Good Agricultural Practices in Onion and Garlic Production

Edited by

R. B. Kale

S. S. Gadge

B. Venkata Rao

V. Mahajan

Major Singh

ICAR-Directorate of Onion and Garlic Reserch, Rajgurunagar

&

National Institute of Agricultural Extension Management, Hyderabad.

Good Agricultural Practices in Onion and Garlic Production

Edited by
R. B. Kale
S. S. Gadge
B. Venkata Rao
V. Mahajan
Major Singh

2022

ICAR- Directorate of Onion and Garlic Research,
Pune, Maharashtra
and
National Institute of Agricultural Extension Management, Hyderabad,
Telangana

Title: Good Agricultural Practices in Onion and Garlic Production.

Editors: Dr. R. B. Kale, Dr. S. S. Gadge, Dr. B. Venkata Rao, Dr. V. Mahajan and Dr. Major Singh

Edition: 2022.

ISBN: 978-93-91668-35-8

Citation: Kale R. B., Gadge, S. S., Venkata Rao B., Mahajan, V. and Singh, M. (2022). Good Agricultural Practices in Onion and Garlic Production is a joint endeavour of National Institute of Agricultural Extension Management (MANAGE) & ICAR-Directorate of Onion and Garlic Research, Rajgurunagar. This e-book is jointly edited and published by ICAR- Directorate of Onion and Garlic Research, Pune, Maharashtra and National Institute of Agricultural Extension Management (MANAGE), Hyderabad to educate agricultural extension officers, students, research scholars, academicians in the field of agriculture and allied sectors.

Published for Dr. P. Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr. Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication

डा. आनन्द कुमार सिंह
उपमहानिदेशक (बागवानी विज्ञान)

Dr. Anand Kumar Singh
Deputy Director General (Hort. Sci.)

भा.कृ.अनु.प.
ICAR

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन–II,
पूसा, नई दिल्ली–110 012

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II,
PUSA, NEW DELHI-110 012 (INDIA)

FOREWORD

Onion and Garlic, being staple partners of many culinary preparations, are important commodities worldwide. India is the second largest producer of onion with production of 266.41 lakh tonnes cultivated on 16.24 lakh ha area (2020-21). India's garlic production is 31.89 lakh tonnes on 3.92 lakh ha area (2021-22). However, the productivity of both the crops is lower than the world average. There is huge demand for Indian onion due to its spicy taste. Good Agricultural Practices (GAP) represent a solution for producers seeking to address consumer concerns in domestic and foreign markets. Inculcating the GAP among the farmers and other stakeholders in the supply chain of the onion and garlic will enhance the yield and quality of the farm produce, fulfil the quality demand of consumer and boost the export. I am happy to know that ICAR-Directorate of Onion and Garlic Research (ICAR-DOGR), Pune is promoting GAP to produce healthy onions for the benefit of the society and natural capitals.

I appreciate the joint efforts of the ICAR-DOGR and MANAGE, Hyderabad for publication of e-book on "Good Agricultural Practice in Onion and Garlic Production'. This e-book may serve as a resource book for the extension functionaries and field practitioners for further spread of the improved management practices of onion and garlic production.

I congratulate the authors and appreciate their sincere efforts in this endeavour.

(A.K. Singh)

Preface

Onion and garlic are important vegetable crops grown today and indispensable ingredient of food preparations in kitchens all over the world. There is a constant increase in the demand for onion across the world. India is world leader in area and production of onion. In garlic crop, area and production are also showing increasing trend. However, the major challenges are low productivity, climate change, seasonal productions shocks, price fluctuations, export irregularities, low price in global market, low level of processing and value chain fragmentation. To address these challenges there is need to improve the quality of the produce to compete in global market with round the year availability to meet the demand and develop a robust value chain starting from the farm to fork. The success in farming and sustainable production is very much dependent on the ability of primary producers, at farm level, to meet the stringent requirements in terms of quantity and quality of different actors along the value chain and ultimate consumers. A new generation of quality conscious consumers is putting more pressure on value chain players including producer for ensuring Good Agricultural Practices (GAP). Compliance with good agricultural practices is becoming inevitable for capturing the opportunities for our agricultural products, especially in high value markets. The adoption of Good Agricultural Practices at each stage of the value chain will certainly help to overcome these issues.

This publication on 'Good Agricultural Practice in Onion and Garlic Production' provide the comprehensive coverage of various aspects of Good Agricultural Practices including global and domestic scenario of onion and garlic, improved varieties and technologies developed, improved package of practices on Integrated Nutrient Management, Integrated Pest and Disease Management, Abiotic Stress Management, Seed Production, Post-Harvest Management, Mechanisation, Storage and Processing, Farmer Participatory Value Chain Management through collectives, Policies for FPOs etc. ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra is putting sincere efforts to bring improved and innovative technologies in onion and garlic crops for the farmers. These technologies need to be transferred in the field to enhance the adoption of good agricultural practices at farm level. This e-book publication is our sincere efforts to provide the information of these practices to different stakeholders.

I hope that this publication will be useful for practitioners, producers, agricultural extension workers and professionals to promote Good Agricultural Practices in Onion and Garlic Crops.

R. B. Kale
S. S. Gadge
B. Venkata Rao
V. Mahajan
Major Singh

Index

Chapter 1

STATUS OF ONION AND GARLIC PRODUCTION IN INDIA AND WORLD

Major Singh, R. B. Kale* and Vijay Mahajan
ICAR-Directorate of Onion and Garlic Reserch, Pune-410505
Email: rajiv.kale@icar.gov.in

Onion enjoys pride place in very cuisines worldwide being a staple partner of many culinary preparations. The traces of onion and major alliums being used for consumption can be traced back to the cave ages of humankind. Besides its rich history, it is rich in thiosulfinates, thiosulfonates, allicin, aliin, ajoene and many other benevolent biochemical components which imparts the medicinal values and the health benefits to resolve the problems of heart diseases, rheumatism, cancer, digestive disorders, blood sugar and prolonged cough by regular consumption of onion. Onion and garlic are the major alliums grown worldwide for their consumption in different forms including fresh, dry, chives, springs, shallots, and many more.

Onion and garlic: World Scenario

Onion: After potato and tomato, onion is considered the third most valuable vegetable in the world grown in 140 countries over an area of 54.8 lakh hectares with an output of 1045.54 lakh tons. The average productivity of the world is 23.06 tons/ha. The area under onion production in the world majorly belongs to India (14.34 lakh ha) and China (10.9 ha) followed by Nigeria (6.6 lakh ha), Indonesia (1.9 lakh ha), Bangladesh (1.9 lakh ha), Pakistan (1.5 lakh ha), Sudan (1.1 lakh ha), Viet Nam (1.0 lakh ha), Egypt (0.9 lakh ha), Uganda (0.8 lakh ha), Myanmar (0.7 lakh ha), Turkey (0.7 lakh ha), Russian Federation (0.6 lakh ha), Ukraine (0.6 lakh ha), (FAOSTAT 2020-21),

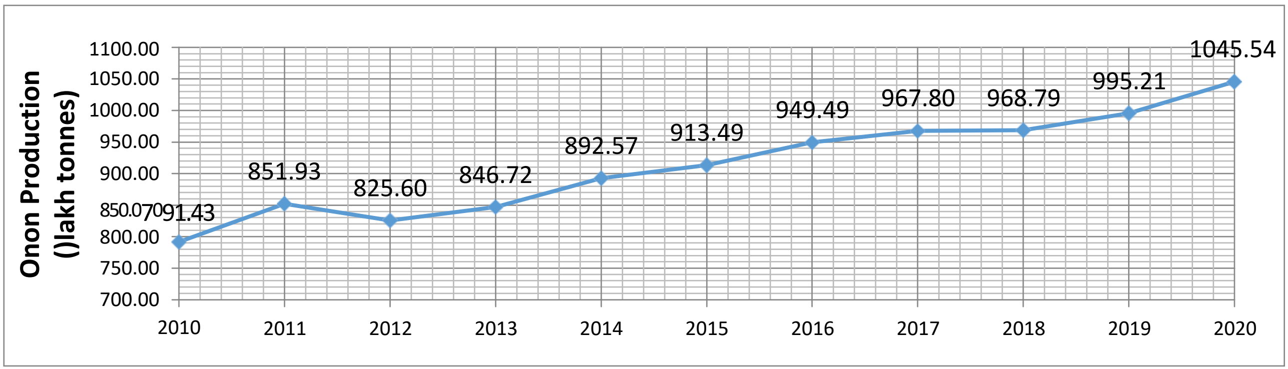


Fig. 1 Worldwide Onion production (lakh tonnes) throughout the decade

But for the productivity Republic of Korea ranks first in the world with productivity of 79.62 tons/ha followed by United States of America (71.10 tons/ha), Australia (54.67 tons/ha), Spain (52.10 tons/ha), Japan (49.32 tons/ha), Guyana (47.96 tons/ha), Chile (47.79 tons/ha), Sweden (47.70 tons/ha), Netherlands (47.34); where India ranks 83rd position with 18.64 tons/ha productivity in 2020-21 (FAOSTAT 2020-21). Globally the last two decades showed a rising trend in both the area and production of onion crop. The congenial environment of long-day conditions favours bulb bulking and raises productivity in major European and American countries. For the Tropical and Subtropical countries; the majorly grown onions are short-day onions which are inherently low in yield. The unavailability of enough quantity of quality seeds of improved varieties is also a constraint. This results higher share of farmer seeds in total cultivation. The disease conditions and the susceptibility of the onion crop to the diseases prevalent in most of the growing seasons affect the productivity in the tropics. Besides this, monsoon vagaries and the shortage of irrigation water at critical growth stages pull down the productivity of onions in India.

The global export of the onion in 2020-21 sums to 3607.67 million dollars from 83.27 lakh tons of quantity exported which also has shown a growing trend throughout the last decade. For the value generated through onion exports Netherlands ranks first with a sum of 797.42 million US dollars followed by China (500.2 million USD), Mexico (419.754 million USD), India (346.64 million USD), United States of America (249.935 million USD), Egypt (175.1 million USD), Spain (155.869 million USD), Pakistan (124.029 million USD). In global trade; India exported 14.49 lakh tons of onion in 2020-21 generating a value of 346.64 million dollars (FAOSTAT 2020-21).

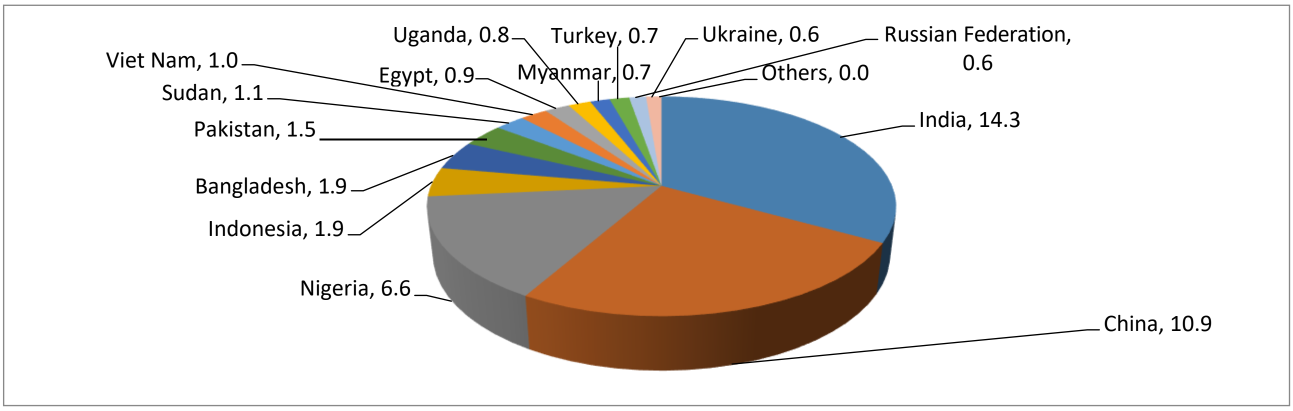


Fig. 2 Area (Lakh Ha) of major Onion Producing Countries (2020-2021)

Garlic: In 2020-21 garlic was grown globally over an area of 16.36 lakh hectares with 280 lakh ton production and an average of 9.47 tons/ha of productivity. The production of garlic is dominated by China with an area of 8.30 lakh ha which is a global half and production of 207.57 lakh tons followed by India (29.17 LT), Bangladesh (4.85 LT), Republic of Korea (3.63 LT), Egypt (3.34 LT), Spain (2.69 LT), Uzbekistan (2.24 LT) (FAOSTAT 2020-21). For productivity, Kuwait ranks first with a productivity of 44.27tons/ha. India ranks 50th in productivity with an average of 8.03 tons/ha which is one of the lowest productivities in the world (FAOSTAT 2020-21)

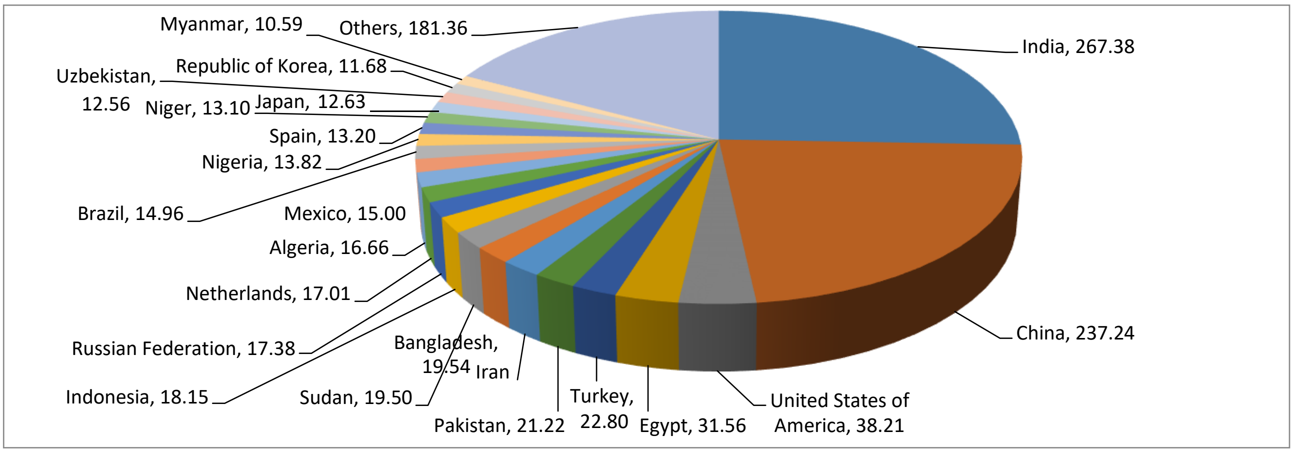


Fig.3 Production (Lakh tons) of Major Onion Producing Countries (2020-2021)

For the tropics, the shorter winter providing fewer days for bulking coupled with a higher incidence of diseases lowers the productivity. For garlic being a crop propagated vegetatively, the availability of virus free seedlings is one of the major concerns. For the global trade, the value generated through garlic trade sums a total of 3189.45 million dollars, where China is a major player with an export of 22.54 lakh tonnes of garlic generating a value of 2063.53 million dollars. For the quantity exported, China is followed by Spain (1.90427 LT), Argentina (0.97797 LT), Egypt (0.53207 LT), United Arab Emirates (0.46822 LT) & Netherlands (0.34186 LT) (FAOSTAT 2020-21)

Onion and Garlic: National Scenario

Onion: With vivid climatic situations, Onion in India is grown through three seasons viz. *kharif*, late *kharif* and *rabi*. Main crop is in *rabi* (60%) and 20% each is in *kharif* and late *kharif* (Lawande and Murkute, 2011; Murkute 2012). During 2020-21, the total area under onion was over 16.24 lakh hectares with a total production of 266.41 lakh tons (NHRDF). Maharashtra, Karnataka, Gujarat, Bihar,

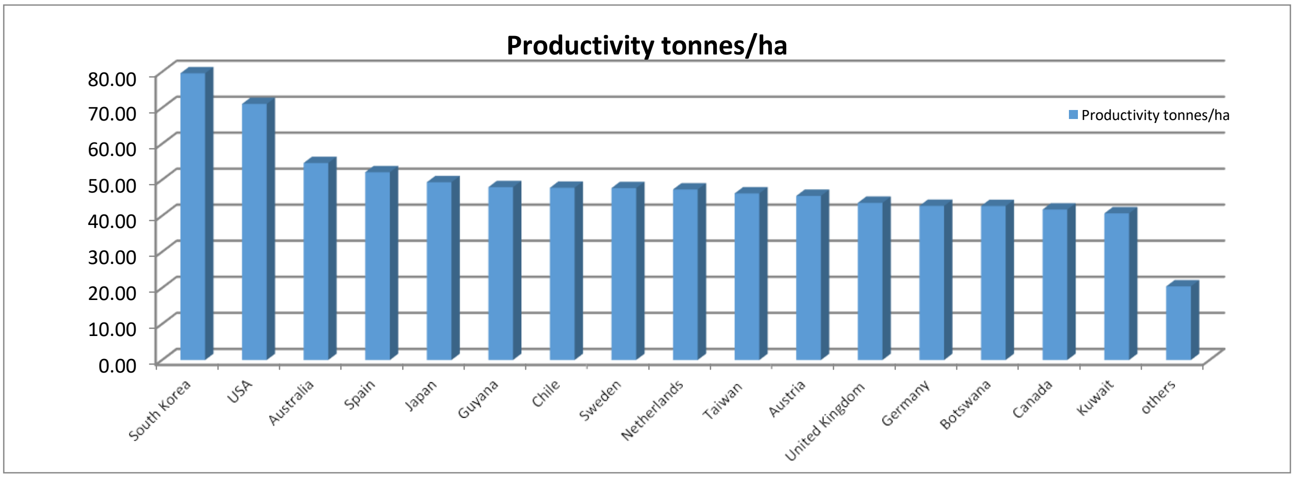


Fig. 4 Productivity (Ton/Ha) of major Onion Producing Countries

Madhya Pradesh, Rajasthan, Andhra Pradesh, and Tamil Nadu are the main onion-growing states. Though in varying quantities onion is grown throughout the nation, the major production i.e., Country's 43.27 % area and 39.32 % production alone comes from Maharashtra (NHRDF). For the production,

