of walnut trees. Moreover, fruit thinning can affect nut uniformity more than number. The kernel rate ranged between 51.54%~52.92% in four treatments. The non-significant differences were observed among four level treatments showing that kernel rate is a relatively stable characteristic of a variety, which is not easily affected by human disturbance.

With increment of retained fruits, macro nutrients (N, P, K) concentrations within kernel from treated trees decreased. In spite of this, there were non-significant differences among fruit thinning levels

Table 2. Effects of different thinning levels on nut characteristics

Fruiting characteristic	Level-I#	Level-II#	Level-III#	Level-IV#	CK#
Diameter at foot	12.57±0.32 a	12.47±0.60 a	13.10±0.26 a	12.37±0.15 a	12.68±0.41 a
Final nut number	--	118.80±25.20 a	202.80±50.78 a	248.80±106.25 a	262.45±152.15 a
Nut retained rate (%)	--	59.40±12.60 a	50.70±12.70 a	41.47±17.71a	31.76±27.71 a
Nut weight (g)	--	10.95±0.08 a	10.80±0.11 a	10.72±0.52 a	10.08±0.84 a
Kernel rate (%)	--	52.87±2.57 a	51.54±4.25 a	52.92±3.41 a	52.38±4.15 a

Table 3. Different thinning levels on mineral nutrient concentrations within kernel

Mineral concentration	Level-I	Level-II	Level-III	Level-IV	CK
N ($g \cdot kg^{-1}$)	--	34.60±3.10 a	31.40±1.60 a	28.61±4.00 a	27.53±5.00 a
P ($g \cdot kg^{-1}$)	--	5.40±0.60 a	5.40±0.56 a	5.36±0.90 a	5.00±0.86 a
K ($g \cdot kg^{-1}$)	--	4.00±0.40 a	3.80±0.30 a	3.65±0.76 a	3.48±0.84 a
Fe ($mg \cdot kg^{-1}$)	--	42.18±2.13 a	40.66±1.64 a	32.80±0.96 b	27.00±0.29 c
Zn ($mg \cdot kg^{-1}$)	--	29.60±1.89 a	29.10±1.15 a	27.42±1.25 ab	26.90±1.14 b
B ($mg \cdot kg^{-1}$)	--	14.87±1.16 a	14.10±1.07 a	11.60±0.86 b	8.37±0.42 c

(Table 3). The result is different from that of previous studies on apples which compete for nutrients among fruits from crop loads (Blanco *et al.*, 1995). The possible reasons may be that accumulative process of nut nutrients concentrations is different from that of fruits. As a special case for stone fruit, nutrients in walnut trees have at least twice adjustment during fruit development. Except for first adjustment that sperm and pericarp tissues competing for nutrients during fruit growth as fruit (Chalmers and Ende, 1977), exo- and meso-carp fruit tissues turn dry, resulting in the nutrients transferring to nut with the fruit maturing approach (Drossopoulos *et al.*, 1996b). So, second adjustment may balance macro nutrient (N, P, K) concentrations within kernel.

There was a similar tendency showing micro nutrient (Fe, Zn, B) concentrations within kernel. There were significant effects on micro nutrient (Fe, Zn, B) concentrations ($P<0.05$). It was similar with Baninasab *et al.* (2007) reported. It means that compared with macro nutrient (N, P, K) concentrations within kernel, micro nutrients (Fe, Zn, B) concentrations within kernel were easily affected by fruit thinning treatment.

Seasonal dynamics of macro-mineral nutrients concentration was within leaves (Fig. 1). Sample time has a significant effect on N concentration within leaves. All measured N exhibited a decrease with sample time. This is in agreement with those reports of other tree species (Volz and Ferguson, 1999; Nachtigall and Dechen, 2006). It is generally acknowledged that N concentration decrease observed in leaves during growing season can be related to a dilution effect occurring with leaf growth. Also, fruit thinning treatment was found to have an effect on the N concentration of leaves.

A significant interaction was found between sampling time and fruit thinning. In fruit growth period, N concentration in leaves from treated trees with more fruits was higher than that with less fruits. But after maturation stage, N concentration in leaves from treated trees with more fruits decreased more dramatically. Previous reports show that concentration of nutrients in leaves appears to be a strong association

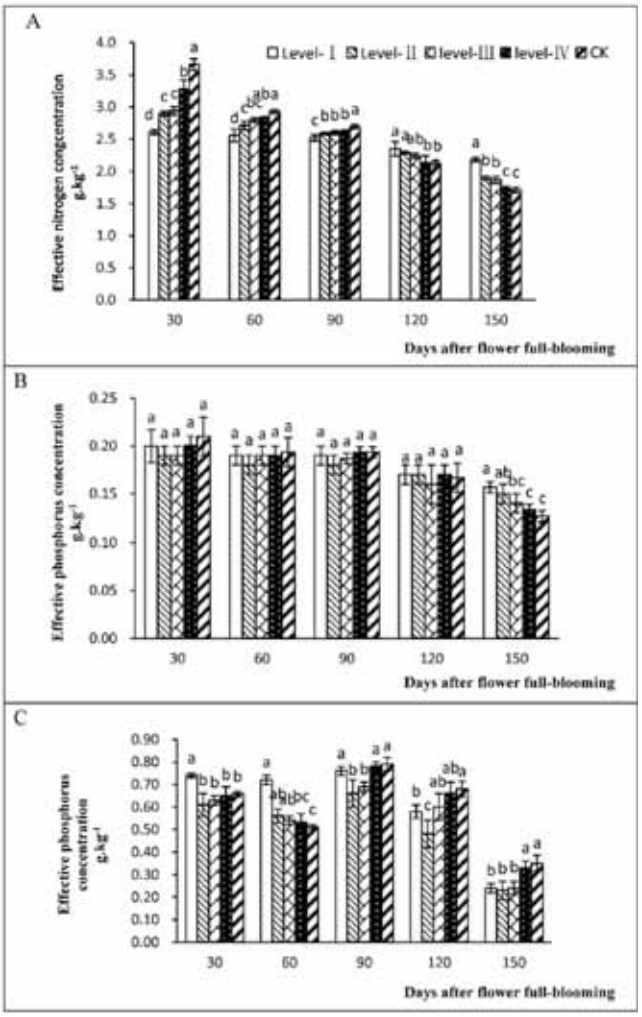

Fig. 1. Seasonal dynamics of macro-nutrient concentration in leaves

with levels of crop load (Avery, 1970; Williamson and Coston, 1989) and nutrient uptake efficiency from soil by root (Taylor, 1967). It means that trees with more fruits may stimulate N absorption and increase its concentration within leaves, and then lead to more nutrient consumption in soil.

The concentration of P within leaves from treated trees slightly declined during fruit growth period (Fig.

1B). It was in agreement with previous reports (Drossopoulos *et al.,* 1996a; Fernandez-Escobar *et al.,* 1999) in which concentration of P in leaves decreased throughout fruit growing season. And there was no significant effect of fruit thinning treatment on P concentration during 30~120 days after flower full-blooming. Previous studies have also shown that the concentration of P in leaves in peach trees was not affected by crop load (Blanco, 1995). However, after maturation stage, concentration of P in leaves from treated trees with more fruits retained dropped more sharply than those with less fruits retained. Significant differences among five treatments imply that a second extensive redistribution of nutrients and carbohydrates takes place from the leaves senescing of deciduous trees before leaf fall period which has been adopted for deciduous trees (Suzuki and Kohmo, 1983; Smith *et al.,* 1987; Loescher *et al.,* 1990).

The concentration of K in leaves from treated trees had twice fluctuations till fruits maturation (Fig. 1C). Its concentration decreased during 30~60 days after full-blooming may be partly attributed to a dilution effect resulting from leaf maturing and fruit swelling growth, which was similar to that Baninasab *et al.* (2007) K concentration in leaves from treated trees with fruits retained were lower than that with no fruit retained during 30~60 days after flower full-blooming, which was similar to previous studies reported (Baninasab *et al.,* 2007; Volz and Ferguson, 1999). Conversely, an increase in the K concentration of the leaves on the sampling data of 90 days after flower full-blooming indicated that the rate of K accumulation exceeds the rate of dry matter accumulation in leaves accumulates (Picchioni, *et al.,* 1997; Zeng *et al.,* 2001). From 90 days after full-blooming, concentration of K in leaves from treated trees with more fruits retained declined slowly. It imply that K played an important role during the fruit maturation, which confirms previous studies (Zhang *et al.,* 2001).