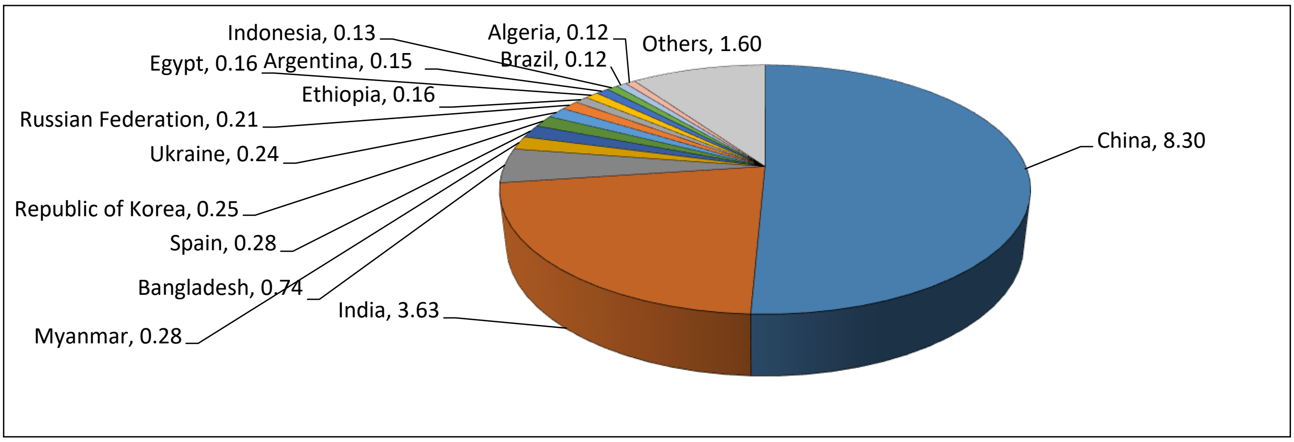


Fig. 5 Area (Lakh Ha) of major Garlic Producing Countries (2020-2021)

Maharashtra is followed by Madhya Pradesh (45.48 LT), Karnataka (26.60 LT), Gujarat (16.57 LT), Rajasthan (13.86 LT), Bihar (13.28 LT), West Bengal (7.47 LT), Andhra Pradesh (6.36 LT)(NHRDF 2021). Maharashtra plays a major role in price determination and distribution throughout the nation. Also, the major quantum exported besides the home consumption is from Maharashtra. There is a critical shortage in arrivals of onions in the market from November to January. From May to November stored onions are used for domestic as well as export markets. November to December *kharif* onion is available in the market, whereas from January to March late *kharif* crop from Maharashtra is available.

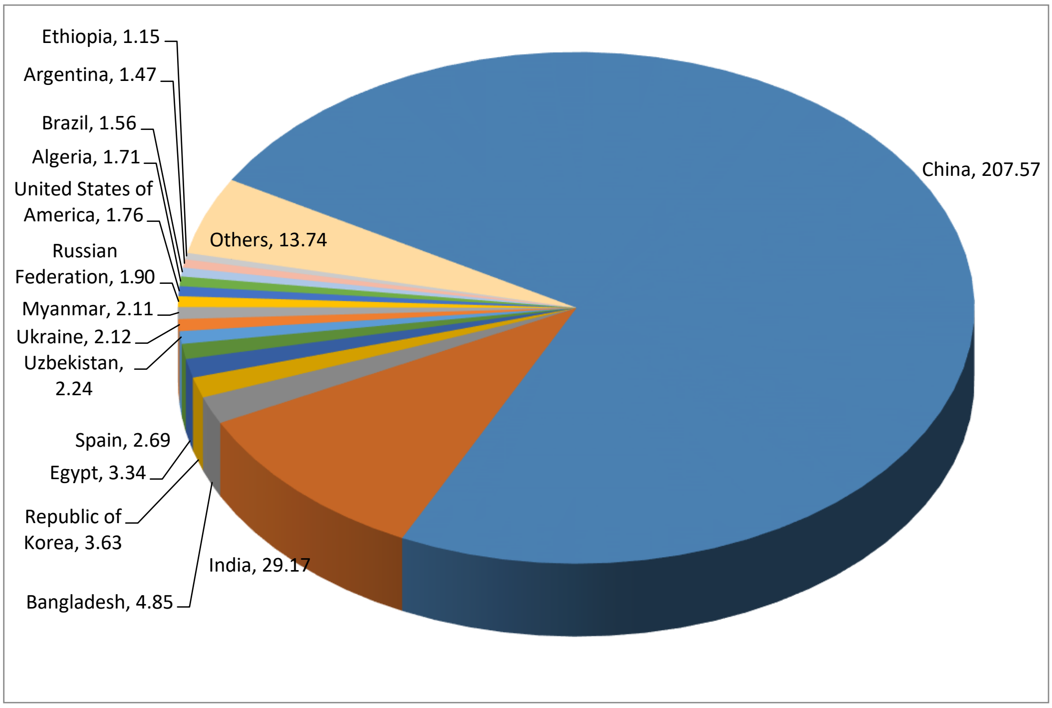


Fig. 6 Production (Lakh Tons) of Major Garlic Producing Countries (2020-2021)

Disease conditions such as anthracnose; prevailing in *kharif*, lower the production in the season drastically. In *rabi* season, a high incidence of thrips aggravates the problem of purple blotch and Stemphylium blight, which again pulls down the productivity. The area under *late kharif* onion production is lowering in the last few years due to higher incidence of bolting.

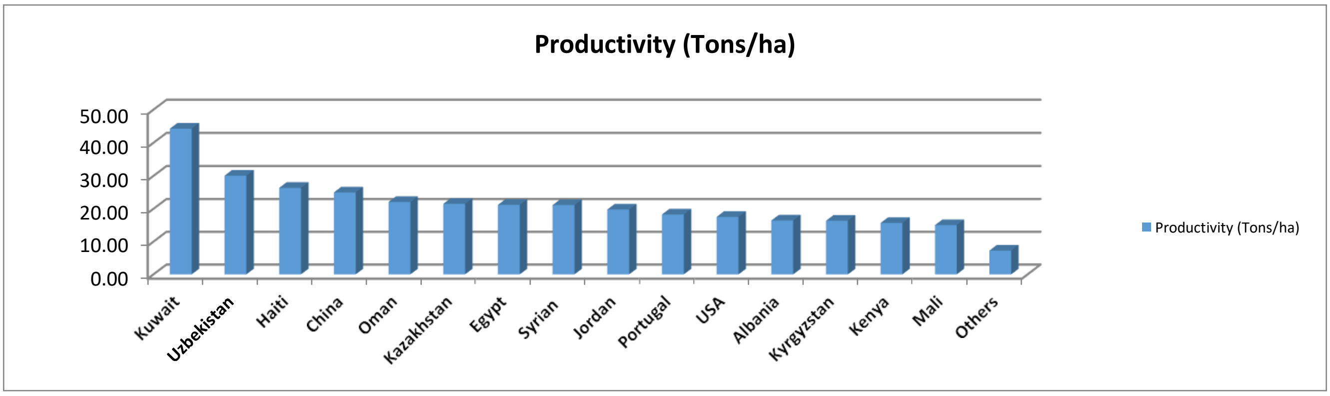


Fig. 7 Productivity (Tons/ha) of Major Garlic Producing Countries (2020-2021)

Garlic: Covering an area of 392.15 thousand hectares, garlic yielded 3189.78 thousand tonnes produce in 2020-21 in India; where Madhya Pradesh was leading state with 49.23 % area i.e., 193 thousand

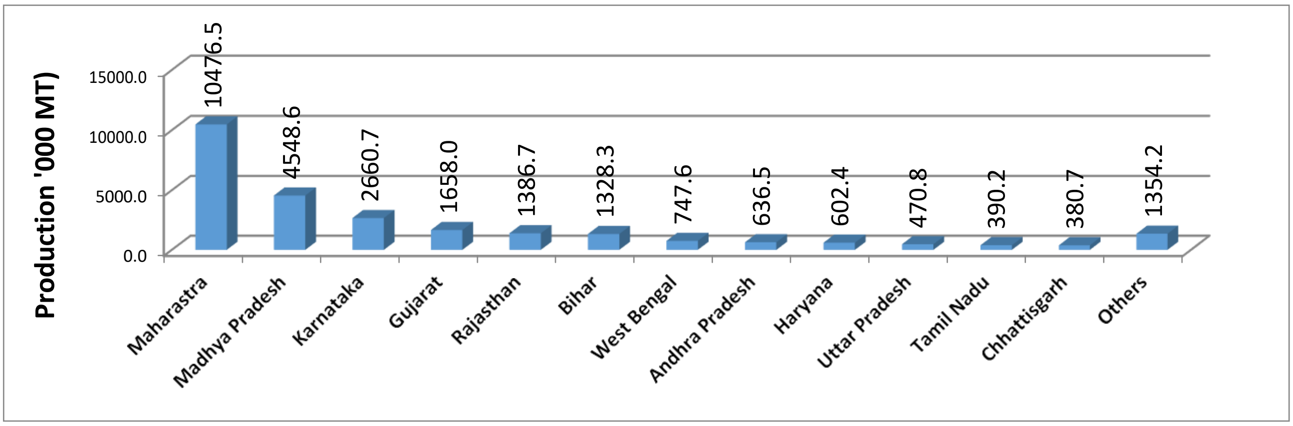


Fig. 8 State wise Onion production in India (2020)

hectares and 19.82 lakh tonnes of production. For the production Madhya Pradesh was followed by Rajasthan (5.1 LT), Uttar Pradesh (2.07 LT), Gujarat (1.18 LT), Punjab (0.96 LT), Assam (0.68 LT), Odisha (0.45 LT), West Bengal (0.37 LT), Haryana (0.31 LT), Maharashtra (0.22 LT) (NHRDF 2021).

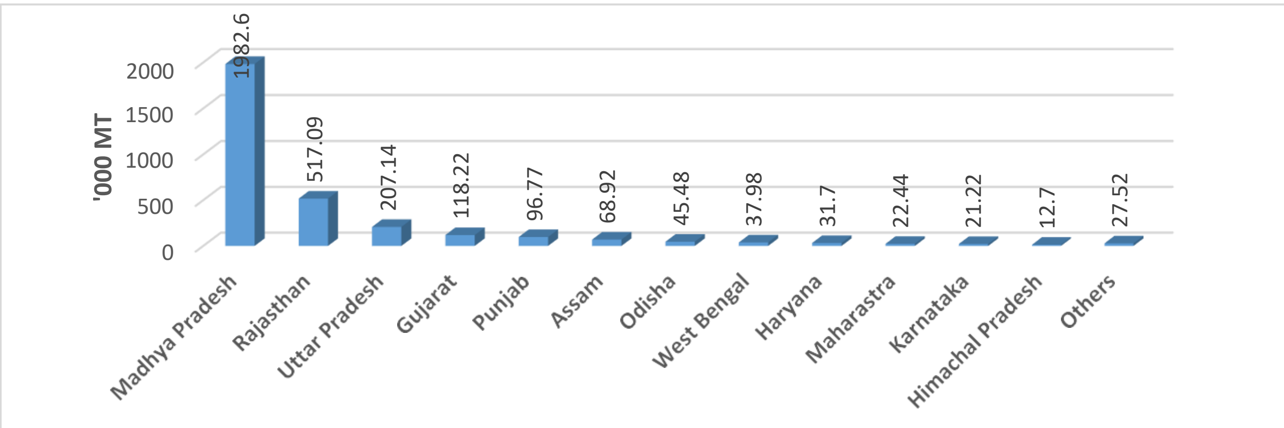


Fig. 9 statewise Garlic Production in India (2020)

During the last few years, with adoption of good agriculture practices and popularization of common garlic production practice among farmers has increased the area and productivity in Madhya Pradesh. The long day conditions available in northern states like Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Leh and Ladakh, avails cultivation of high yielding long day garlic types. But the limitation in area lowers its share in country's total production. Whereas at plains, shorter winter length limits the type grown to mainly the short-day garlics. These garlics are inherently low in yield

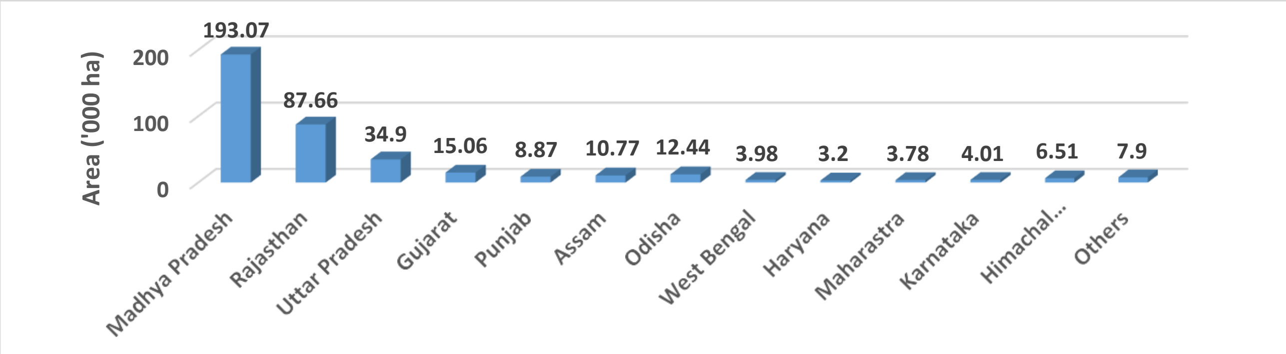


Fig. 10 State wise area under Garlic cultivation in India (2020)

but the area under its cultivation is much higher in plains compared to the hills. Less availability of quality planting material is one of the major constraints in garlic production in India.

Considering the achievements of the center, importance of the commodities in trade and intricate future challenges, the NRC was further strengthened and upgraded as Directorate of Onion and Garlic Research (DOGR) along with All India Network Research Project on Onion & Garlic. Over a decade,

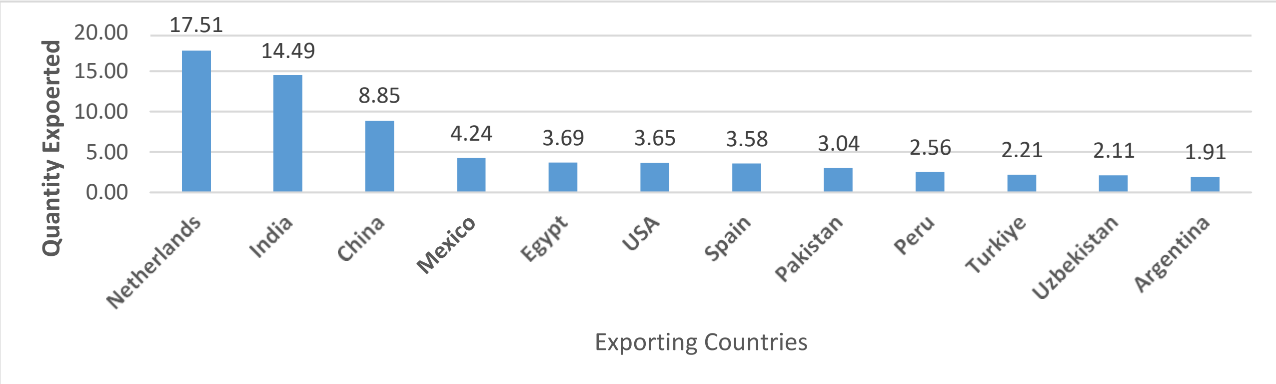


Fig 11. Onion Export in Lakh tons

the center has created infrastructure facilities of high rank and has contributed significantly in increasing the production and productivity of onion and garlic in the country by breeding improved varieties, developing new agricultural practices and by imparting training to stakeholders. The center has identified sustainable and eco-friendly practices for production as well as post-harvest management of onion and garlic to enhance profitability and welfare of the farming community.

Recognizing the significance of these two valuable commodities of the nation, Indian Council of Agricultural Research established National Research Center (NRC) for Onion and Garlic in VIII plan with it's headquarter at Nashik. However, due to technical and working constraints, the Centre could not be established well at Nashik and was shifted to Rajgurunagar in June 1998. Considering the contribution of the center and importance of the commodities, the NRC was further strengthened and upgraded as Directorate of Onion and Garlic Research (DOGR) along with All India Network Research Project on Onion & Garlic. Over a decade, directorate developed good infrastructure facilities and has contributed significantly in enhancing the production and productivity of onion and garlic in the country through research and development in the area like breeding improved varieties, developing new package of practices in production as well as post-harvest management of onion and garlic and popularizing the new technologies among the farmers.

The directorate is marching ahead with the mission to promote overall growth of onion and garlic in terms of enhancement of quality production, export and processing. ICAR-DOGR has All India Network Research Project on Onion and Garlic (AINROG) with 12 main and 14 voluntary centers across the country, with DOGR as the coordinating center. Since the establishment, with the efforts in research and transfer of technology the area under onion and garlic cultivation has increased more than three times, production has increased five times and productivity has increased almost two times.

To inculcate the Good Agricultural Practices among the farmers, ICAR-DOGR has made good efforts in the following areas:

- ICAR- DOGR has developed ten onion and two garlic varieties based on genetic improvement and selection. All these varieties have been released at national level.
- Kharif season is characterized by heavy rainfall which leads to poor drainage and incidence of diseases like anthracnose, purple blotch and Stemphylum blight. These factors led to low yield during kharif season. Keeping this in view, ICAR-DOGR factors c developed kharif onion production technology to increase kharif onion yield.
- To achieve per drop more crop motto, micro irrigation and fertigation technology has been developed.
- Integrated Nutrient Management technology is developed to use balanced fertilizers by farmers and enhance the nutrient use efficiency.
- To control the weed menace in onion and garlic crops recommendation of package of practices are developed.
- Round the year production, aggravate pests and disease problem in onion. To sustain the productivity. Directorate has formulated Integrated Pest and Disease Management (IPDM) strategies.
- Uneven production of onion round the year causes price fluctuation and therefore improved open ventilated onion storage structures of 5, 10, 15, 25 and 50 MT have been developed and these are widely adopted by the farmers mainly in Maharashtra which is onion bowl of the country.
- To store the onion in bulk quantity, Directorate has developed controlled atmospheric onion storage structure with 1000, 2000 & 5000 MT onion storage capacity which will help in storage of Rabi onion and further assist to stabilize the onion prices has been established
- An agri-business incubation centre has been established at ICAR-DOGR to promote new startups and entrepreneurs in onion and garlic.

References

Lawande K.E. (2011) *Onion Production (Marathi)*. Directorate of Onion and Garlic Research, Rajgurunagar, Pune, India. pp.60.

Lawande, K.E. and Murkute, A.A. (2011) Initiatives in onion and garlic cool chain management. *Proceedings of National Symposium on Postharvest Packaging, Cold-chain Logistics and Instrumentation Techniques for Quality and Safety of Perishables*. December 19 – 20, 2011. Central Institute of Post-Harvest Engineering and Technology, Ludhiana, India. pp. 183.

Murkute, A.A. (2012) Evaluation of onion varieties in ambient storage. *DOGR News* 16, 2-3.

Murkute, A.A. and Gopal, J. (2013) Taming the glut. *Agriculture Today* 16, 28 -30.

www.dogr.icar.gov.in

www.faostat.org

www.nhrdf.org

Chapter 2

ONION BULB PRODUCTION TECHNOLOGY

Vijay Mahajan*, A. Thangasamy, A. J. Gupta, Y. P. Khade and R.B. Kale
ICAR-Directorate of Onion and Garlic Reserch, Pune-410505
*Email: vijay.mahajan@icar.gov.in

Onion and garlic are an important vegetable crop cultivated throughout the world for its culinary, dietary, therapeutic and medicinal value. In India, under short day condition onion is harvested during *kharif* (Oct-Nov, 20%), late *kharif* (Feb-March, 20%) and *rabi* (April-May, 60%). *Kharif* and late *kharif* onion harvest is immediately consumed within one or two months as there is heavy demand during those months and therefore does not require storage. However, *rabi* harvest of April-May is in huge quantity creating glut in market and hence, the surplus amount needs to be stored so as to make it available during price hike in market in October-November. To maintain its demand and supply throughout the year, this crop needs proper planning to increase productivity and bulb quality. Average productivity of onion is about 18 t/ha in India which is very less as compared to other onion growing nations. These reasons may be shortage and high prices of quality seeds, high incidence of pests, diseases and moisture stress or excess rains during critical growth stages etc. Onion productivity can be increased by proper crop production and protection practices and prices can be stabilized with proper storage of *rabi* onions by the farmers. Despite of the ample production of both these commodities, generally 40-50% of the produce failed to reach the market due to huge post-harvest losses in storage or poor quality if bulbs. Several modified onion and garlic storage structures has been designed and tested by ICAR-DOGR, Pune, which helps in reduction of storage losses. Additionally, for minimizing these losses an integrated approach needs to be practiced right from selection of varieties to proper soil and water management along-with the integrated pest and disease management system that may help in reducing storage losses from 50 to 20% in onion. There is need to promote *kharif* onion production for regular supply in the market and export of onion. It plays an important role in stabilizing the prices of onion in the country. *Kharif* onion is grown in Maharashtra, Karnataka, Rajasthan, Haryana, Bihar and Tamil Nadu on almost 1.5 lakh hectares area. The *kharif* production is highly vulnerable to erratic monsoon, cloudy weather, continuous drizzling which creates the problem of foliar as well as soil borne diseases.

Climate: Onions are a cool season crop but can be grown under a wide range of climatic conditions such as temperate, tropical and subtropical climate. The best performance can be obtained in a mild weather without the extremes of cold, heat and excessive rainfall. Low temperatures early in the season are desirable with higher temperatures after bulb formation. However, onion plant is hardy and in the young stage can withstand freezing temperature also. Onions are sensitive to photoperiod. Long days are favourable to onion production as this enhances leaf development and formation which is directly related to bulb size. Early varieties require 13 hours for bulb initiation while late varieties require 16 hours for bulb initiation. The optimum temperature for vegetative phase and bulb development is 13-24˚C and 16-25˚C, respectively. It requires about 70% relative humidity for good growth. Cloudy weather and rains particularly during harvesting of bulbs may result in huge losses both during *kharif* and *rabi* season crop and the storage life of *rabi* produce also gets affected. At the time of harvesting dry and clear weather is more suitable.

Soil: Onion can be grown in all types of soils such as sandy loam, clay loam, silt loam and heavy soils. However, the best soil for successful onion cultivation is deep, friable loam and alluvial soils with good drainage, moisture holding capacity and sufficient organic matter. The optimum pH range is 6.0 - 7.5, but onion can also be grown in mild alkaline soils. Addition of organic manure helps in improving fertility status of soil besides improving the soil physical conditions. Onion crop is more sensitive to highly acidic, alkali and saline soils and water logging condition or high-water table, so well drained soils are more suitable. *Kharif* crop should be avoided on black and heavy soil and it should be well drained.

Season: Sowing, transplanting and harvesting timings of onion in different regions of India shown in table 1.

Table 1: Sowing, transplanting and harvesting of onion in India.

Sr. No.	Seasons	Time of Sowing	Time of Transplanting	Time of Harvesting
A.	Maharashtra and some parts of Gujarat *1. Kharif* 2. Early *Rabi* or late *Kharif* *3. Rabi*	May-June Aug. to first week of Sept. Oct. to mid of Nov.	July- mid August Sept.-Oct. Dec.- first week of January	Oct.-December Mid of Jan. to end of Feb. April-May
B.	Tamilnadu / Karnataka and AP 1. Early *kharif* *2. Kharif* *3. Rabi*	March-April May-June Sept.-Oct.	April-May July-Aug. Nov.-Dec.	July-Aug. Oct.-Nov. March-April
C.	Rajasthan/Haryana/Punjab/UP and Bihar *1. Kharif* *2. Rabi*	End of May to June End of Oct.to Nov.	July to mid Aug. Mid of Dec.to Mid of Jan.	Nov.-Dec. May-June
D.	West Bengal & Orissa *1. Kharif* 2. Late *kharif*	June-July Aug.-Sept.	Aug.-Sept. Oct.-Dec.	Nov.-Dec. Feb.- March
E.	Hills *1. Rabi* 2. Summer (long day type)	Sept.-October Nov.-Dec.	Oct.-Nov. Feb.-March	June-July Aug.-Oct.

Varieties:

Varietal selection plays an important role in enhancing productivity of onion. Varieties are notified by either the Central Varietal Release Committee (CVRC) or State Varietal Release Committee (SVRC) for commercial utilization. Hence, these are extensively evaluated for their performance in multi-location trials conducted under the AICVIP/ AINRPOG, which play a key role in testing, identification and release of new varieties. Onion is biennial crop and takes almost 12 to 14 years to purify or develop a new variety which is cumbersome. Varieties in onion were developed by different SAUs and ICAR institutes and tested under coordinated/ network project for release at national level for different agro-climatic conditions. Till now, about 65 onion varieties including 2 F_1 hybrids and 6 multiplier type have been developed and released from public sectors for different colors (light red, dark red, white and yellow), types (common, rose and multiplier type), locations (short and long day) and seasons (*kharif*, late *kharif* and *rabi*) at state or national level. Out of which, ten onion varieties are from ICAR-DOGR notified by CVRC.

A number of cultivars have been developed and released in India and occupies a large area under cultivation, however still a substantial area is under the cultivation of local cultivar or land races. There is urgent need to develop onion cultivars for processing, salad purposes and for resistant to biotic and abiotic stresses. Some of the varieties developed before 1986 and after 1986 are given below.

Extant onion varieties before 1986: N-2-4-1, N-53, N-257-9-1, Pusa Red, Pusa White Flat, Pusa White Round, Pusa Ratnar, S-131, Early Grano, Punjab Selection, Punjab Red Round, Punjab-48, Punjab Red Round, CO-1(Multiplier), CO-2, CO-3, CO-4, MDU-1, Hissar 2, Kalyanpur Red Round, Udaipur 101, Brown Spanish (Long day) and VL-1 (Long day) etc.

Improved onion varieties after 1986: Bhima Red, Bhima Raj, Bhima Super, Bhima Kiran, Bhima Shakti, Bhima Dark Red, Bhima Light Red, Bhima Shubra, Bhima Shweta, Bhima Safed, Baswant-780, Pusa Madhavi, Arka Niketan, Arka Kalyan, Arka Bindu, Arka Pragati, Arka Pitambar, Arka Lalima (F_1 hybrid), Arka Kirtiman (F_1 hybrid), Phule Safed, Phule Suwarna, Phule Samarth, HOS-1, Agrifound Dark Red, Agrifound Light Red, Agrifound White, L-28, Agrifound Rose, Agrifound Red (Multiplier), Line-355, Udaipur 102, Udaipur 103, Punjab Naroya, Punjab White, Punjab White,VL-3 (Long day), Akola Safed, Rajasthan Onion-1 and Aprita (RO-59) etc.

Table 2: Notified varieties of Onion by CVRC

S. No.	Variety	Developed by	Year of Release	Suitable for State	Season
1	Bhima Shakti	ICAR-DOGR, Rajgurunagar	S.O. 692(E). - 5.2.2019	Andhra Pradesh, Chhattisgarh, Karnataka, Madhya Pradesh, Maharashtra, Odisha	Late *Kharif* and *Rabi*
2	Bhima Light Red	ICAR-DOGR, Rajgurunagar	S.O. 261(E). - 16th January, 2018	Karnataka and Tamil Nadu.	*Rabi*

3	Bhima Safed	ICAR-DOGR, Rajgurunagar	S.O. 261(E). - 16th January, 2018	Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and Tamil Nadu	*Kharif*
4	Gujarat Junagadh White Onion-3 (GJWO-3)	JAU, Junagadh	S.O. 261(E). - 16th January, 2018	Gujarat	*Rabi*
5	Gujarat Anand White Onion-2 (GAWO-2)	AAU, Anand	S.O. 261(E). - 16th January, 2018	Gujarat	*Rabi*
6	NHRDF Red-4 (L-744)	NHRDF, Nashik	S.O. 3666(E). -6th December, 2016	Zone-III (Varanashi, Kanpur, Samastipur, Kalyani and Imphal)	*Rabi*
7	Bhima Super	ICAR-DOGR, Rajgurunagar	S.O. 3666(E). -6th December, 2016	Chhattisgarh, Delhi, Gujarat, Haryana, Jammu, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan and Tamil Nadu	*Kharif*
8	CO (On) 5 (multiplier onion)	TNAU, Coimbatore	S.O. 3666(E). -6th December, 2016	Tamil Nadu	*Kharif & Rabi*
9	Pusa Riddhi (Sel-383)	IARI, New Delhi	S.O. 3666(E). -6th December, 2016	NCT of Delhi	*Kharif* and *Rabi*
10	Hisar Onion 4	HAU, Hisar	S.O. 3666(E). -6th December, 2016	Haryana	*Rabi*
11	Pusa Soumya (Sel. BO-4)	IARI, New Delhi	S.O. 3666(E). -6th December, 2016	NCT of Delhi	*Rabi*
12	Bhima Kiran (NRCOG-597)	ICAR-DOGR, Rajgurunagar	S.O. 2277(E). - 17th August, 2015	Delhi, Uttar Pradesh, Haryana, Bihar Punjab, Maharashtra. Karnataka and Andhra Pradesh	*Rabi*

13	Bhima Red (KEL-2) (8-780-5- 3-1)	ICAR-DOGR, Rajgurunagar	S.O. 2277(E). - 17th August, 2015	Haryana, Delhi, Rajasthan, Gujarat and Maharashtra	*Kharif*, Late *Kharif* and *Rabi*
14	Bhima Dark Red (RGO-53)	ICAR-DOGR, Rajgurunagar	S.O. 2277(E). - 17th August, 2015	Chhattisgarh, Delhi, Gujarat, Haryana, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan and Tamil Nadu	*Kharif*
15	Bhima Shubhra (NRCWO-4/W-009)	ICAR-DOGR, Rajgurunagar	S.O. 2277(E). - 17th August, 2015	Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra. Odisha. Rajasthan and Tamil Nadu	*Kharif* and Late *Kharif*
16	Bhima Shweta (NRCWO 2/White Elite Composite Selection)	ICAR-DOGR, Rajgurunagar	S.O. 2277(E). - 17th August, 2015	Delhi, Uttar Pradesh, Haryana, Bihar, Punjab, Madhya Pradesh, Chhattisgarh, Odisha, Karnataka, Maharashtra, Andhra Pradesh, Gujarat, Rajasthan andTamil Nadu	*Kharif* and *Rabi*
17	NHRDF RED 2 (L 355)	NHRDF, Nashik	S.O. 2363(E). -4th October, 2012	Delhi, Uttar Pradesh, Haryana, Bihar, Punjab, Rajasthan, Gujarat, Maharashtra, Karnataka and Andhra Pradesh	*Rabi*
18	Bhima Raj	ICAR-DOGR, Rajgurunagar	S.O. 2978 (E). - 26.12.2008	Delhi, Gujarat, Haryana, Rajasthan, Gujarat, Karnataka and Maharashtra	*Kharif* and Late *Kharif*
19	Phule Samarth (S-1)	MPKV, Rahuri	S.O. 597(E). - 25/4/2006	Maharashtra	*Kharif* and Late *Kharif*
20	Arka Pitamber	IIHR, Bangalore	S.O. 2035(E). -28/11/2006	Karnataka	*Rabi*
21	Arka Bindu	IIHR, Bangalore	S.O. 2035(E). -28/11/2006	Karnataka	*Kharif*, Late *Kharif* and *Rabi*
22	Akola Safed	PDKV, Akola	S.O. 597 (E). - 25/4/2006	Maharashtra	*Rabi*
23	Aprita (RO-59)	RARS, Durgapura	S.O. 664 (E). - 11/5/2005	Rajasthan	*Rabi*

24	Rajasthan Onion-1 (RO-1)	RARS, Durgapura	S.O. 642 (E). - 31/5/2004	Rajasthan	*Rabi*
25	Phule Suvarna	MPKV, Rahuri	S.O. 348(E). - 8/5/2001	Maharashtra	Late *Kharif* and *Rabi*
26	Arka Niketan	IIHR, Bangalore	S.O. 386(E). - 15/5/1999	Madhya Pradesh and Maharashtra	Late *Kharif* *Rabi* and
27	Arka Kalyan	IIHR, Bangalore	S.O. 386(E). - 15/5/1999	Punjab, U.P., Bihar, Rajasthan, Gujarat, Haryana, Delhi, M.P., Maharashtra, Karnataka, Tamil Nadu and Kerala	*Kharif*
28	Punjab White	PAU, Ludhiana	S.O. 843 (E). - 21.9.1998	Punjab and Haryana	*Rabi*
29	Agrifound Dark Red	NHRDF, Nashik	S.O. 1135(E). - 1.12.1998	Punjab, U.P and Bihar	*Kharif*
30	Punjab Naroya (PBR-5)	PAU, Ludhiana	S.O. 115(E). - 10.2.1996	Rajasthan, Gujarat, Haryana and Delhi	*Rabi*
31	Agrifound Light Red	NHRDF, Nashik	S.O. 115(E). - 10.2.1996	Madhya Pradesh and Maharashtra	*Rabi*
32	VL-PIAZ-3 (Long day)	VPKAS, Almora	S.O. 793(E). - 22.11.1991	Uttaranchal	Hills
33	Pusa Madhavi (Line-120)	IARI, New Delhi	S.O. 915(E). - 6/11/1989	Madhya Pradesh and Maharashtra	*Rabi*
34	Baswant -780	MPKV, Rahuri	S.O. 915(E).- 6/11/1989	Maharashtra	*Kharif*
35	CO-4 (Multiplier Onion)	TNAU, Coimbatore	S.O. 596(E).- 13.8.1984	Tamil Nadu	*Kharif* and *Rabi*
36	Kalyanpur Red Round	CSAUA&T, Kanpur	S.O. 2(E).- 3.1.1983	Kanpur	*Rabi*
37	CO-3 (CS-450) (Multiplier Onion)	TNAU, Coimbatore	S.O. 19(E).- 14.1.1982	Tamil Nadu	*Kharif* and *Rabi*
38	Pusa Red	IARI, New Delhi	S.O. 13 19/12/1978	Punjab, U.P., Bihar, Rajasthan, Gujarat, Haryana, Delhi, Karnataka, Tamil Nadu and Kerala	Late *Kharif* and *Rabi*

39	Pusa Ratnar	IARI, New Delhi	S.O. 13 - 19/12/1978	Recommended for cultivation throughout the country	*Rabi*
40	CO-2 (CS-911) (Multiplier Onion)	TNAU, Coimbatore	S.O. 13.- 12/19/1978	TNAU, Coimbatore	*Kharif* and *Rabi*
41	Hisar-2	HAU, Hisar	S.O. 786(E).- 2.2.1976	Haryana and Punjab	*Rabi*
42	Punjab Selection	PAU, Ludhiana	S.O. 361(E).- 30.6.1973	Punjab, U.P., Bihar, M.P., Maharashtra, Karnataka, Tamil Nadu and Kerala	*Rabi*

The ICAR-DOGR has developed various improved varieties suitable for cultivation in different seasons and regions of the country. The varieties Bhima Dark Red, Bhima Super, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Safed are suitable for *kharif* season. Bhima Shakti, Bhima Kiran and Bhima Light Red recommended for *rabi* season are good for storage. The varieties Bhima Raj and Bhima Red can be grown in all three seasons.