The seasonal dynamics of micro-mineral nutrients (Fe, B, Zn) within leaves presented arise first and then a drop (Fig. 2). It is in agreement with the patterns previously reported for other deciduous fruit trees (Leece and Gilmour, 1974; Smith *et al.,* 1987). The peak of Fe, B, Zn concentration appeared on the date of 90, 120, 60 days after flower full-blooming respectively. The B (Fig. 2B) and Zn (Fig. 2C) concentration within leaves from treated trees with more fruits retained were higher. It implies that except for plants transpiring more fruits retained may promote root absorption (Raven, 1980). Different from B and Zn, Fe concentrations within leaves from treated trees with more fruits was lower, as Fe is an important part of the shells (Pei and Lu, 2011), presumably more Fe would

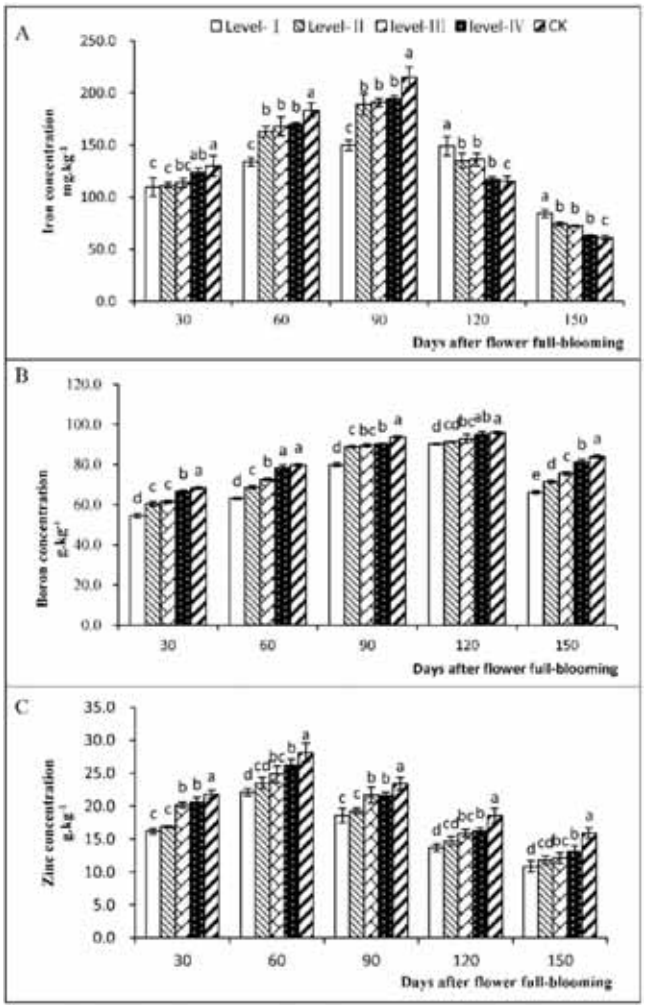

Fig. 2: Graphical representation of trend line of production and area

be needed by more fruits retained to transfer to nuts from leaves.

CONCLUSIONS

The artificial fruit thinning can affect nut uniformity more than final nut number, weight and kernel rate. It has non-significant effect on macro nutrient (N, P, K) concentrations within kernels. But with the increment of retained fruits, micronutrients (Fe, Zn, B) of leaves from thinned trees decrease significantly. Comparatively, fruit thinning treatments have obvious effect on mineral nutrient concentration in leaves during growth season. With more fruits retained on trees, concentration of N, K, Fe, B, Zn in leaves from them increase significantly during fruits development, which means that more mineral nutrients have been consumed with more fruits retained. In order to obtain more commercial nuts with competitive ability, it is necessary to carry out fruit thinning management for early-bearing commercial orchard according to the trees size

and nutritional status of the orchard.

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Standardization of tree architectural techniques for higher apple productivity on dwarfing rootstock

K K Srivastava[1], Dinesh Kumar[2] and S R Singh[3]

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ICAR-Central Institute of Temperate Horticulture, Old Air Field, Rangreth, Srinagar 190 007, (J&K), India

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ABSTRACT

There was a significant and positive correlation between yield and Trunk cross Sectional Area (TCSA). Consistently high productivity (16.7, 52.29, 96.05, 102.35 and 61.84 t/ha) with medium-sized and large number of fruits were recorded in Coe Red Fuji, and minimum (6.0, 30.72, 22.28, 86.45 and 58.01 t/ha) in Spartan during 2011-13. The TCSA is reliable criteria to estimate tree vigor, crop load and yield efficiency, maximum TCSA (25.99, 27.90, 33.31, 37.02 and 38.83) over the years were noted in Coe Red Fuji. The TCSA has positive correlation with fruit weight and yield efficiency. Maximum mean yield efficiency (1.11 kg/cm^2) was recorded in Granny Smith. High chroma (color intensity) observed in all varieties on espalier architecture.

Key Words: Architectural techniques, Espalier, Granny Smith, Coe- Red Fuji, Trunk cross sectional area, Yield efficiency.

Apple (*Malus domestica* Borkh) an important fruit, occupies more than 70% area and 60% production of the total temperate fruits in India. The productivity is a production function of rootstock, planting density, plant architectural techniques and variety in addition to orchard and floor management. With the advancement in knowledge on orchard engineering and science of rootstock and scion, modern days planting initiated on higher tree densities ranging from 1000 to 10,000 trees/ha (Robinson, 2003). Dwarfing and semi-dwarf rootstocks have become widely acceptable by apple industry as effective tools to increase orchard efficiency (Barritt *et al.*, 1995). Smaller and compact trees are more efficiently intercepting the solar energy (Green *et al.*, 2003). High and early productivity in HDP is partly based on their more leaf area/ha, resulting in more light interception of photosynthetically active radiations (PAR) (Jackson, 1989). Tree height and canopy shape also affect the light interception, penetration and distribution into the canopy. High yield and quality depends on light conditions, which can be further improved through designing the appropriate canopy shape (Ugolik, 1994; Buler *et al.*, 1999; Gruca, 2001; Buler and Mika, 2004). High-density orchards have different canopy architecture practiced all over world; however, the most common is the spindle form (Mika, 1984; Buler and Mika, 2004). Plant architecture with angled canopies have demonstrated better light relations and productivity than slender spindle on constant rootstock and spacing (Hampson *et al.*, 2002; Robinson 1997; 2000), tall trees have potential to intercept more light and yield than short statured tree at same spacing (Barrit, 2000; Callesen, 1993; Palmer 1989; Wertheim *et al.* 2001). TCSA at the HDP was 20% less than that of low density (Hampson *et al.*, 2004), the tree size is generally expressed in trunk cross sectional area (TCSA), it is the most common and reliable factor to determine tree size and tree potential to produce fruit (Jimenez and Diaz 2004, Wright *et al.* (2006) and yield efficiency indicates the real potential of tree yield irrespective of the tree size. Annual extension growth exhibited the state of tree health; it is not affected by the training system (Hampson *et al.*, 2004). The fruit weight, yield and fruit color depends on light interception, plant architecture, cultivars, density and rectangularity of planting, a square layout (1:1) is the most favorable for light interception and distribution (Wagenmakers, 1991; Wagenmakers and Callesen, 1995), but it cannot accommodate higher tree density per unit area if

*Corresponding author : kanchanpom@gmail.com

[1,2,3] Principal Scientist, ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Kakori, Lucknow, UP 227 101

machinery alleys are needed, hence, commercial plantings use a rectangular layout. Rectangularity affects both light interception, and distribution which influence the yield, tree size, alternate bearing, flowering density and fruit color in apple (Callesen and Wagenmakers, 1989; Cripps *et al.*, 1975). The HDP in apple being practised with no definite canopy form, thus in order to harvest the potential productivity of apple, the experiments were initiated to standardize the ideal variety and efficient plant architectural techniques on dwarfing rootstock under HDP.

MATERIALS AND METHODS

The experiment was conducted during 2011-2013 on 3-year-old trees at Srinagar, located at 34°, 45' N latitude and of 74°, 50'E longitude and 1640 m asl, assured irrigation facility, receives average maximum and minimum temperature 19.63°C and 6.52° C respectively with rainfall 60.72 cm annually. The experiments were conducted in two sets, first involved three cultivars; Co-Red Fuji (V1), Granny Smith (V2), Spartan (V3), grafted on M.9 rootstock, planted at 1.5m among row and 3.0 m among trees and were trained on espalier architecture (EA). EA had 10 scaffold branches (5 scaffolds on each side) are trained on five-tier galvanized wires, were fixed on the iron angle of 1.5 m height.