Nursery management: This is the most important practice to produce healthy seedlings suitable for transplanting in any season.

- Soil solarisation should be done during hot summer months where there is severe problem of damping off. It should be done when temperature rises up to 40°C to reduce soil borne diseases. The 200 gauges transparent polythene sheet can be used to cover nursery area for 5-6 weeks.
- Preparation of nursery bed: The nursery field should be ploughed deep with mould board plough and 2-3 times with cultivator to break clods. Area of 0.05 hectare is enough for getting seedlings to transplant in one hectare area. Well decomposed Farm Yard Manure (FYM) should be applied @ 500 kg along with *Trichoderma herzianum* @ 1.25 kg at the time of last ploughing and mixed well in the soil. A drip or sprinkler irrigation system with raised bed of 15 cm height, 1.2 m width and length as per convenient should be prepared. In case of non-availability of drip/sprinkler irrigation system, raised bed of 1.0-1.2 m width and 5-6 m length may be prepared to raise the seedlings.
- Seed rate: About 5-7 kg of seeds having >70% germination are recommended to raise seedlings for one hectare area. A good quality seeds and proper nursery management practices will reduce seed rate to 4-5 kg per hectare.
- Seed treatment: To avoid soil as well as seed borne diseases, seeds should be treated with thiram/ captan/ carbendazim @ 2-3 g/kg of seed.
- Seed sowing: Seeds should be sown in lines at 50-75 mm apart at about 1 cm depth to facilitate proper growth, removal of seedlings for transplanting, ease to weeding, spraying etc. After sowing, the seeds should be covered with fine soil and powdered farmyard manure or vermicompost for uniform germination followed by light watering.
- Nutrient Management: NPK fertilizer @ 2:1:1 kg/500 m^2 before sowing and 1 kg N at 20 days after sowing should be applied for producing healthy seedlings.

- Weed control: Application of pre-emergence herbicide pendimethalin @ 2 ml/L is recommended to control weeds in nursery after sowing followed by one hand weeding at 20 days after sowing.
- The use of 50% agri shade net or hessian cloth for shading over nursery beds during summer protects young seedlings from scorching sunlight and ensures rapid and higher seed germination particularly for *kharif* nursery.
- Care should be taken to keep upper layer of soil moist for about first 5-8 days of sowing till its germination. Hence, light irrigation should be given in the morning and evening for initial days. Later irrigation should be applied according to need.
- Onion nursery can be raised successfully using drip or sprinkler system also.

Land preparation for main field: The field should be deeply ploughed and disked properly to eliminate debris and soil clods. About 15 tonnes FYM/ha or 7.5 tonnes poultry manure or vermicompost/ha should be incorporated at the time of last ploughing. Flat beds of the size 1.5-2.0 m width and 4-6 m length should be prepared. In drip/sprinkler irrigation system Broad bed furrows (BBF) of 15 cm height and 120 cm top width with 45 cm furrow between two beds are formed to achieve proper spacing and population density. *Kharif* crop should be always taken on raised bed and well drained soils.

Transplanting: The onion seedling should be transplanted after dipping roots in carbendazim @ 1 gm and carbosulphan 2ml/litre water solution for two hours to reduce the incidence of thrips and fungal diseases during the establishment phase. Age of seedling to be transplanted is most important. Generally, *kharif* season nursery can be transplanted at 35-40 days of sowing whereas, in late *kharif* at 40-45 days and in *rabi* at 50-55 days after sowing of seed in the nursery. Light irrigation should be given 3-4 days before uprooting of seedling which helps in easy uprooting without damaging the roots.

Spacing: The optimum spacing is 15 cm between the rows and 10 cm between plants. Plant population per unit area in onion is most important as we get single bulb from one seedling. If the population per unit is reduced then it will affect directly on production and may get more double bulbs, thick neck bulbs and bulbs may not be of uniform size.

Manures and Fertilizers: About 15 tonnes FYM/ha or 7.5 tonnes poultry manure or vermicompost/ha should be incorporated at the time of last ploughing. Besides this, the recommended dose of chemical fertilizers for *rabi* and late *kharif* is 110:40:60:30 kg NPKS and for *kharif* it is 75:40:40:30 kg NPKS per hectare. One third of recommended N and full dose of P_2O_5, K_2O and S are applied at the time of planting while remaining two third N is applied in two equal splits at 30 and 45 days after planting. In case of sulphur, application of 30 kg S/ha is sufficient for growing onion crop in soils having sulphur level above 15 kg/ha while 45 kg S/ha is needed for soils having sulphur level below 15 kg/ha for optimum production of onion. Application of micronutrients is beneficial based on soil test reports.

Weed management: Weed management is of utmost importance in the successful production of onion crop. Control of weeds at the initial growth stages is essential for getting high marketable bulb yield. Because of labour scarcity, chemical control of weeds along with cultural methods is inevitable. Application of Oxyflurofen @ 23.5% EC (1.5 -2.0 ml/L) or Pendimethalin @ 30% EC (3.5-4ml/L) before transplanting or at the time of transplanting followed by one hand weeding at 40-60 days after transplanting is recommended for efficient weed control.

Irrigation management: Among different factors, water will exert a profound effect on growth. Onion being a shallow rooted bulb crop is highly responsive to better irrigation. This crop should be irrigated frequently throughout the growing season. In general, onion needs irrigation at the time of transplanting, three days after transplanting and subsequently at 8-12 days interval depending upon the season, soil moisture status, climatic conditions and soil type. Irrigation needs to be stopped when the crop attains maturity (10-15 days before harvest) and about 5% top starts falling which helps in reducing the rotting during storage. Application of water, after a dry spell, would initiate new growth in onion bulbs, which would cause splitting and doubling of bulbs. Water, now a days is becoming one of the major limiting factors for *rabi* onion crops, hence, should be judiciously used. *Kharif* onion is grown in rainy season, hence, irrigation is generally not required but whenever there is long dry spell, irrigation is important to save the crop.

Onion crop can be successfully taken using drip or sprinkler irrigation system and it is a need of the day. In case of sprinkler irrigation, good quality of water should be assured. A broad bed furrow (BBF) of 15 cm height and 120 cm top width with 45 cm furrow should be prepared and this bed should be lightly irrigated 3-4 days before transplanting and the seedlings need to be planted at a spacing of 10 x 15 cm on these beds. Each BBF should have two drip laterals at (16 mm size) 60 cm distance with inbuilt emitters. The distance between two inbuilt emitters should be around 30-50 cm and the discharge flow rate is 4 l/hr. After completion of transplanting initial irrigation should be given up to saturation of soil through drip or sprinkler and later in drip irrigation at 100% Pan Evaporation (PE) significantly improved the marketable bulb yield (15-25%) with higher per cent A grade bulbs, water saving of about 35-40% and labour saving of 25-30%. In general, depending upon the soil type, season and climate, irrigation through drip or sprinkler can be given at interval of about 1-2 days for 30 to 45 minutes.

Fertigation: Fertigation is an effective and efficient method of applying fertilizers through drip irrigation which is used as the carrier and distributor of irrigation water and crop nutrients. Application of 40 kg nitrogen as basal dose at the time of transplanting and the remaining nitrogen in six equal splits at ten days interval from transplanting to 60 DAT through drip irrigation is recommended for achieving higher marketable bulb yield and profit. The drip irrigation system not only helps in water saving but also reduces nitrogen losses by leaching into ground water, as in fertigation, fertilizer nutrients are applied in root zone only. Generally, zinc and boron are deficient in Indian soils. To avoid micronutrient deficiency continuous use of organic manures and foliar application of micronutrients (based on soil test report) at 5 ml/l at 45-60 days after transplanting is beneficial.

Harvesting: In case of *rabi* bulbs, better storage bulbs should be harvested when more than 50-70 per cent of the tops are down (neck fall). The bulbs should be harvested along with leaves by hand-pulling from beds and should be cured in the field for about 3-5 days in such a way that bulbs should not be exposed directly to the sun. Hence, bulbs should be cured in the field by covering with the foliage of other bulbs in small heap. After 3-5 days of curing, the roots and tops are clipped which makes bulbs firm and dry and helps in improving their shelf life. The tops should be removed leaving 2.0-2.5 cm stalk above the bulbs. In the field itself small size bulbs, double and bolter bulbs should be removed and immediately sold out. The good quality selected bulbs should be shade cured in the heap of about 2-4 feet height for 10-12 days for better storage. It helps to remove field heat and dry scale is formed over the bulb which helps to increase storage life. Pre-mature harvesting increases post-harvest losses due to physiological weight loss, decay and sprouting. In *kharif* season, bulbs mature in about 90-110 days, but plants remain in the active growth stage and there will not be any top fall. Development of pigments, bulb size and shape are taken as an index for maturity during *kharif* season. After attaining this condition, top fall can be induced mechanically by rolling empty barrels two or three days before harvesting.

Grading: The onion bulbs are classified into three grades based on bulb size i.e. A (> 80 mm), B (50-80 mm) and C (30-50 mm) grades. In India, grading of onion is usually performed manually either before storage or before marketing. It is a cumbersome process and requires many labourers. The grading with machine reduces labour charges and also increases precision. The ICAR-DOGR has developed manual and motorized grading machines for grading. Onion bulbs can be classified into five categories with grading machine based on the bulb size. The efficiency of manual operated grading machine is five times of the manual grading while the efficiency is almost 20 times with motorized grading machine. The accuracy of grading of onion with grading machine is around 90% as against 70% with manual grading.
Storage: Mostly *rabi* onion are recommended for storage to get better price of the produce to the farmers. Recommended variety should be selected for storage and proper management practices should be followed including timely management of pest and diseases. Field and shade cured bulb should be stored in recommended bottom ventilated storage structure. Selected and graded bulbs should be filled at height of 4-5 feet in storage. There are mainly two type of storage structures one is single compartment (single chawl) and another is of double compartments (double chawl). Single compartment storage should be erected opposite the flow of wind direction whereas double compartment should be along the flow of the wind. The length of single compartment storage structure can be as long as our requirement. But double compartment storage structure length should not be more than 40 feet. Normally in one cubic meter, 5-7 quintals of onions can be stored depending on the size of bulbs. Farmers can decide the size of storage structure to be constructed depending upon the area and production of bulbs.

Chapter 3

IMPROVED VARIETIES OF ONION FOR ENHANCING THE PRODUCTION

Y.P. Khade*, R. B. Kale, Soumia P.S., B.R. Bibwe, V. Karuppaiah and V. Mahajan.
ICAR-Directorate of Onion and Garlic Research, Pune-410505
*Email: yogesh.iari@gmail.com

As onion crop is biannual in nature, it takes almost 10-12 years to develop or purify a new variety hence one should have about its varietal development. Onion is cultivated in all the three seasons in India i.e., *kharif*, late *kharif* and *rabi* season, therefore, varieties also need to be developed for suitability in different seasons. In our country, onion varietal development programmes were strengthened under All India Network Research Project on Onion and Garlic (AINRPOG) through SAU's and ICAR institutes. So far, more than 50 varieties of onion including hybrids and multiplier onion have been developed and released for different locations and seasons at state and national level. Being a cross pollinated crop, onion always provide scope for selection as natural variability is created constantly. The systematic breeding programme was started in early 90's at Pimpalgaon Baswant, Nashik, later on at IARI, New Delhi. The early maturity varieties developed through selection viz., N-2-4-2 are dominating in onion production.

Selection of suitable bulb crop varieties: Selection of variety for cultivation of onion and garlic depends on multiple factors such as agro-climatic situation, market demand and market destinations, preference of consumers.

Agro-climatic situation: In India, there is large variation in agro-climatic situation including soil type, climate, rainfall, day-length. The one variety which is suitable in one region may not be suitable in another region. The varieties developed by different research institutes are tested in different locations and the recommendation of the suitable varieties for particular state or location has given. Therefore, bulb cultivator should consider the recommendations of the research institutes while selecting the varieties for cultivation.

Market demand and market destinations: Bulb cultivator should consider market demand and market destinations while selecting the varieties for cultivation. In India, some markets are famous for specific quality of onion such as Nashik (Lasalgaon market) is famous for red onion. Therefore, farmers should consider market destination such as local market or export of onion. If farmer is exporting the onion which variety is suitable for export and which county demands which type of onion these factors must be considered while selecting the varieties for cultivation. The improvement of onion crop has not attracted much attention of the breeders in India. Perhaps, because of biennial habit of the crop requiring longer time for breeding and difficulties in attaining and maintaining genetic uniformity due to high degree of natural cross pollination and rapid inbreeding depression. Though, number of varieties have been developed in India, still there is enough scope to develop onion varieties with high TSS for dehydration, short day yellow varieties for export and varieties resistance to diseases and insect pests. Descriptions of some of the varieties are given in table 14.1.

Table 1. Common onion varieties with brief description

Sr. No	Variety	Organization	Salient features
1	Pusa Red	IARI, New Delhi	Average bulb weight: 70 – 90 g; Bronze red in colour; Flat to globular in shape; Good in storage. Maturity:140-145 DAT; TSS 12-13^0 Brix; Average yield: 25 t/ha; Suitable for late *kharif* and *rabi* in Maharashtra.
2	Pusa Madhavi	IARI, New Delhi	Selected form local collection of Muzaffarnagar in 1987 and identified for Indo-Gangetic plains; Light red in colour; Flatish round in shape; Good for storage; Maturity: 130-145 DAT; Average yield: 30 t/ha; Recommended for *rabi* season.
3	Pusa White Round	IARI, New Delhi	Identified in 1975 for zone IV, VI and VII; Bulbs white in colour; Roundish flat in shape; TSS: 12-13^0 Brix; Good in storage; Maturity: 130-135 DAT; Suitable for dehydration; Average yield is 30-32 t/ha.
4	Pusa White Flat	IARI, New Delhi	Identified in 1975 for zone IV, VI and VII. Bulbs are attractive white; Flattish round; TSS: 11-12^0 Brix; Maturity: 130-135 DAT; Good in storage; Suitable for dehydration and green onion; Average yield: 32-35 t/ha.
5	Spanish Brown	IARI, New Delhi	Long daytype variety; Developed at regional station Katrain, Kullu; Bulbs are attractive brown in colour; TSS: 13 –14^0 Brix; Maturity: 160-180 DAT; Good in storage at hills; Average yield: 280-300 q/ha.
6	Early Grano	IARI, New Delhi	Introduced by IARI from USA; Bulbs are globular in shape; Yellow in colour; Very mild in pungency; TSS 6-7^0 Brix; Maturity: 95 to 110 DAT; Poor in storage; Average yield : 50-60 t/ha; Suitable for cultivation in plains during *kharif* and *rabi* seasons.
7	Arka Kalyan	IIHR, Bangalore	Selected from local collection of Kalwantaluka of Maharashtra, identified for IV, VI, VII and VIII zones during 1987; Bulbs shape – globose; Dark red colour; TSS: 11-12^0 Brix; Average in storage; Maturity: 100-110 DAT; Average yield: 33t/ha; Suitable for *kharif* season.
8	Arka Niketan	IIHR, Bangalore	Identified in 1987 for zones IV, VII and VIII; Bulb shape - globular with thin neck; Attractive light red colour; 4-6 cm diameter; TSS: 12-14^0 Brix; Good for storage; Matures in 145 DAT; Average yield is 34 t/ha; Recommended for *rabi* season.
9.	Arka Pragati	IIHR, Bangalore	Improvement over local collection IIHR-149 of Nashik; Colour of bulb attractive pink, Globular shape, Uniform size

			with thin neck, highly pungent; Early in maturity 95 to 100 DAT; Average yield is 20 t/ha.
10	Arka Pitamber	IIHR, Bangalore	Notified during 2006, Released for cultivation in Karnataka; Bulbs yellow in colour; globe shape; very firm, thin neck, mild pungent; good keeping quality; It is suitable for export to European countries, USA and Japan; Yield potential: 35 – 37 t/ha.
11	Arka Bindu	IIHR, Bangalore	Developed from local collection for Chickballapur area of Karnataka particularly for export; Bulbs deep pink in colour; Bulbs flattish globe in shape; Free from bolters and doubles; TSS: 14-16^0 Brix; Maturity: 100 DAT; Average yield : 25t/ha
12	Agrifound Dark Red	NHRDF, Nashik	Selected from local collection of *kharif* onion grown at Nashik; Recommended in 1987 for the plains of Sutlej-Ganga; Bulbs dark red in colour; Globular in shape; TSS: 12 –13^0 Brix; Maturity: 95-110 DAT; Yield: 30-40 t/ha; Average in storage; Recommended for *kharif* season all over the country
13	Agrifound Light Red	NHRDF, Nashik	Developed through mass selection in 1993; Bulbs globular in shape; light red colour; TSS: 13^0 Brix; Good for storage; Maturity: 115-120 DAT; Average yield: 30-32 t/ha; Recommended for growing in *rabi* season all over the country; Can be grown in late *kharif* season in Nashik districts of Maharashtra
14	Agrifound Rose	NHRDF, Nashik	Pickling type variety developed at Chickbalapur grown in Kolar and Bangalore districts of Karnataka and Cuddapah districts of Andhra Pradesh; Exclusively for export; Bulbs flattish round in shape; Deep scarlet red in colour; Maturity: 95-110 DAS; TSS: 15-16^0 Brix; Average yield: 19–20 t/ha; Suitable for growing in *kharif* in Cuddapah district and allthree seasons in Karnataka
15	Agrifound White	NHRDF, Nashik	Selected from local germplasm of white onion grown in Nimad area of MP; Bulbs - globular in shape with tight skin; Silvery attractive white colour; TSS: 14-15^0 Brix; Good in storage; Maturity: 115-120 DAP. Averages yield: 20-25 t/ha; Good for dehydration suitable for *rabi* season.
16	L-28	NHRDF, Nashik	Developed through selection for *rabi* season; Identified by AICRP (VC) in 2006 recommended for cultivation in north India; Leaves dark green; Erect with thin waxy coating; Bulb dark scarlet red; Globular round with thick inner scales; TSS: 13 – 14^0 Brix; Yield potential: 25– 28 t/ha.