First wire was fitted at 45 cm from ground level and rest 4 wires at 30 cm interval, the angles were fixed at 8 m distance. The experiment was laid out in complete randomized block design with six replications and 2 plants / replication, replicated thrice, with two plants / replication. Uniform cultural practices were applied in all the trees. Each year the trunk diameters of each variety were measured 15 cm above the graft union. The trunk cross sectional area was calculated by using standard formulae (TCSA=Girth^2 / 4π). For fruit weight, 15 fruits were randomly harvested at maturity, weighted using digital electronic balance and fruit yield was calculated as total weight of fruit per unit TCSA (kg / cm^2 of TCSA) at the time of harvesting. The color was recorded using the head 15 mm in diameter of the Hunter colour lab, it was calibrated using the manufacturers' standard white tile and were expressed in L*, a* and b*. The color intensity (chroma) was worked out using formula $(a^2+b^2)^{1/2}$). The data were analyzed statistically as per procedure given Sheoran *et al.* (1998), and are being presented in the table for interpretation of the results.

RESULTS AND DISCUSSION

Annual extension growth is indicator of tree vigour, during the 5 evaluation years, difference in AEG among varieties were present. Throughout test period Granny

Table 1. Varietal effect on annual extension growth under espalier architecture

Variety	Annual extension growth (cm)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	106.67	113.66	116.89	121.0	127.17	
Granny Smith	139.66	142.50	145.50	148.17	152.33	
Spartan	97.67	105.87	111.17	118.67	121.83	
r with TCSA*	-0.368	-0.053	-0.325	-0.025	-0.035	
CV (%)	8.90	8.91	7.10	6.15	6.17	-
LSD (p= 0.05)	13.31	16.95	10.75	9.73	10.75	-

*r = Correlation matrix (p=0.05)

Table 2. Effect of varieties on fruit weight under espalier architecture

Variety	Fruit weight (g)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	154.71	163.03	148.47	155.67	182.53	159.98
Granny Smith	176.14	172.76	160.58	208.28	207.68	184.09
Spartan	86.28	125.67	94.62	166.97	171.86	128.68
r with yield efficiency	0.933	0.988	0.919	0.985	0.602	0.950
CV (%)	3.0	2.41	4.90	1.92	2.50	1.50
LSD (p= 0.05)	4.87	4.38	7.71	4.00	4.82	2.73

*r = Correlation matrix (p=0.05)

Smith showed the greatest variation in AEG, 139.66 cm (2010), 149.50 cm (2011), 137.17 cm (2013) and 157.33 cm (2014) whereas it was minimum in Spartan, 97.67 cm (2010), 115.87 cm (2011), 100.17 cm (2012) 102.67 cm (2013) and 115.83 cm (2014) (Table 1). Similar trend in fruit weight with respect to variety was recorded. Granny Smith exhibited maximum fruit weight throughout 176.14g (2010), 172.76g (2011), 160.58g (2012), 208.28g (2013) and 177.68g (2014) per fruit were recorded in Granny Smith variety. Smaller fruit weight recorded in Spartan, 86.28g (2010), 125.67g (2011), 94.62g (2012), 166.97g (2013) and 159.86g (2014) (Table 2). A strong and positive correlation (0.990) was observed between mean fruit weight and mean TCSA and between fruit weight and yield efficiency, over the years. Yield per tree was also influenced by the cultivars under espalier architecture significantly maximum yield 7.52 (2010), 26.09 (2011), 46.26 (2012), 46.22 (2013) and 24.18 (2014) kg / tree recorded in Coe red Fuji over the years, whereas minimum was noted in Spartan 2.70 (2010), 13.50 (2011), 10.72 (2012), 38.40 (2013) and 14.90 (2014) kg / tree. Significant and positive correlation coefficient observed between yield and TCSA (Table 3).

Since, apple on dwarfing rootstock caused precocity hence, good bearing starts 2nd year after planting. Similar trend in yield was noted the variety which has high yield / tree have high yield per hectare also. Coe Red Fuji has tendency to bear more fruits / tree of medium sized in turn had maximum productivity / ha (16.7(2010), 52.29(2011), 96.05(2012), 102.35(2013) and 61.84 (2014) t / ha, while Spartan has comparatively low productivity over the years, 6.0(2010), 30.72 (2011), 22.28 (2012), 86.45 (2013) and 58.01 (2014) t / ha (Fig. 1). TCSA is reliable procedure which is used to estimate tree vigor, crop load and yield efficiency, in apple where the per tree yield varied plant to plant in such circumstance the TCSA is a reliable tool to measure tree yield potential. Maximum TCSA was noted in Coe Red Fuji over the years, 25.99 (2010), 27.90(2011), 33.31 (2012), 37.02 (2013) and 38.83 (2014) where as it was at par in Granny Smith

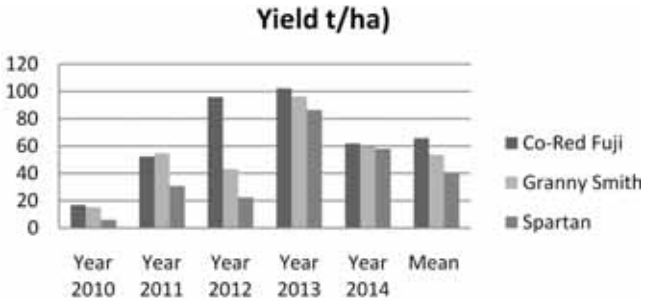

Fig. 1. Yield of apple varieties under espalier architecture.

Table 3. Effect of apple varieties on yield under espalier architecture

Variety	Yield (kg / tree)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	7.52	26.09	43.26	46.22	24.18	29.45
Granny Smith	6.80	22.83	20.19	43.91	15.67	21.88
Spartan	2.70	13.50	10.72	38.40	14.90	16.04
r with TCSA	0.782	0.643	0.875	0.638	0.977	0.870
CV (%)	5.18	12.87	9.1	5.08	12.16	4.25
LSD (p= 0.05)	1.20	3.15	2.70	2.60	2.61	1.30

*r = Correlation matrix (p=0.05)

Table 4. Trunk cross sectional area (TCSA) of apple varieties under espalier architecture

Variety	TCSA (cm^2)					
	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	25.99	27.90	33.31	37.02	40.83	33.01
Granny Smith	17.54	19.87	21.70	24.97	28.13	22.44
Spartan	17.22	19.49	22.03	25.97	28.93	22.72
r with fruit weight	0.321	0.246	0.135	0.552	0.392	0.990
r with yield efficiency	0.639	0.592	0.511	0.385	0.956	0.638
CV (%)	14.47	9.20	8.5	9.90	4.67	2.5
LSD (p= 0.05)	3.45	2.4	2.47	3.2	1.8	0.75

*r = Correlation matrix (p=0.05)

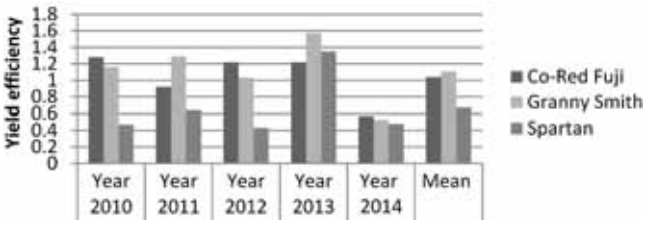

Fig. 2. Yield efficiency of apple under espalier architecture

and Spartan varieties (Table 4). Correlation matrix showed that TCSA has positive correlation with fruit weight and yield efficiency (Fig. 2). Yield efficiency permits comparisons among the trees of varying sizes and used as reliable criteria to estimate yield potential of different varieties grown under different spacing. Maximum mean yield efficiency (1.11 kg / cm^2) recorded in Granny Smith followed by Coe Red Fuji (1.04 kg / cm^2) where as minimum recorded in Spartan (0.67 kg / cm^2). Chroma values were worked out to show the quality of color purity (intensity) all the studied varieties exhibited high color intensity as per their genetic constituents, so no considerable variations were observed on chroma values among the studied varieties over the years (Table 5).

The Scion growth is such variable, which is not affected by tree architecture as it is innate property of the cultivars. Similarity in scion growth was reported by Hampson *et al.* (2004), who observed that the scion growth was affected by genetic constituents of cultivars not by training systems. The Coe Red Fuji have prolific bearing habit, fruits are medium in size with large number of fruits per tree (4-5 thousand) on single tree after 3 years, these results are in agreement with Srivastava *et al.* (2015) who reported high yields in Coe Red fuji, Granny Smith and Spartan on espalier architecture. Fruit weight was also related to yield; it decreased with yield independent of planting density (Costa *et al.*, 1997). The TCSA of the tree was positively correlated with the transporting and distribution of the photosynthates from source to sink, which ultimately affects the vegetative growth and fruit yield (Hartmann and Kester, 2002), the productivity efficiency of the tree increased with increased in TCSA.