17	N-2-4-1	Agriculture Dept., Maharashtra	Identified in 1985 for zones IV, VI and VII; Globular in shape; Pungent in taste; Good for storage; Maturity: 140-145 DAT; TSS: 12-13^0 Brix; Average yield: 25-30 t/ha; Recommended for *rabi* season but can be grown in late *kharif* and *rabi* in Maharashtra.
18	N-53	Agriculture Dept., Maharashtra	Suitable for *kharif* season all over country; Bulbs globular in shape; Scarlet red in colour; TSS: 11-12^0 Brix; Poor in storage; Maturity: 100–110 DAT. Average yield is 15-20 t/ ha.
19	Baswant - 780	MPKV, Rahuri	Bulbs attractive red in colour; Globular in shape; Less bolting with doubles; TSS: 11-12^0 Brix; Average in storage; Maturity:100-110 DAT; Average yield: 20-25 t/ha; Suitable for *kharif* season in Maharashtra.
20	Phule Safed	MPKV, Rahuri	White colored variety; Developed through selection; Released in 1994; Bulbs globular in shape; TSS: 13^0 Brix; Suitable for dehydration; Average yield: 25-30 t/ha; Storage life 2-3 months; Recommended for late *kharif* and *rabi* season.
21	Phule Suwarna	MPKV, Rahuri	Bulbs yellow in colour; Suitable for export to Europe, Australia and America; Less pungent; TSS: 11.5^0 Brix; Good in storage; Suitable for late *kharif* and *rabi* season. Average yield: 24 t/ha.
22	Phule Samarth	MPKV, Rahuri	Developed through selection from Sangamner; Notified in 2006; Bulbs are Dark red in colour; Moderately resistant to purple blotch; Yield potential of 30 – 31 t/ha in *kharif* and 50–52 t/ha in late *kharif*.
23.	Punjab Selection	PAU, Ludhiana	Identified for zone IV, VII and VIII during 1975; Bulbs red in colour; Globular in shape; Average weight: 50-70 g; Good in storage. TSS: 14^0 Brix. Average yield: 20 t/ha. Recommended for *rabi* season.
24	Punjab Red Round	PAU, Ludhiana	Bulbs shining red in colour; Round in shape with thin neck; Average yield is 30 t/ha. Early in maturity.
25	Punjab-48	PAU, Ludhiana	Identified in 1975 for sub humid plains of Sutlej-Ganga; Bulbs flattish round; White in colour; Suitable for dehydration; Good in storage; Average yield: 30 t/ha.
26	Punjab White	PAU, Ludhiana	Notified in 1998; Recommended for cultivation in Punjab and Haryana; Bulbs white in colour; Suitable for dehydration; TSS: 15^0 Brix, Round in shape; thin neck; Yield potential: 31 – 33 t/ha.

27	Punjab Naroya	PAU, Ludhiana	Notified in 1996; recommended for cultivation in Rajasthan, Gujarat, Haryana and Delhi; Shoots medium tall and green; Bulbs red, medium to large, round with thin neck. Plants tolerant to purple blotch, thrips and *Heliothis*. Yield potential: 37 – 40 t/ha.
28	Hissar -2	HAU, Hissar	Bulbs colour -bronze red; Globular in shape; Tight skin; Sweet to pungent in taste; TSS: 11.5 – 13.5^0 Brix; Maturity: 120 DAT. Average yield: 25 t/ha. Suitable for cultivation during *rabi* in Haryana and Punjab.
29	HOS-1	HAU, Hissar	Identified by AICRP (VC) in 2006 for cultivation in U.P., Bihar, Jharkhand and Uttaranchal; Bulbs bronze red; Globular shape; 11-13^0 Brix TSS; Yield potential: 20-25 t/ha; Maturity: 165 days, suitable for *rabi* season.
30	Udaipur-102	RAU, Udaipur	Bulbs white in colour; Round to flat in shape; Maturity: 120 DAT. TSS: 12^0 Brix. Average yield: 30-35 t/ha.
31	Aprita	Durgapura	Notified in 2005; Average bulb weight: 74.6 g; Bulb shape flattened globe; red colour; Mild pungent with TSS: 10.2^0 Brix; Resistant to purple blotch; Yield potential: 35–40 t/ha; Maturity: 122 –126 DAT.
32	Rajasthan Onion-1	RARS, Durgapura	Notified in 2004 for cultivation in Rajasthan; Bulb weight 65.9 g; Shape flattened globe; Copper red, TSS: 10.5^0 Brix.; Resistant to purple blotch; Yield potential: 32–36 t/ha; Maturity: 130–140 DAT.
33	Kalyanpur Red Round	CSAUAT, Kanpur	Bulbs bronze red in colour; Globular in shape; Moderately sweet and moderately pungent; TSS: 13-14^0 Brix; Maturity: 105-115 DAT. Good in storage. Average yield: 25-30 t/ha.
34	Akola Safed	PDKV, Akola	Notified in 2006; Bulbs white in colour with thin neck; Average bulb weight 70-80 g; TSS: 11-12^0 Brix; Maturity: 130-135 DAT. Yield: 27 – 30 t/ha.
35	Bhima Super	ICAR-DOGR, Rajgurunagar	Suitable for *kharif and* late *kharif* cultivation in Maharashtra, Karnataka and Gujarat; Medium red colour; Round with tapering neck; TSS: 10-11^0 Brix; Average yield: 26-28 t/ha in *kharif and* 40 to 45 t/ha in late *kharif*. Early maturing in about 108 days DAT during *kharif and* 115-120 DAT during late *kharif* and *rabi*.

36	Bhima Red	ICAR-DOGR, Rajgurunagar	Recommended for *rabi* season by AICRP (VC) during 2009 for Zone VII (Maharashtra and Madhya Pradesh); can be cultivated during *kharif* and late *kharif* in Maharashtra, Karnataka and Gujarat; Bulbs attractive red colour; round shape; TSS: 10 to 11^0 Brix; Average yield 27, 52 and 31 t/ha in *kharif*, late *kharif* and *rabi*, respectively; Bolters less than 5% during late *kharif* and almost nil during *rabi*; Tolerant to diseases and pests; Maturity -115-120 DAT for late *kharif* and *rabi*.
37	Bhima Raj	ICAR-DOGR, Rajgurunagar	Identified by AICRP (VC) during 2007 for *rabi* cultivation in zone VI (Rajasthan, Gujarat, Haryana and Delhi); Bulbs dark red in colour; oval shaped; TSS: 10 to 11^0 Brix.; Suitable for *kharif* and late *kharif* also in the states of Maharashtra, Karnataka and Gujarat. Maturity: 120-125 DAT; no bolters in *rabi*; Average yield -25-30 t/ha; yield potential: 40-45 t/ha during late *kharif*.
38	VL Piaz-3	VPKAS, Almora	Long day type variety; Notified in 1991; Bulbs red in colour; medium, globular and pungent; Recommended for cultivation in Uttaranchal region; Yield potential: 25 – 27 t/ha; maturity: 145 DAP.
39	Bhima Dark Red	ICAR-DOGR, Rajgurunagar	Recommended for Chhattisgarh, Delhi. Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan and Tamilnadu for *kharif* season; Average marketable yield: 22-24t/ha; Matures in 100-110 days, Dark red in colour flat glob shape bulb.
40	Bhima Kiran	ICAR-DOGR, Rajgurunagar	Recommended for Andhra Pradesh, Haryana, Karnataka, Maharashtra, Uttar Pradesh, Bihar, Punjab for *rabi* season. Average marketable yield: 28-32t/ha; maturity: 125-135 DAT; TSS: $11.5\text{-}12.5^0$ Brix. Field tolerance to thrips and foliar diseases.
41	Bhima Shakti	ICAR-DOGR, Rajgurunagar	Recommended for Chhattisgarh, Andhra Pradesh, and Delhi, Uttar Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, and Rajasthan. *Late kharif*- Gujarat, Karnataka, Maharashtra; Average marketable yield- 22-24t/ha; maturity- 100-110DAT; Dark red in colour; flat glob shape bulb;
42	Bhima Light Red	ICAR-DOGR, Rajgurunagar	Recommended for Maharashtra and Tamil Nadu for *rabi* season. Average marketable yield is 38.5 t/ha; matures in 115 days; TSS: 13^0 Brix. Almost free from doubles and bolters.
43	Bhima Shweta	ICAR-DOGR, Rajgurunagar	Recommended for Chhattisgarh, Maharashtra, Madhya Pradesh, Karnataka, Rajasthan and Tamil Nadu for *kharif*;. For *rabi*- Andhra Pradesh, Bihar, Chhattisgarh, Delhi,

			Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab and Uttar Pradesh; Average marketable yield: 18-20t/ha (*kharif*), 26-30t/ha (*rabi*); matures in 110-120 days, White in colour, suitable for processing.
44	Bhima Shubhra	ICAR-DOGR, Rajgurunagar	Recommended for Chhattisgarh, Maharashtra, Madhya Pradesh, Karnataka, Rajasthan and Tamil Nadu for *kharif* season; For *late rabi*- Gujarat, Karnataka, Maharashtra; Average marketable yield: 18-20t/ha (*kharif*), 36-42t/ha (late *kharif*); maturity: 110-115 days; White in colour; suitable for processing. TSS: 10-12^0 Brix.
45	Bhima Safed	ICAR-DOGR, Rajgurunagar	*Kharif* – Chhattisgarh, Gujarat, Karnataka, MP, Maharashtra, Orissa, Rajasthan and Tamil Nadu; Average marketable yield: 18-20 t/ha; maturity: 110-120 DAT. TSS: 11-12^0 Brix; less than 5% doubles and bolters. Suitable for processing.
46	NHRDF Red -2,	NHRDF, Nashik	Recommended for Delhi, Uttar Pradesh, Haryana, Bihar, Punjab, Rajasthan, Gujarat, Maharashtra, Karnataka and Andhra Pradesh; Bulb globular round, light red, thin neck, TSS 13-14^0 Brix and dry matter 14-15 %, matures in 100-120 days. Moderately resistant to foliar diseases like *stemphylium* blight. Average yield: 300-350 q/ha. Keeping quality good up to five months with total losses of 18-25 %.
47	Pusa Shobha	IARI, New Delhi	Bulbs flat globe; Brownish in colour; TSS $17^0 \pm 2^0$ Brix; Suitable for storage, drying, processing and export; Average yield- 250.4 qt/ha; Maturity: 140-160 days.; Recommended for Delhi, Uttar Pradesh, Haryana, Bihar, Punjab, Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh and Orissa

Multiplier Onion

46	CO-1	TNAU, Coimbatore	Medium plant height with green leaves; Medium sized bulblets of red colour; 7-8 bulblets /plant; Average weight of bulblets is 55-60 g/ clump; Average yield 10 t/ha; Adapted throughout Tamil Nadu; Maturity- 90 DAP. Fairly pungent with medium TSS
47	CO-2	TNAU, Coimbatore	Plant height is medium with light green cylindrical foliage; Moderately bigger size bulblets of crimpson colour; 7-9 bulblets per clump; Shorter duration than CO-1; matures in 65 days after planting; Average yield -12 t/ha; Pungent with high TSS; Adaptability throughout Tamil Nadu; Good in storage; moderately resistant to thrips and *Alternaria* blight.

48	CO-3	TNAU, Coimbatore	Plants taller than CO-1 and CO-2; Foliage light green in colour; erect cylindrical leaves; Bulblets pink in colour and bigger than CO-2; 8-10 bulblets per plant; weighing 75 g per clump; Maturity in 65 DAPS; Moderately resistant to thrips; Average yield -16 t/ha; TSS 13%; Good in storage; No sprouting up to 120 days.
49	CO-4	TNAU, Coimbatore	8-10 bulblets per plant with light brown colour bulbs weighing 90 g per clump; Maturity- 60-65 DAP. Average yield -18 t/ha; Moderately resistant to thrips.
50	MDU-1	TNAU, Coimbatore	Developed at Madurai campus; Plant with medium height and leaves cylindrical light to dark green; Bulbs uniform, bigger in size with bright red in colour; Adapted in Southern districts of Tamil Nadu; Weighing 75 g per clump; 10-11 bulblets /plant; Average yield 15 t/ha; Maturity- 60-75 DAP. Good in storage; Tolerant to lodging due to thick erect leaves.
51	Agrifound Red	NHRDF, Nashik	Developed at Dindigul; light red in colour; Average size of cluster 7.15 cm, weight 65-67 g.; Number of bulblets /cluster 5.79 (average); weight of single bulblet - 8.85 g; Maturity- 65-67DAP. Average yield- 18-20 t/ha.

Chapter 4

GOOD AGRICULTURAL PRACTICES OF NUTRIENT AND WATER MANAGEMENT IN ONION AND GARLIC

Thangasamy, A. and Major Singh
ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune-410505
Email: astsamy@yahoo.co.in

Irrigation and fertilization are the two most important factors in crop production. Total nutrient consumption ($N+P_2O_5 + K_2O$) is 25.95 million metric tonne (MMT) in 2016-17. N consumption at 16.74 MMT and P_2O_5 at 6.71 MMT registered decline of 3.7% and 3.9%, respectively, during 2016-17 over the previous year. However, K_2O consumption at 2.51 MMT increased by 4.4% during the period. Per hectare use of total nutrients reduced from 134.9 kg in 2015-16 to 130.8 kg in 2016-17. All-India NPK use ratio changed from 7.2:2.9:1 during 2015-16 to 6.7:2.7:1 during 2016-17 (FAI 2017). The increased rate of grain production is much lower, illustrating that the nutrient use efficiency (NUE) is very low and a large amount of fertilizer nutrients are lost to the environment. Fertilizer use efficiency in Indian agriculture is quite low even with good management practices. Efficiency of N fertilizer use seldom exceeds 40%. P and micronutrients the efficiency is only 20% and 2%, respectively and for K, the efficiency is about 50%. Nutrient use efficiency is also low in onion and garlic crops.

Onion and garlic are important bulbous vegetable crops grown in India, and have higher nutritive and medicinal values. India ranks second in area and production of onion and garlic next to China. The production onion and garlic during last decade were increased by 195 and 104%, respectively. The increase in production of onion and garlic are mainly due introduction of high yielding varieties, application of chemical fertilizers, intensive farming and bringing the non-traditional areas under cultivation. However, productivity of these crops increased marginally. The lower increase in productivity could be due to unbalanced use of fertilizers and poor irrigation management practices. The use of precision irrigation and fertilizer application technology may increase nutrient use efficiency and yields sustainably.

Integrated nutrient management technology

Current fertilization practices are largely based on empirical methods, which frequently result in the over-application of nutrients (Passam and Rekoumi 2009), with consequent wastage and damage to the environment (Addiscott *et al.* 1991). Integrated nutrient management technologies have been developed to avoid over-application of fertilizers. Integrated nutrient management technology is an age-old concept. Its importance was not realized earlier as nutrient removal by the crops was very low due to subsistence farming. At present, IPNS system has a great significance because of intensive farming. Its need in modern agriculture has arisen due to high price of chemical fertilizers, unbalance in NPK use, and deterioration of soil health, consumption of non-renewable energy sources by inorganic fertilizers, organic materials as a source of secondary and micronutrients (Mahajan *et al*., 2008). Inclusion of organic manures in IPNS can reduce costly inorganic fertilizer requirement and save energy by reducing the fertilizer production. Several studies had been conducted to evaluate the effect of combined application of inorganic and organic manures on yield and yield parameters at different locations.

Vinay Singh and Manoj Pandey (2006) reported that application of 75% NPK along with 10 t FYM/ha and *Azotobacter* produced yield at par with 100% recommended dose of fertilizers which was significantly higher over the control without fertilizer application in sandy loam soils of Bichpuri, Uttar Pradesh. Similarly, combined application of 75% NPK, 10 t FYM or 5 t Poultry manure or 5 t vermi-compost/ha and *Azotobacter* produced yield at par with 100 % RDF + 20 t FYM/ha and 100 % RDF at Rajgurunagar (Thangasamy and Lawande, 2015). Similar results were recorded at Srinagar, Udaipur, Dharwad, Samastipur, Hisar, and Jabalpur. However, mean bulb yield recorded varied significantly between different locations (AINRPOG Annual report, 2011). Qureshi and Lawande (2006) revealed that onion yield was increased with increasing sulphur nutrition level up to 75 kg/ha in low sulphur soils (<10 ppm S) while no increase was recorded in soils having high sulphur levels (Yoo *et al.*, 2006). Further, application 20 kg S/ha was found to be sufficient for optimum onion bulb production in soils having sufficient sulphur level. Continuous application of sulphur to onion crop at 50 kg/ha to soils having low sulphur level every season over the decade enhanced the soil sulphur level to sufficient level (Thangasamy *et al.*, 2013).

Field experiment was conducted to evaluate the effect of integrated use of inorganic fertilizers with poultry manure, or farm yard manure and vermicompost with nine treatments at Rajgurunagar, Durgapura, Jabalpur, Hisar and Kanpur through All India Network Research Project on Onion and Garlic. The results showed that application of 75:40:40:40 kg NPKS/ha along with organic manures (FYM, Poultry manure and Vermicompost) equivalent to 75 kg N/ha produced bulb yield at par with 100:50:50:50 kg NPKS + 20t FYM/ha at Rajgurunagar, Jabalpur and Durgapura. The bulb yield at Rajgurunagar, Jabalpur and Durgapura ranged from 4 to 8 t/ha. Whereas application of 100:50:50:50 kg NPKS + 20t FYM/ha significantly increased garlic yield over 75:40:40:40 kg NPKS/ha along with organic manures (FYM, Poultry manure and Vermicompost) equivalent to 75 kg N/ha at Hisar and Kanpur where the bulb yield ranged from 8-15 t/ha. Post harvest soil analysis showed that application of organic manures significantly increased soil organic carbon over NPK alone applied treatments (AINRPOG, 2013). Application of recommended organic manures, inorganic fertilizers and foliar application of Fe or Zn at 60 and 70 days after transplanting significantly increased plant vegetative growth (Singh and Tiwari, 1995) and bulb yield and quality of onion (Singh and Tiwari, 1996) Integrated use of inorganic fertilizers, vemicompost and foliar application of micronutrient mixture increased onion yield by 16.9% followed by foliar application of zinc sulphate @ 0.5% (10.5%) and foliar application of boric acid @ 0.25% (8.3%) in comparison to control (Thangasamy et al. 2016). By adopting of these technologies, the farmers can save 25% mineral fertilizers without reducing yield. Even now, there is a scope to increase nutrient use efficiency and bulb yield in these crops by matching nutrient supply and demand.

Nutrient requirement of onion and garlic crops

Fertilizer is applied mainly in the form of a base dressing followed by additional side dressings of N up to 60 days after planting. Increasing concern about damage to the environment caused by the excessive use of synthetic fertilizers necessitates the implementation of rational fertilizer application programmes (Addiscott et al. 1991).

Table 1 Nutrient uptake/dry matter accumulation by onion cv. Bhima Kiran to produce 45 t onion bulbs/ha and garlic cv. Bhima Omkar to produce 6–8 t/ha of garlic

	Onion				Garlic			
	Nutrient uptake/dry matter accumulation			Harvest	Nutrient uptake/dry matter accumulation			Harvest
Nutrient/dry matter	Leaves	Bulbs	Total	Index	Leaves	Bulbs	Total	Index
Dry matter yield (kg/ha)	708.9	3604.2	4313.1	83.6	1144.0	4231.0	5375.0	78.7
Nitrogen (kg/ha)	6.1	74.4	80.5	92.5	14.5	103.4	117.9	87.7
Phosphorus (kg/ha)	0.5	15.3	15.8	97.1	1.1	13.2	14.3	92.4
Potassium (kg/ha)	15.6	52.8	68.4	77.2	26.7	48.3	75.0	64.4
Sulphur (kg/ha)	1.7	13.1	14.8	88.6	3.5	34.4	38.0	90.7
Iron (g/ha)	543.0	592.0	1135.0	52.2	2014.9	3791.2	5806.1	65.3
Zinc (g/ha)	17.2	90.5	107.7	84.1	23.7	133.0	156.7	84.9
Manganese (g/ha)	42.9	65.3	108.2	60.4	54.6	124.0	178.6	69.4
Copper (g/ha)	2.7	10.8	13.5	79.9	5.3	13.0	18.2	71.1
Boron (g/ha)	407.0	1273.0	1680.0	75.8	-	-	-	-

For developing rational fertilizer application programmes of onion and garlic, knowledge on total nutrient requirement, nutrient uptake pattern and the distribution of nutrients among the tissues of the plant are required. The research conducted at different locations in India showed that the onion crops required about 2.10 – 2.16 kg N, 0.70-0.80 kg P_2O_5, 2.00-2.25 kg K_2O and 0.25-0.30 kg S to produce one tone of onion bulbs (AINRPOG Annual report, 2011). Similarly, the results of field experiment conducted at China indicated that onion crop needs about 2.93, 1.16 and 2.69 kg of N, P_2O_5 and K_2O for one tone of onion bulbs, respectively (Zhao *et al*., 2009). Dogliotti (2003) also reported that the onion crop removed 1.92 kg N, 0.30 kg P and 1.30 kg K to produce one tone of onion bulbs. From this, it is clear that the nutrient requirements to produce one tone of onion bulbs are more or less similar at different locations. However, The actual nutrient needs of onion and garlic largely depends on growing season, variety, yield goal, and soil fertility status. Total nutrient uptake and harvest index of onion and garlic were also more or less same (Table 1). The total nutrients removed by these crop should be replaced through external sources to sustain soil health and increase yield.

Nutrient uptake pattern of onion and garlic crops

The dry-matter accumulation and nutrient-uptake pattern is essential for optimizing quantity and timing of fertilizer application for onion and garlic. Appropriate fertilizer timing and placement must coincide with onion growth stages for maximum nutrient uptake, higher bulb yield and better quality. The dry-matter accumulation and nutrient uptake in onion and garlic followed the sigmoid growth curve pattern (Sullivan 2001; Thangasamy 2016; Thangasamy and Chavan 2017). The research conducted at ICAR-Directorate of Onion and Garlic Research revealed that uptake of nitrogen and potassium in onion was slow for the first 15 days (Figure 1). Rapid uptake of N and K occurred during

15 to 60 days after transplanting and accounted for 76.2–78.2% of total uptake. Uptake of phosphorus, sulphur, manganese, zinc, and copper uptake was greater during 30 to 75 days after transplanting and accounted for 64.9–70.6% of total uptake (Thangasamy, 2016). Thangasamy and Chavan (2017) reported that the garlic plants accumulated 84.7 and 84.6% of total nitrogen (N) and potassium (K) from planting to 75 days after planting (DAP). The peak N and K uptake coincided with the active vegetative growth stage (Figure 2).

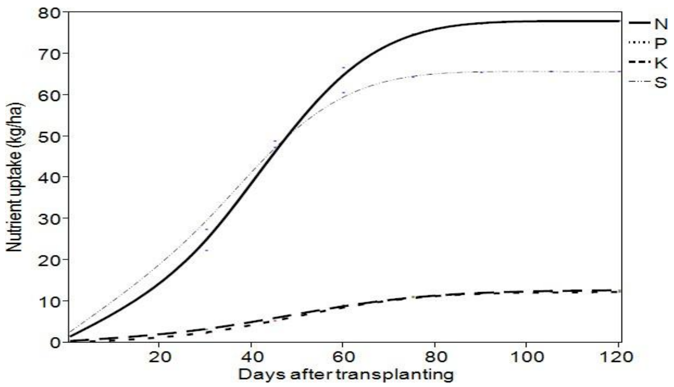


Figure 1 Macronutrient uptake pattern of onion

Whereas, the total phosphorus (P), sulphur (S), zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) uptake accounted for 59.5-66.7% of total uptake from planting to 75 DAP. The peak uptake of these nutrients coincided with bulb initiation and development stages. However, onion and garlic crop require micronutrients till maturity and need to apply micronutrients till maturity (Figure 3 and 4). N is very mobile and a portion can be absorbed through the leaf, strategic timing would be particularly beneficial for farmers. Generally, nitrogen fertilizers are top-dressed during active vegetative growth stages (15-60 days after planting) of onion and garlic. If N deficiency occurs during growth period, foliar application N fertilizers recommended. P and K fertilizer would be applied continuously to the root zone during early to mid-plant growth stages when P and K uptake are high. However, because P is very immobile and K is relatively immobile in the soil, this is not practical. In-season applications will likely not work their way into the root zone and foliar applications are not very effective since little P or K is taken up directly through the leaf. Therefore, P and K are best applied prior to planting through broadcasting. Sitthaphanit et al. (2009) reported that less than 20 percent of total N,

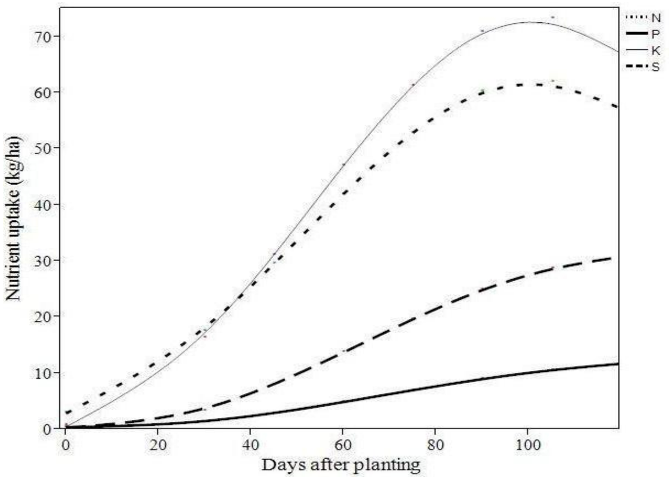


Figure 2 Macronutrient uptake pattern of garlic

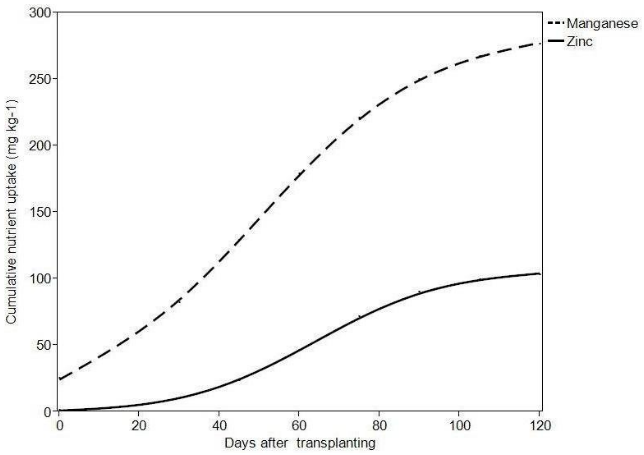


Figure 3 Manganese and zinc uptake pattern of onion

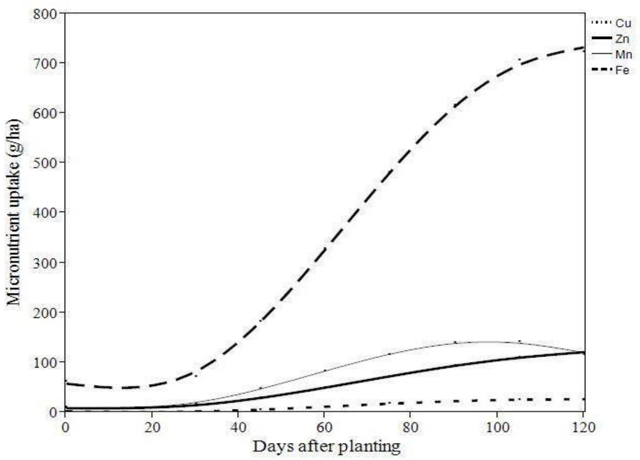


Figure 4 Micronutrient uptake pattern of garlic

phosphorus (P), and potassium (K) uptake occurs during the first 4 weeks of planting, a basal application of fertilizer does not synchronize with the crop nutrient demand. Absorption of N, P and

K in onion at the seedling stage was very low, which accounted for about 4% of the total nutrient requirement. Maximum uptake was recorded during active growth stages (Zhao *et al*. 2009). Onion and garlic are a shallow-rooted crop and the root system is restricted to the top 0–15 cm during the first 30 days of growth (Thangasamy et al., 2010). The excess nutrients applied as a basal dose may leached to the subsurface with percolating irrigation water beyond its active root zone (Sitthaphanit et al. 2009). Therefore, fertilizer application should match crop nutrient uptake to increase nutrient-use efficiency and crop productivity (Heckman 2003). The method and timing fertilizer application is very important for obtaining higher nutrient use efficiency. Fertilizer should be applied in small amounts regularly (Neeraja et al. 1999) to increase nutrient use efficiency and reduce leaching loss (Shock et al. 1995).

Fertilizer application through drip system

Fertigation is the precise application of fertilizers along with irrigation water to meet the current crop demand. Water and plant nutrient losses could be minimized along with better fertilizer use efficiency in fertigation. Other advantages include direct supply of nutrients to the root zone of the plant and, therefore, nutrient balance in the soil can be optimized. Minimizing the use of soil as a storage reservoir for nutrients and water leads to less nutrient fixation and losses by either leaching and/or volatilization. Fertigation also provides flexibility in timing of fertilizer application in relation to crop demand in addition to improved yield and water use efficiency. Currently in water constrained countries such as India, fertigation seems to be the best available technique for judicious water and fertilizer supply for better yield.

Savitha et al. (2010) reported that application of 75% recommended dose of fertilizers through drip system produced significantly higher bulb yield compared to soil application 100% RDF at the time of transplanting in both big and multiplier onion. Priyanka et al. (2015) reported that application of fertilizer nutrient significantly increased onion yield in comparison to soil application. Mohammad and Zuraiqi (2002) reported that application of nitrogen fertilizers increased garlic yield and nitrogen and water use efficiency compared to soil application. Shedeed et al. (2009) reported that fertigation with 100% NPK water soluble fertilizers increased tomato fruit yield significantly (58.8 t/ha) compared to furrow irrigated control, drip irrigation, 50% fertigation (48.2 t/ha) and 75% NPK fertigation (54.2 t/ha). Gupta et al. (2015) reported that drip irrigation at 80% ET and fertigation with 60% recommended NPK significantly enhanced fruit yield of (989.3 q/ha), higher water use efficiency (49.9 q/ha-cm) and fertilizers use efficiency (10.9, 18.3 and 27.4 q/kg NPK, respectively). Application of 100% RDF (110:40:60:30 kg NPKS/ha) at 6 days interval through drip irrigation system increased marketable bulb yield by 20.8-56.3% compared to flood irrigation with broadcasting method of fertilizer application. In garlic, application of 100% (100:50:50:30 kg NPKS/ha) at 6 days interval + 5 t compost /ha increased marketable yield by 9.42-50.7% compared to the control. In both the crops, higher benefit cost ratio was recorded in treatment received 100% RDF at 6 days interval + 5 t compost /ha followed by 80 and 60% RDF. Furthermore, application of fertilizers through drip system significantly reduced post harvest losses compared to the control (AINRPOG Annual report, 2021).

Nutrient balance approach

Currently, the fertilizer rates are quantified using empirical methods and therefore, should be used within the same environments where they have been developed. This limitation is partially overcome by methods which are based on the principles of plant nutrition. One of these methods is the nutrient balance approach (Kee *et al.*, 1994). The nutrient balance approach specifically attempts to balance the nutrient demand with the nutrient supply. The components of nutrient demand are plant nutrient uptake for growth and production, nutrient losses through soil processes such as runoff and leaching (environmental losses) and nutrient immobilization. The components of nutrient supply are precipitation, pruned fronds, applied by-products such as empty fruit bunches. Any shortfall between nutrient supply and demand is met by fertilizer input. Ng (1977) considered the major variables in the nutrient balance sheet to be soil nutrient supply and plant nutrient demand. The INFERS model is a nutrient balance approach, which is based on achieving a predicted site yield potential and takes into account nutrient supply and demand (Kee *et al.*,1994).

Site specific nutrient management

An alternative to blanket guidance, site specific nutrient management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through four key principles (Table 2). The principles, called the "4 Rs", date back to at least 1988 and are attributed to the International Plant Nutrition Institute (Bruulselma et al. 2012). They are: right product, right rate, right time and right place. SSNM will ensure balanced nutrition for the crop and reduce the risk of nutrient deficiencies and decreased crop yield. It should also reduce fertilizer loss, increase nutrient use efficiency and is an environmentally sensitive management strategy.