Similar growth pattern in TCSA with yield and TCSA with AEG were reported by Dalal and Barar (2012) in Kinnow Mandarin, Dhaliwal and Dhillon (2003) in guava, Kumar *et al.* (2010) in Banana. In general fruit weight is positively correlated with tree density, high tree density, and low fruit weight. In espalier, vertical axis and cordon plant architecture, initially no clear cut trend in fruit weight observed because of negligible competition among fruit-lets for photo-synthates, space, and light energy. Similarly, Palmer *et al.* (1997) reported that fruit weight was greatest when there were minimum competition between fruits. The yield per tree showed increasing trend, since the observations were taken 3 years after planting, the trend may change with the age of the trees.

The plant architecture determined the tree shape, but not overall tree size (Hampson *et al.*, 2004). Further, horizontal growing shoots have lower auxin content as compared to upright shoots (Kato and Ito, 1962). Luckwill (1968) reported that the supply of nutrient to the apex is controlled by auxin in top meristem. Srivastava *et al.* (2008) also reported that at 60 and 900 angle branch in Conian Itly apricot, minimum growth in shoot diameter were observed. Granny Smith being green colored variety have chroma value at par. The Granny Smith variety color was very intense and pure however, Costa *et. al.* (1997) reported decrease in chroma values with tree density in Braeburn apple.

Yield efficiency is reliable parameter for estimating the yield potential of varying tree size, AEG have positive correlation with yield efficiency, it may be due to more vegetative growth, more production of photosynthates resulting high partitioning of photo-assimilates to developing fruits thus increased yield efficiency. Similarly Srivastava *et al.* (2008) recorded maximum yield in apricot tree branched at 60° angle. Maximum color intensity (chroma) recorded in T2 architecture, it may be due to the maximum exposed leaves to the solar radiations which results, more

Table 5. Chroma value of apple on espalier architecture

Treatment	Year 2010	Year 2011	Year 2012	Year 2013	Year 2014	Mean
Co-Red Fuji	26.53	27.14	26.35	25.67	29.68	27.07
Granny Smith	23.27	28.47	28.37	26.70	27.70	26.90
Spartan	25.25	25.71	25.71	28.00	27.85	26.50
r with AEG	-0.822	0.853	-0.014	-0.660	-0.185	0.760
CV (%)	9.07	1.90	10.16	11.53	8.20	5.80
LSD (p= 0.05)	NS	1.33	NS	NS	NS	NS

*r = Correlation matrix (p=0.05)

carbohydrate production, increased sugar content in fruits helps in the development of color intensity (Chadha, 2001).

The Coe Red Fuji and Granny Smith performed best on espalier architecture, though the initial cost for erection of training structure was high. The AEG was an indicator of tree vigour, cultivar Granny Smith exhibited high growth and fruit weight but the overall productivity was recorded high in Coe red Fuji on espalier architecture. The TCSA showed positive correlation with fruit weight, yield efficiency and yield (kg / tree).

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Evaluation of gladiolus *(Gladiolus grandiflora)* genotypes for morphological diversity and corm yield

Kishan Swaroop, Kanwar P. Singh and Prabhat Kumar

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Division of Floriculture and Landscaping
ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

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ABSTRACT

An experiment was conducted to evaluate 37 genotypes of gladiolus for their morphological genetic variation for improvement at the Research Farm of Division of Floriculture and Landscaping, ICAR-Indian Agricultural Research Institute, New Delhi, during 2016-17. There was morphological genetic variability in different cultivars for their different flowering traits. The cultivars, Punjab Glad-2, Praha, Vink's Glory and Punjab Glance, showed earliness, whereas Malviya Kundan, Malviya Kiran, True Love, Ocilla and Yellow Star were late in flowering. The maximum plant height (122.00, 119.66, 117.66, 114.33 and 113.33 cm) were recorded in Nauvalux, Tiger Flam, Malviya Kiran, Arka Tilak and GS-2 cultivars respectively. The spike and rachis length were also maximum by these cultivars. More number of florets / spike (19.33, 18.33, 17.66 and 17.33) was recorded in Punjab Pink Elegance, Arka Ayush, C.P.G, Tiger Flam and Lady John respectively. All genotypes had a vast morphological genetic diversity.

Key Words: Morphological diversity, florets, Corm traits, Genotypes, Variability, Plant height, Flowering.

Gladiolus (*Gladiolus grandiflora* L.) is an important bulbous flower grown throughout the world. It is used on interior decoration as well as making high quality bouquet (Lepcha *et al.,* 2007). It is one of the most popular landscape plant and cut flower both in domestic and international flower industry (Mehra *et al.,* 2016). There are excellent varieties of gladiolus with magnificant inflorescence in exhausting range of colours different shades varying number of florets arrangement of florets spike length post harvest life and adaptability to different seasons (Kumar *et al.*, 2013). The highly decorative and attractive spikes are predominantly used for cut flowers (Gupta *et al.*, 2013). Most of the cultivars were introduced from abroad like U.S.A, Holland, U.K., Canada, Russia, Australia, Poland, Japan, New Zealand and France. But, initially, American breed gladiolus was very popular across the world. Every year, there is an addition of new varieties (Kumar and Yadav 2005). Multiplication of planting material of gladiolus is most important, because the cut flower trade of gladiolus is lagging behind over the recent years, owing to the unavailability of sufficient quality planting material at large scale (Barman *et al.*, 2005). As a result, cultivars, which perform well in one region, may not perform same in other regions of varying climatic conditions (Kamble *et al.* 2004). It is also important to evaluate exotic genotypes with the existing cultivar for their superior desirable characters (Archana *et al.* 2008). Hence, it becomes very much necessary to study the morphological genetic variation and evaluation of genotypes and also to identify the suitable germplasm for further improvement programme. Genetic variability or divergence existing in the population will help in selecting suitable parents for hybridization programme according to climate change.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of Division of Floriculture and Landscaping, at the Indian Agricultural Research Institute, New Delhi, during 2016-17. The planting material consisting of exotic and Indian varieties, Yellow Star (yellow), Punjab Morning, Nauvalux (yellow), Fire Flam, Lady John, Arka Tilak, Arka Ayush (orange), Arka Sapna (white), Arka Nazrana (red), Kalima (red), Roshni (pink striped), Amethyst (blue), Neelima (purple), Pink Lady, GS-2 (yellow), Limon Cello (red), Ocilla (yellow), Malviya Kiran (white), Algarve (Light red), Malviya Shatabdi, Malviya Kundan (yellowish orange), Fedelia

(purple), Necola (orange red), True Love (pink), Aldebaran (yellow, red spot), Tiger Flam (orange), Victor (yellow), C.P.G., Punjab Pink Elegance (yellow), Punjab Lemon Delight, J.V.G. (yellow), Punjab Glad-1, Anglia, Punjab Glance, Punjab Glad-2, Praha, Vink's Glorind Pusa Kiran (control) were evaluated to study the morphological genetic diversity and to identify suitable genotypes for various traits and further improvement programme. The evaluation trial was laid out in a randomized block design with three replications. Uniform size of each genotype was planted during October. The experiment was planted at a spacing of 50 cm × 15 cm at 6-8 cm depth in a plot size of 5.00 m × 3.00 m. Irrigation was given immediately after planting.

The fertilizer dose was given according to need of the crop at appropriate time. Plots were kept weed free by hand weeding. Adequate soil moisture was maintained in the soil by giving regular irrigation from time to time. Disease control measures were taken up by spraying fungicides, Bavistin, Captan or M-45 whenever necessary throughout the experiment to grow a healthy crop. Other cultural practices were followed as and when required. Five plants were selected for taking observations in each genotype and replication which were recorded on various growth and flowering characters, *viz.* plant height, spike length, rachis length, number days taken to first floret opening, number of florets per spike, and number of corms per plant. Data were recorded at appropriate time after planting and analyzed statistically as suggested by Panse and Sukhatme (1965).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences among all the characters studied, indicating considerable amount of morphological variability in gladiolus cultivars and the mean performance indicated significantly for days to flowering, plant height, spike length, rachis length and corm parameters. The data pertaining to these characters is presented in the Table 1. Among different genotypes studied and found vast morphological diversity among them. Out of all cultivars evaluated for their flowering characters few of them had shown as earliness for flowering such as Punjab Glad-2, Praha, Vink's Glory, Roshni, Arka Sapna and Punjab Glance, whereas, late blooming cultivars were: Malviya Kundan, Malviya Kiran, Malviya Shatabdi, Algarve, True Love, Yellow Star and Ocilla. The maximum plant height were recorded by Nauvalux, Tiger Flam, Malviya Kiran, Arka Tilak and GS-2 cultivars respectively, whereas it was minimum in Punjab Glance and Punjab Pink Elegance. Similar variations for plant height was also observed by Kalasaraddi (1996) and Shiramgond (1997), Sidhu and Arora (2000) in different gladiolus cultivars.

The influences of the growth, flowering behavior, yield, colour variation were observed due to genetic diversity and according to climatic conditions of a place. When different cultivars are grown under identical conditions, it is the genetic factor that expresses the phenotypic differences. These characters may be attributed to the inherent growth characters of the genotype.Variability in gladiolus genotypes has also been reported with the genetic constitution of genotypes. Certain cultivars generally revealed exotic nature and exhibit genetic basis for the expression of certain traits even in useful appealing characters. It has been also observed in gladiolus by Misra and Singh (1998) and Anuradha and Gowda (1990).

The highest spike length was recorded in Nauvalux followed by Tiger Flame and minimum in Punjab Pink Elegance. Rachis length is another important crucial character for cut flower trait. Rachis length was recorded maximum by Malviya Kiran, Ocilla, and Kalima, while minimum was observed in Praha cultivar (Table 1). The results are in accordance with the findings of Gupta *et al.,* (2001). Variation for spike length and rachis length was also observed by Hegde (1996). More number of florets per spike had recorded in Punjab Pink Elegance, Arka Ayush, C.P.G, Tiger Flame and Lady John cultivars respectively; whereas, minimum number of florets was in recorded in Vinks Glori cultivar. Further, table 1 revealed that many cultivars were observed as higher multiplier of corms and cultivars which had produced more number of corms per plant was Aldebaran followed by Fedelia, Punjab Glad-2, and Punjab Glance. It was minimum in check cultivar, but, statistically it was at par with GS-2 and Limon Cello cultivars.

Similar results were also obtained by Gupta *et al.*, (2002). More over cultivars varied in the corm production depending upon their hereditary traits and their response to the climatic conditions prevailing in the area. Rao and Sushma (2015), Jana and Das (2013), Shaukat *et al.*, (2012), Hossain *et al.* (2011) also observed variations in the number of corms of different gladiolus cultivars. For easy understanding of these cultivars table 1 further shows spike length more than 100 cm, florets more than 16.00 per spike and number of corms more than 3.00 have been depicted. Sharma and Gupta (2003) reported that availability of more food material stored in bigger sized mother corms that helped in better plant growth might be associated with the beneficial effect and corms production depends on the size of corms. These findings confirm the results of present investigation. Analysis of variance revealed significant differences among all the morphological

Table 1. Morphological genetic diversity in different gladiolus genotypes and their performance

Cultivars	Days to first flowering	Plant height (cm)	Spike length (cm)	Rachis length (cm)	Number of florets / spike	Number of corms / plant
Yellow Star (yellow)	113.33	86.33	75.66	44.33	14.33	2.33
Punjab Morning	100.66	97.00	87.33	44.66	15.66	2.33
Novalux (yellow)	108.00	122.00	112.66	58.66	15.66	2.66
Fire Flame	98.00	106.00	94.66	45.33	13.33	2.00
Lady John	110.33	99.33	89.33	43.66	17.33	2.00
Arka Tilak	109.66	114.33	100.33	47.66	16.00	2.00
Arka Ayush (orange)	106.00	100.66	90.00	50.66	18.33	2.66
Arka Sapna (white)	88.00	105.00	94.66	56.00	16.33	2.66
Arka Nazrana (red)	102.00	99.00	88.00	46.00	15.66	2.00
Kalima (red)	108.00	112.00	103.00	59.66	16.00	2.33
Roshni (pink striped)	87.33	108.00	98.00	50.66	15.66	2.00
Amethyst (blue)	109.33	91.33	87.00	47.33	14.00	2.33
Neelima (purple)	105.00	98.33	85.66	44.66	15.66	2.00
Pink Lady	106.33	105.66	95.00	46.66	16.66	2.33
GS-2 (yellow)	103.66	113.33	104.33	55.33	12.33	1.66
Limon Cello (red)	110.00	108.00	97.66	56.00	15.66	1.66
Ocilla (yellow)	112.33	113.00	103.33	60.00	16.00	2.33
Malviya Kiran (white)	115.33	117.66	107.00	61.00	17.00	2.33
Algarve (light red)	113.33	108.00	98.00	59.00	16.00	2.00
Malviya Shatabdi	115.00	100.33	90.66	50.66	13.66	2.33
Malviya Kundan (yellowish orange)	117.66	111.00	100.00	45.66	14.66	2.00
Fedelia (purple)	105.66	82.00	92.00	51.33	15.33	3.33
Necola (orange Red)	98.66	102.33	92.00	51.66	13.66	2.66
True Love (pink)	113.33	101.66	91.66	51.33	13.66	2.66
Aldebaran (yellow, red spot)	106.66	104.66	94.66	48.00	12.66	3.66
Tiger Flame (orange)	106.33	119.66	110.00	56.00	17.66	2.33
Victor (yellow)	101.33	104.66	94.33	50.33	14.66	2.33
C.P.G.	100.00	105.00	94.33	49.66	17.66	2.33
Punjab Pink Elegance (yellow)	95.00	85.00	75.33	44.66	19.33	2.66
Punjab Lemon Delight	92.33	96.00	85.00	44.66	12.66	2.33
J.V.G. (yellow)	106.66	112.33	101.66	48.66	16.00	2.66
Punjab Glad-1	102.33	100.66	90.00	58.66	15.33	2.33
Anglia	104.00	102.33	92.33	48.33	16.33	2.66
Punjab Glance	89.33	79.00	68.33	32.33	12.66	2.66
Punjab Glad-2	83.00	96.00	87.00	47.00	16.66	3.33
Praha	83.00	100.33	90.00	16.55	15.33	3.33
Vink's Glori	87.00	105.00	95.00	41.00	11.33	3.00
Pusa Kiran (control)	105.00	113.33	103.33	50.00	18.33	2.66
White Prosperity (control)	102.66	108.00	97.00	59.66	16.00	1.66
CD (5%)	2.735	4.009	3.801	1.714	0.891	0.984

characters studied, indicating considerable amount of diversity in gladiolus cultivars. It can be concluded from the present study that amongst the gladiolus genotypes / cultivars assessed and based on the results for various vegetative, flowering and corm characters, the aforesaid genotypes had a vast morphological genetic diversity under the present climate.

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Effect of different fertility levels and biofertilizers on quality and economics of knol-khol (*Brassica oleracea* var. caulorapa L.) under agroclimatic condition of Bikaner region

Mamta Meena, A K Soni, L N Bairwa and H D Choudhary

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Department of Horticulture, SKN College of Agriculture, Bikaner (Rajasthan), India

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ABSTRACT

A field experiment was conducted to find out the effect of fertility levels and biofertilizers on quality and economics of knoll-knol (*Brassica oleracea* var. caulorapa L.) at Horticulture Farm, College of Agriculture, Bikaner, during 2010-11. The experiment consisting of 16 treatments, *viz.* four levels of fertility and four different biofertilizer inoculations alone and in combination was laid out in RBD with three replications. The treatment combination, 100 per cent recommended dose of NPK + PSB, exhibited dry matter, protein, N and K content and uptake significantly higher over the control, than application of fertilizers and biofertilizers alone. It was statistically at par with 150 per cent recommended dose of NPK in combination with other biofertilizers inoculations. The maximum net return of ₹ 85,089 / ha with the best of B:C ratio of 3.86 : 1 was obtained when its crop was treated with treatment combination of 100 per cent recommended dose of NPK + PSB.

Key Words: NPK, PSB, Quality, Economics, Biofertilizers, Inoculants, Net returns, Dose

Knol-Khol (*Brassica oleracea* var. caulorapa L.) is a winter season crop mostly cultivated in Kashmir, West Bengal and some parts of south India. In North India, it is widely cultivated in Punjab, Himachal Pradesh, Haryana, Delhi and also in the vicinity of big cities of Rajasthan. Most of the soils in Rajasthan are poor in phosphorus and low in organic matter. About 93-99% of total phosphorus in soil is insoluble form and is directly not available to plants. Only about a quarter of water-soluble phosphate is taken up by the plants in the season of its application and the remaining is converted into insoluble, unavailable forms (Verma, 1993). Potassium is other most abundant nutrient constituting about 2.5% of the lithosphere. In recent years, biofertilizers have emerged as a promising component of integrated nutrient supply system. Among biofertilizers, biological nitrogen fixers are largely exploited. The nitrogen-fixing organisms associated with vegetable crops are Rhizobium species, living in symbiotic relationship with the leguminous plants and free-living fixers like Azotobacter and Azospirillum living in association with the root system of crop plants. They are likely to assume greater significance as a complement or supplement to inorganic nitrogen fertilizers because of their high nutrient turnover, low costs and soil and environmental protection (Bahadur and Manohar, 2001). Phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhiza (VAM) are the important microbes in releasing and making available phosphorus by colonizing root surface of growing plant root. They also improve the uptake particularly of phosphorus, zinc and other micronutrients (Asokan *et al.*, 2000). Therefore, an experiment was conducted to find out the effect of fertility levels and biofertilizers and quality and economics of knol-knol.