Table 2 Examples of key scientific principles and associated practices of 4R nutrient stewardship

SSNM principle	Scientific basis	Associated practices
Product	Ensure balanced supply of nutrients Suit soil properties	Commercial fertilizer Livestock manure Compost Crop residue
Rate	Assess nutrient supply from all sources Assess plant demand	Test soil for nutrients Balance crop removal
Time	Assess dynamics of crop uptake and soil supply Determine timing of loss risk	Apply nutrients: Pre-planting At planting At vegetative stage At bulb development
Place	Recognize crop rooting patterns Manage spatial variability	Broadcast Band/drill/inject Variable-rate application

Water management

Water requirement of any crop depends upon the nature of crop, soil, evapotranspiration rate of that particular locality and stage of growth of plant. Onion and garlic are an important bulb vegetable cultivated all over India having very shallow roots and frequent irrigation is necessary for better growth and bulb development. This crop is very sensitive to moisture stress conditions during bulb initiation and development stages. Its root system is normally restricted to top 3 cm and roots penetrate seldom deeper than 15 cm. The water requirement of the crop at the initial growth period is less and also depends on crop growth, soil type and planting season

The most common method of applying water to the onion and garlic is border strip flooding or furrow irrigation. Irrigation requirement of onion and garlic depends on the season, soil type, method of irrigation and age of the crop. In general, onion and garlic needs irrigation at the time of planting, three days after planting and subsequent irrigation at 7-10 days interval depending upon the soil type and moisture content. In general, *kharif* crop needs 5-8 irrigations, late *kharif* crop requires 10-12 and *rabi* crop needs 12-15 irrigations while garlic require about 12-15 irrigations. Frequent irrigation during early crop growth period and more frequent applications during bulb development are essential. Onion and garlic consume less water immediately after the establishment of the crop but the consumption increases with advance of the season. Irrigation needs to be stopped when the crop attains maturity (10-15 days before harvest). In case of onion, Irrigation needs to be stopped when top starts falling which helps in reducing the rotting during storage. Excess irrigation is always harmful and dry spell followed by irrigation will result in splitting of the outer scales and also formation of bolters in onion. Irrigation at 10-12 days interval during November–December, 10 days interval during January and 7 days interval during February was optimum for successful *rabi* onion and garlic production at Maharashtra particularly Pune conditions. In clay soils of Andhra Pradesh, irrigation at 5 days interval gave higher yields of December-May crop and an average total of 12-15 irrigations are essential to complete life cycle of onion grown during *rabi* season.

Research carried out at Bangalore indicated that maintenance of soil water potential of – 0.85 bar or less either during pre bulb development (20 - 60 days after transplanting) or bulb development stages (60-110 days after transplanting) significantly reduced onion bulb yield and bulb development stage was found to be more sensitive to moisture stress than pre bulb development stage (Hegde, 1986). According to Saha *et al.* (1997) optimum exploitation of the yield potential of Taherpuri onion, with maximum efficiency of irrigation water use, 10 to 20% depletion of field capacity moisture might be the most suitable criteria for irrigation. Koriem *et al* (1999) revealed that water consumptive use of onion cv. Giza 6 plants increased with increasing available soil moisture. Water use efficiency was the highest when irrigation was with held, followed by irrigation after depletion of 30 percent of available soil moisture. According to Ramamoorthy *et al.* (2000) onion cv. CO - 4 was irrigated at IW/CPE values of 0.6, 0.8, 1.0 or 1.2 during the *kharif* and *summer* seasons. Bulb yield increased as IW/CPE values are increased. Water use efficiency was higher when onions were irrigated at IW/CPE of 1.2.

Bulbs grown under low moisture are liable to dry out earlier and lose more weight during storage than those grown with adequate moisture. Over irrigation as well as under irrigation may result into lower yields. The foliage of onion and garlic receiving excessive irrigation acquires an appearance of yellowish green colour. Irrigating heavily at the time of harvest or within 1-2 weeks of harvest may cause immature bulbs, thick-skinned bulbs. Frequent irrigation also delays maturity of onion bulbs. When the plants start to mature, irrigation should be discontinued and the soil allowed to dry out as much as possible which facilitates the bulbs to mature quickly, otherwise secondary growth may start, which is very difficult to stop and also complicate the process of proper curing of onions. Moreover, irrigation after leaf withering pre-disposes the bulbs to infection by *Fusarium.* Frequent irrigation reduces the total soluble solids of the bulbs. Moisture stress increases No_3 - N content in bulbs.

Micro irrigation

In India, flood irrigation method is widely practiced, which results in inefficient use of irrigation water due to different losses *viz*. losses in evaporation, deep percolation and distribution. At the same time, water use efficiency of properly designed and well-managed micro irrigation system may go up to 90 percent. Modern irrigation techniques such as drip and micro sprinkler irrigation help in saving irrigation water and improve the marketable bulb yield significantly. Micro irrigation also ensures higher water use efficiency. Several research workers reported that through micro irrigation, higher crop yields can be obtained along with considerable saving in irrigation water (Bhonde *et al*. 2003, Sankar *et al*. 2008).

Modern irrigation techniques such as drip and micro sprinkler irrigation helps in saving irrigation water and improve the marketable bulb yield of onion and garlic. In case of drip irrigation, onion and garlic need to be planted at a spacing of 10 x 15 cm in a broad bed furrow (BBF) of 15 cm height and 120 cm top width with 45 cm furrow. Each BBF should have two drip laterals at (16 mm size) 60 cm distance with inbuilt emitters. The distance between two inbuilt emitters should be around 30-50 cm and the discharge flow rate is 4 l/hr. In case of micro sprinkler, the distance between two laterals (20 mm) of micro sprinkler should be 6 m and with a discharge rate of 135 l/hr. According to Gorantiwar *et al.* (1991), the highest yield (441.76 q/ha) and water use efficiency were obtained with drip irrigation in onion cv.N-2-4-1 in comparison to furrow and sprinkler irrigation. Studies at MPKV, Rahuri revealed that the highest bulb yield was obtained with drip irrigation at 100 percent CPE. Water use efficiency was higher with all rates of drip irrigation than with surface irrigation. Patil *et al.* (2000) reported that both the micro irrigation system (drip and drip tape) were superior over control and overall 53-69 percent water saving was achieved in white onion cv. Phule Safed during summer season. According to Gethe *et al.* (2006) higher water use efficiency in onion was obtained in raised bed planting with micro sprinkler irrigation method. The research outcome from ICAR-DOGR indicated that both drip and micro sprinkler irrigation systems improved growth, yield and yield contributing parameters of onion and garlic. Among the different irrigation methods and levels tested, drip irrigation at 100% pan evaporation showed the higher marketable bulb yield, more percentage of A grade bulbs combined with improved post-harvest storage life of onion and garlic followed by micro sprinkler irrigation at 100% pan evaporation. Moreover, it was clearly indicated from the experiment that the saving of irrigation water was to the tune of 37.8 percent in drip irrigation and 32.5 percent in sprinkler irrigation system under the best treatment as compared to surface irrigation, when it was scheduled at 50mm CPE with 7 cm depth (Sankar *et al*. 2008).

Summary

Implementation of improved nutrient management can not only improve onion and garlic yield, but also enhance nutrient use efficiency coupled with better economic returns to farmers while reducing environmental risks. The actual nutrient needs of these crops largely depend on growing season, variety, yield goal, and soil fertility status. Currently, blanket fertilizer recommendations have been followed for onion and garlic. Hence, decision support system for fertilizer management needs to be developed with available nutrient uptake data for estimating fertilizer demand for different location. Decision support system for fertilizer management and the 4R Nutrient Stewardship approach may provide a framework to identify the best options to meet nutrient demands of these crops. Appropriate fertilizer timing and placement must coincide with critical growth stages for maximum nutrient uptake, higher bulb yield and better quality. In addition, micro-irrigation with broad bed furrow system showed better in onion and garlic

Reference

Addiscott, T. M., Whitmore, A. P. and Powlson, D. S. (1991) Farming, Fertilizers and the Nitrate Problem. CAB international, Wallingford, U.K., pp170.

AINRPOG Annual report (2011). All India Network Research Project on Onion and Garlic Annual report. Directorate of Onion and Garlic Research, Rajgurunagar. Pune.

AINRPOG Annual report (2013). All India Network Research Project on Onion and Garlic Annual report. Directorate of Onion and Garlic Research, Rajgurunagar. Pune.

AINRPOG Annual report (2021). All India Network Research Project on Onion and Garlic Annual report 2019-2020. Directorate of Onion and Garlic Research, Rajgurunagar. Pune.

Bairagi, P., Yadav, S. R. and Dinesh Kumar (2015). Response of onion (*Allium cepa* L.) to different levels of NPK and FYM under arid condition of Rajasthan. *An Asian Journal of Soil Science.* 10(1):42-46.

Bruulselma TW, Fixen PE, Sulewski GD (eds) (2012). 4R Plant Nutrition Manual: A Manual for Improving the Management of Plant Nutrition. International Plant Nutrition Institute (IPNI), Norcross, GA, USA.

Dogliotti, S. (2003). Exploring options for sustainable development of vegetable farms in South Uruguay, Ph. D. Thesis, Wageningen University, Wageningen, The Netherlands.

FAI (2017). Annual review of fertilizer production and consumption 2016-17. *Indian Journal of Fertilizers*. October 2017. pp.97-99. https://www.faidelhi.org/general/Executive%20summary.pdf.

Gethe, R.M., Pawar,V.S., Sonawane, D.A and Kadlag, A.D (2006) Influence of planting, layouts, irrigation regimes and fertilizer levels on growth and yield of onion under microsprinkler. *Journal of Maharashtra Agricultural University* 31(3), 272-4.

Gorantiwar,S.D., Papattiwar, P.S., Legad, S.M and Borude, D.M. (1991) Evaluation of sprinkler and border methods of irrigation for onion. *Maharastra Journal of Agriuculture* 5;2, 88-92:6.

Gupta, A. J., Chattoo, M. A., and Singh, L. (2015). Drip irrigation and fertigation technology for improved yield, quality, water and fertilizer use efficiency in hybrid tomato. ***Journal of AgriSearch***. 2(2):94-99.

Heckman, J. R. (2003). Comparative nutrient demand and fertilizer practice. *Soil Profile Newsletter*. 12–13:1–8.

Hegde, M.(1986) Effect of irrigation regimes on drymatter production, yield, nutrient uptake and water use of onion. *Indian Journal of Agronomy* 31, 343-348.

Kee, K. K., Goh, K. J., Chew, P. S. and Tey, S. H. (1994). An integrated site specific fertilliser recommendations system (INFERS) for high productivity in mature oilpalms. In: ISP Planters' Conference on Managing Oil Palms for Enhanced Profitability (Chee, K.H., ed.), Inc. Soc. Planters, Kuala Lumpur: 83-100.

Koriem,S.O., Koliey,M.M and El Sheekh, H.M.(1999) Effect of drought conditions on yield, quality and some water relationships of onion. *Assiut Journal of Agricultural Sciences*, 30: 1, 75-84; 21.

Mahajan, A., Bhagat, R. M. and Gupta, R. D. (2008). Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. *SAARC Journal of Agriculture*. 6(2): 1-16.

Mohammad, M. J. and Zuraiqi, S. (2002). Enhancement of yield and nitrogen and water use efficiencies by nitrogen drip-fertigation of garlic. *Journal of Plant Nutrition*. 26:9. 1749-1766. DOI: 10.1081/PLN-120023280.

Neeraja, G., Reddy, K. M., Reddy, I. P. and Reddy, Y. N. (1999). Effect of irrigation and nitrogen on growth yield and yield attributes of Rabi onion (*Allium cepa*) in Andhra Pradesh. *Vegetable Science*. 26 (1): 64–68.

Ng, S. K. (1977). Review of oil palm nutrition and manuring – scope for greater economy in fertilizer usage. *Oleagineux*. 32: 107-209.

Passam, H. C. and Rekoumi, K. (2009). Okra in Greece – production and constraints. In: Dhankhar BS and Singh R. (eds) Okra Handbook, HNB Publishing, N.Y. pp. 347-359.

Patil,S.L., More, N.N., Firke., Desale,S.B and More,T.A. (2000) Effect of micro irrigation system and nitrogen fertigation levels on yield and quality of white onion.cv. Phule Safed during summer season. Paper presented in *National symposium on onion and Garlic production and Post harvest management Challenges and Strategies* held at Nashik.

Qureshi, A. A. and Lawande, K. E. (2006). Response of onion (*Allium cepa*) to sulphur application for yield, quality and its storability in S-deficient soils. *Indian Journal of Agricultural Sciences.* 76(9):535-537.

Ramamoorthy, K., Selvaraj, K.V. and Velayutham, A.(2000) Effect of irrigation and nitrogen levels on bulb yield of small onion (*Allium cepa* L.). *Madras Agricultural Journal* 86: 1-3, 140-141.

Saha, U.K., Khan, M.S.I., Haider, J and Saha, R.R (1997) Yield and water use of onion under different irrigation schedules in Bangladesh. *Japanese Journal of Tropical Agriculture* 41: 4, 268-274.

Salo, T., Suojala, T. and Kallela, M. (2002). The effect of fertigation on yield and nutrient uptake of cabbage, carrot and onion. *Acta Horticulturae*. 571, 235-241.DOI: 10.17660/ActaHortic.2002.571.28.

Sankar,V., Lawande, K.E. and Tripathi.P.C.(2008) Effect of micro irrigation practices on growth and yield of onion. *Indian Journal of Agricultural Sciences* 78 (7), 584-588.

Savitha, B. K., Paramaguru, P. and Pugalendhi, L. (2010). Effect of drip fertigation on growth and yield of onion. *Indian Journal of Horticulture*. 67: 334-336.

Shedeed, S. I., Zaghloul, S. M. and Yassen, A. A. (2009). Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. *Ozean Journal of Applied Sciences.* 2(2): 139-147.

Shock, C., Holmes, Z., Stieber, T., Eldredge, F.and Zhang, P. (1995). The effect of timed water stress on quality, total solids and reducing sugar content of potatoes. *American Journal of Potato Research*. p70.

Singh, D. P. and Tiwari, R. S. (1995). Effect of micronutrients on growth and yield of onion (*Allium Cepa* L.) variety Pusa Red. *Recent Horticulture*. 2(2):70-77.

Singh, D. P. and Tiwari, R. S. (1996). Effect of micronutrients on yield and quality of onion (*Allium Cepa* L.) variety Pusa Red. *Recent Horticulture*. 3(1):111-117.

Sitthaphanit, S., V. Limpinuntana, B. Toomsan, S. Panchaban, and Bell, R. W. (2009). Fertiliser strategies for improvednutrient use efficiency on sandy soils in high rainfall regimes. *Nutrient Cycling in Agroecosystems*. 85 (2):123–39. doi:10.1007/s10705-009-9253-z.

Sullivan, D. M., Brown, B. D., Shock, C. C., Horneck, D. A., Stevens, R. G., Pelter, G. Q. and Feibert, E. B. G. (2001). Nutrient management for onions in the Pacific Northwest. Pacific Northwest Extension Publication. PNW 546, Corvallis, USA.

Thangasamy A. (2016). Quantification of dry matter accumulation and nutrient uptake pattern of short day onion (*Allium cepa* L.). *Communications in Soil Science and Plant Analysis*. 47(2):246–254, DOI: 10.1080/00103624.2015.1118116.

Thangasamy, A. and K. E. Lawande (2015). Integrated nutrients management for sustainable onion production. *Indian Journal of Horticulture*. 72 (3):347-352.

Thangasamy, A. and K. M. Chavan (2017). Assessment of dry matter accumulation and nutrient uptake pattern of garlic crop. *Indian Journal of Horticulture*.74(1). 80-84.

Thangasamy, A., Kalyani Gorrepati, Vanita Salunkhe, Gawande, S. J., Chavan, K. M., and Kedar Pathak (2016). Effect of micronutrient application on onion production and storage life. Souvenir: Second National Symposium on edible Alliums: Challenges and future strategies for sustainable production held at Jalna.

Thangasamy, A., Sankar, V., Lawande, K. E. (2010). Integrated nutrient management in onion and garlic. *Indian Journal Fertilizers* 6(11): 100–107

Thangasamy, A., V. Sankar, and K. E. Lawande, (2013). Effect of sulphur nutrition on pungency and storage life of short day onion (*Allium cepa*). *Indian Journal of Agricultural Sciences*. 83 (10):1086-1089.

Vinay singh and Manoj Pandey (2006). Effect of integrated nutrient management on yield of and nutrient uptake by onion and on soil fertility. *Journal of the Indian Society of Soil Science*. 54(3): 365-367.

Yoo, K.S., Pike, L., Crosby, K., Jones, R. and Leskovar, D. (2006). Differences in onion pungency due to cultivars, growth environment, and bulb sizes. *Scientia Horticulturae*. 110:144–149.

Zhao, K., Xu, K., Xu, N. and Wang, Y.G. (2009). Absorption and Distribution of Nitrogen, Phosphorus and Potassium in Onion. *Plant Nutrition and Fertilizer Science.* 15(1):241-246.