MATERIALS AND METHODS

The experiment was conducted to find out the effect of different fertility levels and biofertilizers on growth and yield of Knol-khol during *rabi* season of 2010-11 at Horticulture Farm, College of Agriculture, Bikaner. The experiment was laid out in randomized block design with three replications. The Bikaner zone has arid climatic conditions with scorching summer, cold winter scantly and scattered rain fall. The annual average

*Corresponding author :

rainfall is 260 mm and more than 80% rainfall is received during south-west monsoon season. During summers, maximum temperature may go as high as 48°C, while in winter, it may fall as low as 0°C. The region is prone to high wind velocity and soil erosion. Soil drifting due high speed of winds leads to soil erosion which is a major problem in summers. The soil of the experimental field was loamy sand in texture, slightly alkaline in reaction and poor in organic carbon with low available nitrogen (< 250 kg/ha), phosphorus (< 20 kg/ha) and medium in potassium contents (125-300 kg/ha).

RESULTS AND DISCUSSION

The results reveal that N, P and K were taken up and translocated in knob with increased fertility levels. The significant increase in all these quality characters were observed with 100% recommended dose of NPK which was statistically at par with 150% recommended dose of NPK (Tables 1 and 2). The effect of nitrogen fertilization with NPK content of knob appeared due to improved nutrition environment both in root zone and the plant system, leading to better accumulation to edible parts. Thus, adequate supply of N, P and K early

Table 1. Effect of different fertility levels and biofertilizers on protein, dry-matter content and nutrients of knob

Treatment	Protein content (%)	Dry matter content (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Fertility levels					
F_0	13.78	10.06	2.205	0.389	2.458
F_1	14.53	11.64	2.325	0.404	2.886
F_2	14.89	12.93	2.383	0.441	3.111
F_3	15.00	13.25	2.400	0.455	3.158
SEm±	0.15	0.18	0.024	0.003	0.017
CD (5%)	0.43	0.51	0.068	0.010	0.048
Bio-fertilizers					
B_0	14.14	11.43	2.262	0.429	2.855
B_1	14.55	11.79	2.328	0.420	2.909
B_2	14.62	12.10	2.339	0.420	2.920
B_3	14.90	12.56	2.384	0.420	2.930
SEm±	0.15	0.18	0.024	0.003	0.017
CD (5%)	0.43	0.51	0.068	NS	0.048

Table 2. Effect of different fertility levels and biofertilizers on nutrient uptake by plant and available nutrient content in soil after harvesting

Treatment	Nutrient uptake by plant (kg/ha)			Available nutrient content in soil after harvest (kg/ha)		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Fertility levels						
F_0	20.40	3.57	23.71	96.55	19.48	211.27
F_1	38.33	6.55	49.58	98.06	20.28	214.73
F_2	68.90	12.64	93.37	99.83	20.57	218.83
F_3	76.26	14.36	104.41	100.44	21.00	219.38
SEm±	1.59	0.25	1.84	0.66	0.24	1.64
CD (5%)	4.60	0.71	5.32	1.90	0.70	4.73
Biofertilizers						
B_0	41.14	7.93	56.19	95.88	19.24	209.13
B_1	50.77	9.21	67.61	99.14	20.36	217.76
B_2	53.66	9.69	71.39	99.44	20.67	218.09
B_3	58.31	10.29	75.88	100.41	21.05	219.19
SEm±	1.59	0.25	1.84	0.66	0.24	1.64
CD (5%)	4.60	0.71	5.32	1.90	0.70	4.73

Table 3. Economics of various treatment combinations

Treatment combination	Common cost (₹/ha)	Treatment cost (₹/ha)	Total cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
F_0B_0	25900	0	25900	36343	10443	1.40
F_1B_0	25900	1891	27791	80266	52475	2.89
F_2B_0	25900	3582	29482	96181	66699	3.26
F_3B_0	25900	5274	31174	97917	66743	3.14
F_0B_1	25900	475	26375	54688	28313	2.07
F_0B_2	25900	1160	27060	58160	31100	2.15
F_0B_3	25900	475	26375	61343	34968	2.33
F_1B_1	25900	2366	28266	84896	56630	3.00
F_2B_1	25900	4057	29957	112789	82832	3.77
F_3B_1	25900	5749	31649	116030	84381	3.67
F_1B_2	25900	3051	28951	83912	54961	2.90
F_2B_2	25900	4742	30642	112905	82263	3.68
F_3B_2	25900	6434	32334	115278	82944	3.57
F_1B_3	25900	2366	28266	85822	57556	3.04
F_2B_3	25900	4057	29957	115046	85089	3.84
F_3B_3	25900	5749	31649	116377	84728	3.68

Rate of fresh knob of knol-khol ₹ 100/kg

in crop season increased their availability in root zone coupled with increased metabolic activity at cellular level thereby increased the nutrient uptake and there accumulation in the vegetative and edible plant part. The increase in NPK content in knob was also observed by Stamatiadis *et al.* (1999) in broccoli.

A significant increase in protein content, dry matter, NPK content and uptake were recorded in inoculation with PSB and VAM content. The maximum increase in all these characters were observed with PSB inoculation (Tables 1 and 2) which might be due to improved environment for nutrient availability in root zone and solubilization of native phosphorus status of soil by PSB. Phosphorus-solubilising bacteria enhances availability of phosphorus to plants and gives rise to better utilization of nutrients by crop which might have intern resulted in greater root development, nodulation and higher nitrogen fixation in the soil. Jat (1996) and Yadav (2001) in cauliflower. Kumawat (2009) in cabbage, Kadlag *et al.* (2007) in tomato, Kumawat (2010) in broccoli, Manohar (2006) in knol-khol and Soni, 2004) in onion. The nutrient content in plant due to higher functional activity of microbes in the root zone for longer duration under inoculation of PSB and VAM was also reported by Mukherjee and Rai (2000).

The data showed that application of 100% NPK with PSB inoculation (F_2B_3) resulted in maximum benefit : cost ratio of 3.84 : 1 with net return of 85809/ followed by 150% recommended dose of NPK with PSB inoculation (F_1B_1) with benefit : cost ratio of 3.77 : 1 and net return of ₹ 82832 (Table 3).

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Analysis of trend in area, production and productivity of okra *(Abelmoschus esculentus)* in India

Sanjeev Panwar[1], Nitin Kumar[2], Anil Kumar[3], Ranjit Paul[3] and Susheel Kumar Sarkar[3]

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Indian Council of Agricultural Research, Krishi Bhavan, New Delhi, India

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ABSTRACT

The analysis of production and area under okra (*Abelmoschus esculentus* Linn.) in India showed a perceptible trend in growing preference of okra crops among farmers. There is a decline in growth rate of yield of okra. The analysis also showed that though there is a steady increase in the area as well in production under okra crops. The growth rate as well as forecasting from 2017-18 to 2020-21 showed the increasing trend. Graphical representation also showed the increasing trend of okra.

Key Words: Trend, Linear model, Growth rate, Forecasting, Productivity

Okra (*Abelmoschus esculentus* Linn.) is a widely consumed as a potential vegetable in tropical regions the world over. In Indian kitchen, okra is one of the most versatile foods. It is quite popular in India, Nigeria, Pakistan, Cameroon, Iraq and Ghana. The total area and production of okra is 1148.0 thousand ha and 7896.3 thousand tonnes. It is mainly grown in India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Benin, Saudi Arabia, Mexico and Cameroon. Largest area and production is in India, followed by Nigeria. Highest productivity is reported from Egypt (12.5 tonnes/ha), followed by Saudi Arabia (13.3 tonnes/ha). Andhra Pradesh is the leading okra-producing state in India (1,184.2 thousand tonnes), followed by West Bengal (862.1 thousand tonnes).

Okra varieties, Pusa Makhmali, Pusa Sawani, IIHR 20-31, Pujab Padmini, Arka Anamika, Parbhani Kranti, Selection-2, Arka Abhey *etc*. are popular ones. In India, a number of cultivars and hybrids are available for cultivation, with a productivity ranging between 15 and 20 tonns/ha. Reliable and timely forecasts provide important and useful input for proper, foresighted and informed planning, more so, in agriculture which is full of uncertainties (Chandaran, 2004). Under the changed scenario today, forecasting of various aspects relating to agriculture is becoming essential. Therefore, an aanalysis to find out the trend in area, production and productivity, and yield prediction of okra in India was done.Linear models play a central part in modern statistical methods. On the one hand, these models are able to approximate a large amount of metric data structures in their entire range of definition or at least piece wise.

* Corresponding author : sanjeevp.icar@gov.in
[1] Principal Scientist, ICAR-Krishi Bhavan, New Delhi
[2] SO, CPWD (Horticulture), New Delhi
[3] Scientist, ICAR-IISR, New Delhi

MATERIALS AND METHODS

The data on annual area, production and productivity of okra in India from 2001-02 to 2016-17were collected from sources such as Horticultural at a Glance, Department of Agricultural Cooperation and Farmers' Welfare, Government of India, New Delhi.

Linear Model : A mathematical model is an equation or a set of equations which represents the behaviour of a system (France and Thornley, 2006). It can be either 'linear' or 'non-linear'. A linear model is one in which all the parameters appear linearly. Some examples of linear model (Fisher, 1924) are:

(a) Multiple linear regression

$Y = a0 + a1 X 1 + ... + ap X p + \varepsilon$, where Y is response variable, Xi are explanatory (or predictor) variables and ε is the error term.

(b) Polynomial models with one predictor variable

$Y = a + b X + \varepsilon$ (First-order model)

$Y = a + b X + c X 2 + \varepsilon$ (Second-order or Quadratic or Curvilinear model)

Growth rates are computed as simple growth rate and compound growth rate. Simple growth rate is expressed, as simple growth rate between the two periods and generally, it does not account for the data in between the period under study (Panwar *et al.*, 2017). Generally, it is employed to represent YoY (year over year) growth or when the growth is linear and non-cumulative. Here, an outlier in the selected year will distort the actual general growth observed in the series.However, in the real world scenario, most of the growth patterns observed are cumulative in nature and compound growth rate suffice in these cases. Compound growth rate takes into account of various distributions in data observed in the series. The most commonly used distribution for the study of growth rate is exponential, which is employed in this study.

$$Y_t = \alpha\beta^t \quad (1)$$

where, Y_t is production of fruits (000'tonnes) during the period 't' α and β are parameters to be estimated.

The equation (1) is transformed in natural logarithmic as $\log Y_t = \log \alpha + (\log \beta)t$.

The transformed equation is estimated using OLS method.Finally, compound growth rate (expressed in percent) is computed as $G = (e\beta - 1) \times 100$.

RESULTS AND DISCUSSION

The quadratic fit is the best model of okra production, since there is highest correlation coefficient and low standard error (Table 1). The annual growth rate in area underokra in India is 4.43 per cent, whereas the compound of India is 2.95 per cent (Table 2). This shows a perceptible trend in growing preference of okra crops among farmers. There is a decline in growth rate of yield of fruit crops and okra in India (Agarwal and Mehta, 2007) (Table 3). On the national front, growth rates of major fruit crops are either negative or minimal, while that of other crops (minor fruit crops) are positive and significant at 5.05 per cent per annum. The analysis shows that though there is a steady increase in area as well in production also under okra crops in India. The growth rate as well as forecasting from 2017-18 to 2020-21 shows the increasing trend (Table 3). Graphical representation also shows that the trend of okra in terms of area and production is increasing (Figs 1 and 2).

Table 2. Computation of growth rates (production)

Growth rate (percent per year)	Compound growth rate
4.43	3.91

Table 3. Production and future forecast

Year	Production	Growth rate
2001-02	3324.7	
2002-03	3244.5	-2.41225
2003-04	3631.4	11.9248
2004-05	3512.4	-3.27697
2005-06	3974.6	13.15909
2006-07	4070.0	2.400242
2007-08	4179.0	2.678133
2008-09	4528.0	8.35128
2009-10	4803.3	6.079947
2010-11	5784.0	20.41721
2011-12	6259.2	8.215768
2012-13	6350.3	1.455458
2013-14	6346.0	-0.06771
2014-15	5708.7	-10.0425
2015-16	5848.6	2.450646
2016-17	6146.0	5.084978
	Forecasting	
2017-18	6418.1	
2018-19	6702.3	
2019-20	6999.1	
2020-21	7309.0	

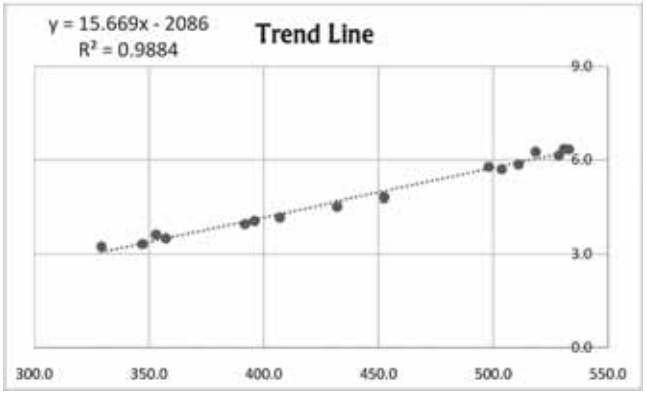

Fig. 1: Graphical representation of trend line

Table 1. Model fitting (production)

Model fitting	Linear fitting $y = a + bx$	Quadratic fitting $y = a + bx + cx^2$	Exponential association $y = a(1 - \exp(-bx)$
Standard error	1168.7592461	439.9291469	1171.6811397
Correlation coefficient	0.7240736	0.9680355	0.7224272

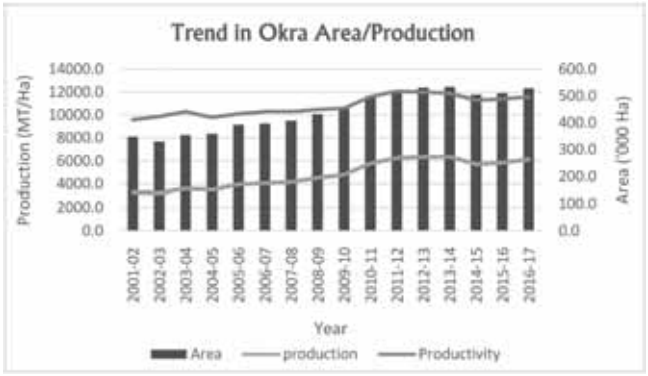

Fig. 2: Graphical representation of trend line of production and area

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Effect of petroleum-based oil on management of sigatoka leaf spot (*Fusarium* sp.) on banana (*Musa* sp.)

Ajeet Singh[1], Megha Vibhute[2] and Sunil Kumar[3]

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Krishi Vigyan Kendra , Burhanpur, Madhya Pradesh 450 331, India

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ABSTRACT

A field experiment was conducted at farmers' fields to find out the effect of different treatments against sigatoka leaf spot caused by *Mycosphaerella* spp. on banana (*Musa* sp.) during 2014-15 and 2015-16 at KVK, Burhanpur, Madhya Pradesh, India. The experiment was laid out in a randomized block design in three replications with nine treatments. There was minimum per cent disease severity index of sigatoka (13.57%) by the treatment T_8, *i.e.* spraying of Hexaconazole (H) @ 0.05% + petroleum based oil (Benole) @ 1% with maximum yield (69.9 t/ha), followed by treatment T_7 Propiconazole(P) @ 0.05% + Petroleum based oil (Benole) @ 1% (67.33 t/ha) as compared with rest of the treatments.

Key Words: Fungicides, Sigatoka leaf spot, PDI, Yield, Economics

Banana (*Musa* sp.) is most widely consumed fruit in the world because of its taste, nutritional value and potential health benefits. Sigatoka leaf spot disease causes extensive defoliation, reducing the photo-synthetic capacity of plant as a consequence of necrotic leaf lesions, and induces physiological alterations of plant. In general, farmers use contact as well as systemic fungicides for controlling leaf spot diseases. The chemical control of disease which is being practised in our country involves excessive use of chemical, fungicide which are normally dangerous to environment compelling the pathogen to develop strains resisitant to fungicides (Meena *et al.*, 2018).

Petroleum oil (Benole), which is biodegradable banana spray oil, is being used extensively in banana exporting countries for the management of sigatoka disease. Spraying of oil at different concentration (1%, 2%, 3%) reduce the diseases severity significantly. Petroleum based mineral oil (benole)has been used in combination with half of the recommended dose of different fungicide, *viz.* Carbendazim, Propiconazole, Hexaconazole and Tridemorph of these fungicides (Pardeshi *et al.*, 2015). Since the oil improves effectiveness of fungicides and diffusion of active ingredients through the cuticle of the plant, an experiment was conducted to find out the effect of petroleum-based oil on management of sigatoka leaf spot on banana.

MATERIALS AND METHODS

The field experiment was conducted during 2014-15 and 2015-16 at farmers' fields in district- Burhanpur, Madhya Pradesh, to test the efficacy of different treatment on intensity of sigatoka leaf spot and yield of banana. The experiment was laid out in randomized block design (RBD) with the three replication and nine treatments (Table 1).

The experiment was conducted on cultivar G9 which was grown with a row-to-row and plant spacing 1.8m × 1.8m. Five plants from each treatment was selected as representative sample for observation. Spray schedule was started after six month of the planting of the crop. The Observations with respect to per cent disease index were recorded one week after each spray.

RESULTS AND DISCUSSION

The pooled data revealed the least percent disease

*Corresponding author : meghavibhute@gmail.com
[1] Senior Scientist & Head, Krishi Vigyan Kendra, Burhanpur, Madhya Pradesh, ajeet_1969@yahoo.co.in
[2] Subject Matter Specialist, Krishi Vigyan Kendra, Burhanpur, Madhya Pradesh
[3] Prof., Deptt. of Floriculture, College of Horticultulture & Forestry, Pasighat, Arunachal Pradesh, sunu159@gmail.com

Table 1. Treatment details

T_1	Control
T_2	Carbendazim(C) @ 0.1%
T_3	Propiconazole (P) @ 0.1%
T_4	Hexaconazole (H) @ 0.1 %
T_5	Tridemorph (T) 0.1 %
T_6	Carbendazim(C) @ 0.05% + petroleum based oil (Benole) @1%
T_7	Propiconazole(P) @ 0.05% + petroleum based oil (Benole) @1%
T_8	Hexaconazole (H) @ 0.05% + petroleum based oil (Benole) @1%
T_9	Tridemorph (T) @ 0.05% + petroleum based oil (Benole) @1%

intensity 13.57 was recorded by the treatment T_8 (Hexaconazole (H) @ 0.05% + petroleum based oil (Benole) @1%), was at par with treatment T_7 *i.e.* spraying (Propiconazole (P) @ 0.05% + petroleum based oil (Benole) @1%) and found significantly superior with rest of the treatments, which recorded the per cent disease intensity in the range of 15.94-31.29 and it was highest 49.53 percent under untreated control (Deshmukh *et al.*, 2018 and Gurudatt *et al.*, 2014).

Higher number of disease free leaves was observed by the treatment T_8 (10.25), *i.e.* (Hexaconazole (H) @ 0.05% + Petroleum based oil (Benole) @1%) was found significantly superior with all the treatments. Similar fungistatic effect at different intervals against sigatoka leaf spot disease of banana under field condition were earlier reported by several workers Shinde *et al.*, (2014) and Kulkarni (2004).

Pooled data revealed that there was significant effect on banana by different treatments.Maximum banana yield was obtained from treatment T_8, *i.e.* Hexaconazole (H) @ 0.05% + petroleum-based oil (Benole) @1% (69.9t/ha) and it was at par with treatment T_7 Propiconazole (P) @ 0.05% + Petroleum based oil (Benole) @1% (67.33t/ha) and significantly superior with rest of the treatments.

Thammiah *et al.* (2005) reported three spray of propiconalzole @ 0.05 % effectively managed sigatoka leaf spot disease in main as well as in first ratoon crop. In the main crop, 3 sprays of propiconazole @ 0.05% at 15 days interval effictively controlled leaf spot disease. Meena *et al.* (2018) reported that, disease reduction and higher yields were obtainted in the propiconazole sprayed plots.

Maximum benefit : cost ratio was recorded by the treatments T_8, *i.e.* Hexaconazole (H) @ 0.05% + Petroleum based oil (Benole) @1% (3.195), followed by treatment T_7 Propiconazole (P) @ 0.05% + Petroleum based oil (Benole) @1% (3.131) as compared with rest of the treatments. The similar results were reported by the Dattatrya *et al.* (2015).

The economics of all treatments in trial over untreated control was calculated (Table 3). The maximum gross returns and net monetary return per ha was noticed with treatment of Hexaconazole (H) @ 0.05% + petroleum based oil (Benole) @ 1% ₹ 559200/ha and 384200/ha respectively. Similar findings were

Table 2. Disease status of banana under different treatments

Treatment	Pool Disease Index (%)			Disease Free Leaves (DFL)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	47.22	49.32	49.53	3.12	4.01	3.52
T_2	31.44	30.14	31.29	5.56	5.97	5.54
T_3	22.67	23.15	22.97	7.01	7.65	7.36
T_4	21.70	20.20	20.78	6.55	7.90	7.40
T_5	28.17	29.11	29.16	5.97	6.32	6.24
T_6	15.81	16.32	15.94	7.69	8.81	8.45
T_7	15.22	15.69	15.00	8.96	9.65	9.50
T_8	14.22	13.27	13.57	9.89	10.76	10.25
T_9	22.13	24.66	24.00	6.90	5.51	6.35
CD	3.61	2.98	2.34	0.69	0.91	0.46
CV (%)	8.57	6.99	5.48	5.80	7.08	3.74

Table 3. Yield and economics of banana under different treatments

Treatment	Banana Yield (t/ha)			Cost of production (₹/ha)	Gross income (₹/ha)	Net Retrun (₹/ha)	B:C Ratio
	2014-15	2015-16	Pooled				
T_1	35.69	36.70	37.20	150000	297600	147600	1.984
T_2	41.60	40.80	40.86	165000	326880	161880	1.981
T_3	54.60	58.90	56.43	168000	451440	283440	2.687
T_4	55.10	58.70	57.73	169000	461840	292840	2.732
T_5	38.11	38.60	38.82	155000	310560	155560	2.003
T_6	59.80	62.70	60.96	171000	487680	316680	2.851
T_7	67.60	68.60	67.33	172000	538640	366,640	3.131
T_8	68.60	74.00	69.90	175000	559200	384200	3.195
T_9	45.50	48.60	47.43	166000	379440	213440	2.285
CD	6.20	6.45	5.16				
CV (%)	6.91	6.88	5.63				

also reported by Meena *et al.* (2018) and Arzanlou *et al.* (2010).

Repeated use of contact fungicide or systemic fungicide may develop the resistance in pathogen and plant get more attacked by the pathogen as compared when these fungicides were used in alternation or in combination with other fungicides. Similar results on effect of different fungicidal sprays when used in alternation or combination with other fungicides against for management of sigatoka leaf spot disease of banana and for estimation of yield losses were reported by several workers" Shinde *et al.* (2014), Kulkarni (2004) and Thammaiah *et al.* (2005).

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Indian Horticulture Summit - 2020

The Society for Horticultural Research and Development, Ghaziabad, Uttar Pradesh, India, in collaboration with the Gautam Kalloo Research and Development Foundation, Varanasi and Sewa International, Bharat, has proposed to hold the **Indian Horticulture Summit-2020** during 14-16 February 2020 on Mitigating Climatic Changes and Doubling Farmers' Income at the Mahatma Gandhi Chitrakoot Gramodya Vishwavidyalaya, Chitrakoot (Madhya Pradesh) .

OBJECTIVES OF THE SUMMIT

The Indian Horticulture Summit-2020 will focus on various emerging topics in Horticultural Science.

THE PARTICIPANTS

The Summit is open to all stakeholders interested in horticultural R&D and related sectors, namely representatives from both public and private sectors, central and state government ministries, scientists and students from agricultural institutes and universities, farmers, representatives from international agencies, farmers' associations, agri-input associations (like seeds, fertilizers, plant-protection chemicals, growers' associations, NGOs, etc. The deliberation of the Summit shall be in English.

PRESENTATION

The Summit will cover lead, oral and poster presentations in each session. The lead papers on specific topics highlighting the central theme of each session will be invited by the organising committee on the basis of suggestions received. This slot is reserved for those scientists known for their scientific intellect.

Both members and non-members of society within India and abroad shall be considered for oral presentation subject to the relevance of the title and experience of the scientist related to the subject to the presentations shall be state- of- the- art repo.

THE AWARDS

The Society recognizes the contribution of R&D personnel in different fields for the development of Horticultural Science and Horticulture Sector as such in the country. Therefore, the Society for Horticultural Research and Development has instituted various awards in different fields, *viz*. lifetime achievements award, distinguished scientist award, young scientist award, best thesis award, fellowships of the society, women scientist award, best farmer award, best research paper award published in the **Current Horticulture** *etc*. Best oral and poster presentation awards will be given in each session. Applications for awards along with relevant biodata may be sent at **E-mail: hortsummit@gmail.com**. All awards will be decided by the high-profile committee.

THE ABSTRACT

The abstract should be prepared in MS word not exceeding 250 words. It must contain a clear title, name and affiliation of the authors. The name of the presenting author should be underlined and E-mail should be given at the end. There should not be any sub-headings, figures, tables or references in the abstract. The abstract may be submitted through email and/or by post along with a soft copy. The detailed specifications for preparing the poster paper (size 4½' × 3'), would be mailed to those authors whose abstracts are accepted for presentation.

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Website : www.currenthorticulture.com
Write to : somdutticar@gmail.com
Mobile : 91+9868815197

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