Chapter 5

INTEGRATED DISEASE MANAGEMENT OF ONION AND GARLIC PATHOGENS

Suresh J. Gawande
ICAR-Directorate of Onion and Garlic Research, Pune-410505
Email: suresh.gawande@icar.gov.in

Diseases caused by fungi and viruses are the major constraints for onion and garlic production. Under favorable condition up to 100% losses have been reported due to various diseases. Although, many fungicides have been reported to be effective against diseases but they comes with their hazardous effect on health and environment. Unfortunately, very few cultivars have been reported to be tolerant to various diseases of onion and garlic. Many biocontrol agents have been reported to be effective against fungal foliar diseases of onion and garlic but their utility at field level is limited. Due to these issues, integrated disease management (IDM) is a most viable option to manage the diseases of onion and garlic. Therefore, here, we will be discussing briefly the major diseases of onion and garlic and IDM strategy to manage them. Both onion and garlic have common pathogens, therefore, the management strategy for both the crop is similar to each other. Among the diseases, Stemphylium blight caused by *Stemphylium vesicarium* is one of the most devastating disease infecting onion and garlic globally. During the past 20 years, this disease has come to prominence in temperate and tropical regions throughout the world. It is a major disease of onion in Southeast Asia and India (Gupta *et al.* 1994). It has been reported from all over India (AINRPOG, disease survey). Further, this disease also reported from other onion and garlic growing regions of the world. Its outbreaks caused significant losses in Texas and New York in North America (Miller *et al.* 1978; Lorbeer 1993). It frequently occurs at the same time and on the same plants as *Alternaria porri*, the cause of purple blotch, as a disease complex. The fungus has also been recorded from Europe, Africa, North and South America (Ellis, 1971). In some fields, foliage losses of 80-90% were recorded. Similarly, purple blotch is a pandemic disease known to cause heavy yield losses. This disease has been observed throughout the world, but is most serious in hot humid climates. Apart from onion, the pathogen attacks members of *Allium* family including onion (*A. Cepa*), Egyptian onion (*A. proliferum*), Welsh onion (*A. fistulosum*), leek (A. *ampeloprasum* var. *porrum*) and possibly others (Shef and Macnab, 1986). The name purple blotch was proposed by Nolla (1927) who named the fungus *Alternaria allii sp nov*; which was later amended *Alternaria porri* (Ellis) Cif. Anthracnose is predominantly observed whenever kharif onion is grown. In India 80% of Kharif area is from Maharashtra and Karnataka. This disease is a predominantly observed in these two states during kharif season. The third important disease infecting onion particularly in kharif season is anthracnose or twister caused by *Colletotrichum gloeosporioides.* Anthracnose is major limiting factor in case of kharif onion production since Kharif onion production is crucial for stabilizing onion prices during Oct-Nov, when stored Rabi onions are not available in the market. The disease was first recorded during 1924-1925 in the eastern and northern part of Puerto Rico (Nolla, 1926). Presently it has been

reported from Africa, Brazil, Asian countries. Acquina and Wandesly (1966) reported anthracnose as "Seven Curls" as a serious disease in Brazil. Onion twister disease was reported from Africa near Zaria, northern Nigeria, in 1969 (Ebenebe, 1980), where there have been 50-100% losses in yield.
In India, it was 1st recorded from the Lonand area of Satara district in Maharashtra during 1981. It was further observed during 1982 and 1983 on crops grown in Nashik and Pune districts and it was reported from Karnataka during 1987 (Qadri & Shrivastava, 1985; Quadri 1988).

In the past, there was controversy regarding etiology of twister disease symptoms. Asif *et.al*. (1976); Viets; (1967) reported possible causes of symptoms to be zinc deficiency or virus/mycoplasma infection. Robbs *et.al*. (1972) reported *Fusarim oxysporum f. cepae* to be causal organism for these symptoms. Finally, Ebenebe (1980) conclusively proved *Colletotrichum gloeosporides* to be causal organism of the twister disease. Among viral diseases, *Iris yellow spot virus* (IYSV) is one of the major tospovirus responsible for significant losses in bulb and seed onion crop in India and other onion growing parts of the world. Upto 100% yield yield losses recorded due to IYSV. In India, IYSV has been reported on onion, garlic and chives. This virus is transmitted by persistent and propagative manner by thrips. Earlier, *Thrips tabaci* was the only known vector of IYSV but, recently, in USA, *Frankliniella fusca* was also reported to vector IYSV with low efficiency beisdes IYSV.

Integrated management strategy for onion diseases

Clean cultivation: Pathogens of onion and garlic survives on debris of previous crop. Similarly, weeds and volunteer plants also helps in survival of the pathogens. Removal of debris from previous crop helps to lowering the initial load of pathogen inoculum.

Drainage: Onion and garlic crops are highly sensitive to low and excess moisture. This moisture stress make both the crop highly vulnerable to various pathogens. For example, under high soil moisture, the incidence of fungal diseases such as anthracnose and stemphylium blight flares up. Therefore, water stagnation in the field should be avoided. Growing of onion on raised bed helps for good drainage and avoids water stagnation which ultimately results in checking disease incidence.

Judicious use of fertilizer: Application of fertilizers beyond recommended dose is detrimental to the health of the onion and garlic crop. Particularly, high nitrogen doses increases the incidence of fungal diseases and viral diseases by attracting vectors such as thrips. High fertilizer application also causes high percentage of rotting during storage thereby reduces the storage life of onion.

Use of bioagents: Bioagents such as Trichoderma, fluorescent Pseudomonas, *Bacillus subtillis* not only manages the diseases but they also have growth promoting effect on the onion and garlic crop. Besides these biocontrol agents, endosymbionts such as VAM and Piriformospora indica have been demonstrated to have growth promoting and systemic resistance inducing effect on onion crop.

Crop rotation: Crop rotation is an important practice that helps in avoiding perpetual buildup of pathogen in the soils. For onion and garlic, dicots such legume crops should be preferred since legume fixes nitrogen, this helps in nutrient availability too. Long term crop rotation proven to be helpful in managing basal rots of onion rot garlic caused by *Fusarium oxysporum* fsp. *cepae*.

Use of tolerant cultivars: Unfortunately, here we have very limited options available in India. Very few cultivars shows resistance to the diseases. Although cultivar such as Arka Kalyan reported to be resistance to purple blotch disease but, this cultivar is recommended for cultivation in the limited parts of India.

Seed treatment: Seed treatment is an integral part of IDM for onion and garlic. Seed treatment not only protects the seed from pathogens but it also reduces the initial incidence of the diseases. Seed treatment with Trichoderma 5-10gm/kg or Carbendazim 3gm/kg of seed is recommended for onion. For garlic clove treatment with 3 gm/kg of cloves is recommended. Similarly, dipping of seedlings in 0.1% Carbandazim at the time of transplanting is recommended to manage the soilborne and foliar diseases of onion.

Chemical fungicides: Use of fungicides should be the last option for the management of the diseases of onion and garlic. Need based application of fungicides is advised for managing diseases of onion and garlic. Fungicides such as Hexaconazole (1g/L), Tricyclazole (0.1gm/L) is recommended for managing fungal foliar diseases of onion and garlic. Some commercial mixed formulations such as Cabriotop, Amistertop and Avancer Glow are also found effecting in managing diseases of onion and garlic.

Chapter 6

MANAGEMENT OF FUNGAL DISEASES IN ONION AND GARLIC

Ram Dutta*, Sharath MN and Major Singh
ICAR-Directorate of Onion and Garlic Research, Pune-410505
*Email: ram.dutta@icar.gov.in

As we know, the onion and garlic are the most profitable and highly cultivated spice-vegetable crops, full yield potential of these crops is not realized due to number of constraints. Among the various constraints, vulnerability of the crop to different diseases encountered during the production, storage and marketing are more crucial. Economic losses due to diseases vary significantly across three seasons. Being favourable environmental conditions, *kharif* rainy crop is more prone to disease attacks resulting in sometimes 50-60% of yield loss as compared to 20-30% yield loss in *rabi* crop. In this chapter, we have tried to incorporate the desired information for important fungal diseases and their management.

Damping-Off Disease

Damping-off is a serious problem in onion nurseries, more prevalent during *kharif* season and reduces seed germination, poor stand of seedlings and leads to seedling mortality of about 60-75%.

Symptoms:

- Damping-off occurs in two stages, i.e., the pre-emergence and the post-emergence phase as in the field patches in which all plants are killed.
- In the pre-emergence, seedlings are killed just before they reach the soil surface. The young radical and the plumule are killed and there is complete rotting of the seedlings.
- The post-emergence phase is characterized by the infection of the young seedlings. The young tissues of the collar at or below the ground level. The infected tissues become soft and water-soaked. The seedlings topple over after they emerge from the soil and the plant collapses.

Causal organism: It is caused by several soil-inhabiting fungi predominant being *Pythium aphanidermatum, Pythium debaryanum, Phytophthora spp*. *Rhizoctonia solani and Fusarium spp. Colletotrichum circinanas* has also been found involved in causing damping-off in warm humid conditions. Damping-off and delayed seedling emergence is also caused by *F. oxysporum* f.sp. *cepae*.

Favourable Conditions:

- Overcrowding of the seedling.
- Ill drained nursery beds / Excessive and frequent irrigation
- Heavy shade in nursery
- High atmospheric humidity (90-100 %)
- High soil moisture with temperature around 25 °C

Disease Cycle: The disease is soil-bornein nature and the practice of monoculture together makes the crop prone to disease. The pathogen survives in the soil and on infected seed, crop debris as oospores, and chlamydospores. The primary infection is from the soil-borne fungal spores and secondary spread through sporangia and zoospores transmitted by wind and irrigation water.

Management:

- Deep Summer ploughing
- Soil solarization
- Sowing onion on the raised bed
- Healthy seeds for sowing
- Raising seedlings in Portrays
- Avoid excess irrigation and overcrowding of seedlings
- Seed treatment with *Trichoderma harizianum* at 10 g/kg seed or Thiram / Captan at 3g/kg or carbendazim at 2 g/kg seed
- Soil application of *Trichoderma harizianum* at 5 Kg enriched in 250 kg of FYM per ha.
- Drenching the nursery beds by Captan or Thiram at 0.2% or Carbendazim at 0.1% (avoid Carbendazim, in case using *Trichoderma*) or Copper oxychloride at 0.3%. or Metalaxyl at 0.2%.

Purple Blotch

The disease is also known as leaf spot or blight disease of onion and is the most destructive disease that prevails in almost all onion growing areas during *kharif* and *rabi* and drastically reduces the yield. The intensity of the diseases varies from season to season, variety to variety and region to region.

***Symptoms*:**

- The symptoms appear after 1-4 days of infection appears on leaves, scapes, pseudostem, and bulbs
- Initially small, elliptical water-soaked lesions with small white centers or white sunken spots appear
- Lesions usually appear on older leaves and that often turn purplish-brown which are surrounded by a chlorotic margin as the disease progresses
- If the spots enlarge, the chlorotic margin extend above and below the actual lesion and becomes zonate. Under moist conditions, lesions get covered with brown to dark gray fungal sporulation
- In advanced stages, lesions coalesce to form larger spots leads to girdling of leaves, causing them to necrosis and wilt, which then delays bulb formation and maturation. Lesions may also start at the tips of older leaves
- Bulbs are usually infected through neck wounds and become undersized due to which yields are reduced
- Infection can cause a semi watery rot on necks of bulbs or bulb rot begin as soft like water-soaked areas, and eventually turn into dark reddish-purple and then brownish/black lesions within 5 days
- Infected bulb tissues eventually become papery and finally leads to decay

Causal organism: The pathogen of this disease is *Alternaria porri*, causing most destructive disease of *Allium* spp. (onion, garlic, shallots, leeks, scallions and chives). The pathogenicity of *Alternaria spp*. is due to the production of host-specific or nonspecific toxins that may induce disease.

Favourable conditions:

- ❖ High humidity 80–90%
- ❖ Warm temperature 21–30°C
- ❖ Frequent rain and dews
- ❖ Prolonged leaf wetness (12 hours or more)

Disease Cycle: Diseased debris containing pathogen fruiting body with conidia in the farm field or nearby farm is the primary source of inoculum for succeeding bulb crop followed by seed crop of onion. The fungus survives as dormant mycelium and remains viable for 12 months and also survives as chlamydospores. It is seed-borne in nature and initiates the disease. Spores formed during humid nights and leaf wetness periods >12 hrs. The fungal infection/spores spread within and among fields by wind, rain, and splashing water and it does spread by the punctures made by thrips, the opening of stomata pores, and epidermal layers. Susceptibility is influenced by age of crop, season, foliage architecture, insect injuries. Secondary spread of the is disease favoured by warm temperature, humidity, and prolonged leaf wetness.

Management:

- ❖ Field sanitation
- ❖ Crop rotation with non-hosts
- ❖ Raised bed with good drainage
- ❖ Use disease-free seeds for sowing
- ❖ Avoid sprinkler irrigation
- ❖ Optimum spacing for planting (15cm x 10cm)
- ❖ Avoid excess nitrogenous fertilizer applications
- ❖ Seed treatment with Thiram or Captan or Mancozeb at 3 g/kg seed
- ❖ Soil application of *Trichoderma* spp. at 5 Kg enriched in 250 kg of FYM per ha.
- ❖ Spray fungicides, Mancozeb @ 0.25% / Tricyclazole @ 0.1% / Hexaconazole @ 0.1% /Propiconazole @ 0.1% at 10-15 days intervals from 30 days after transplanting or as soon as disease appears

Stemphylium Blight

Stemphylium blight has become an economic threat for past few years, especially in Northern and Eastern India and it was more severe in *rabi* than in the *kharif* season causing huge crop losses. The disease associated with purple blotch becomes complex and difficult to manage.

Symptoms:

- ❖ Pathogen infects plants after long, warm periods when leaves remain wet and the symptoms appears on the radical leaves at 3-4 leaf stage.

- ❖ Small yellow to orange flecks or streaks develop in the middle of the leaf which soon develop into elongated, spindle-shaped to ovate elongate diffused spots surrounded by characteristic pinkish margin.
- ❖ The spots progress from the tip to the base of the leaves. The spots coalesce into extended patches, blighting the leaves and gradually the entire foliage.
- ❖ Another typical symptom is necrotic dieback of the leaf tips. As the disease spreads, the lesions rapidly progress along with the leaf initially in an asymmetric pattern causing longer lesions down one side of the leaves but eventually resulting in complete defoliation.
- ❖ Production of conidia is commonly observed on lesions it turns from light brown to tan purple at the center and later to dark olive-brown to black. Similar symptoms appear on scapes too.
- ❖ The disease can prematurely defoliate the crop which can deteriorate the bulb quality and making it more susceptible to secondary and postharvest infections

Causal organism: Stemphylium blight caused by hemibiotrophic pathogen *Stemphylium vesicarium*. It is presumed that the fungus survives on alternate hosts in the absence of onion crop.

Favourable conditions:

- ❖ Warm temperature 18- 25 °C
- ❖ Relative humidity 78-91%
- ❖ Prolonged leaf wetness (16 hours or more)

Disease cycle: Pathogen survives in crop debris or/and volunteers from the previous season acts as the primary source of inoculum. The pathogen colonizes crop debris and produces pseudothecia and conidia. Conidia can be spread by wind and/or rain splash over short distances to infect through stomata or directly through the leaf epidermis. Ascospores are liberated and transported by wind to facilitate longer-range, between field spread resulting in new infections if deposited in susceptible hosts. Multiple infection cycles from conidia result in rapid spread and polycyclic epidemics. Onion thrips (*Thrips tabaci*) have also been implicated in the spread of *S. vesicarium* through direct transfer of conidia.

Management:

- ❖ Field sanitation collection and burning of crop residues
- ❖ Long crop rotations with non-host crops
- ❖ Good field drainage
- ❖ Reduce the plant density by optimum spacing (15 cm x 10cm)
- ❖ Avoid excess nitrogenous fertilizer applications
- ❖ Seed treatment with Thiram or Captan or Mancozeb at 3 g/kg seed
- ❖ Soil application of *Trichoderma* spp. at 5 Kg enriched in 250 kg of FYM per ha.
- ❖ Spray fungicides, Mancozeb @ 0.25% / Tricyclazole @ 0.1% / Hexaconazole @ 0.1% /Propiconazole @ 0.1% at 10-15 days interval from 30 days after transplanting or as soon as disease appears

Anthracnose / Twister / Colletotrichum Blight

Onion anthracnose-twister or seven curl a disease of rainy season onion, reported to be widespread throughout the world but more usual in the tropics and subtropics. The disease is severe during *kharif* season causing huge losses, if the disease is not taken care of.

Symptoms:

- ❖ Pathogen affects leaves, leaf sheath, neck and bulbs.
- ❖ The characteristic symptoms are curling, twisting, chlorosis of the leaves, and abnormal elongation of the neck or pseudostem followed by bulb rotting.
- ❖ Initially white or pale-yellow water-soaked oval sunken lesions appear on leaf blades at the early vegetative stage.
- ❖ As the disease progresses lesions get enlarged and extended covering the entire leaf later numerous black colored slightly raised structures/fruiting bodies are produced in the central portion, which may be arranged in concentric rings.
- ❖ At the final stages, these lesions become paper-like and brittle; this can easily fall off at the point of lesion. In severe conditions, the lesion can be seen on bulb scales, rotting of bulbs and death of the whole plant
- ❖ The roots of infected plants become sparse and shorter.
- ❖ The affected plants produce slender bulbs which decay rapidly in storage. In severely affected crops there is no bulb formation and the plant dies before bulb formation.

Causal organism: Disease caused by *Colletotrichum gloeosporioides*, a facultative parasite having a wide host range and *Glomerella cingulata* is the perfect state. In *Allium* majorly *C. gloeosporioides, C. acutatum and C. coccodes* are causing anthracnose which is also suspected to be the cause of twisting and abnormal neck elongation due to excessive accumulation of gibberellins in onions. Twister disease is complex in nature caused by pathogens *Colletotrichum spp*. and *Fusarium spp*.

Favourable conditions:

- ❖ Humidity 85-96%
- ❖ Optimum temperature (20-31°C)
- ❖ Cloudy rainy weather in the crop stand

Disease cycle: The fungus survives and overwinters in infected crop debris or seed as acervulli hence it is seed borne in nature and transmits through seedlings and bulbs. The pathogen also survives in alternate hosts because *C. gleosporioides* having wide host range. The disease progression depends on the intensity and frequency of rainfall. This disease more severe in *kharif* season. The secondary spread takes place through airborne conidia and rain splash, irrigation water and also through insects.

Management:

- ❖ Field sanitation, destruction of crop debris
- ❖ Crop rotation for 3-4 years
- ❖ Planting onion on the raised bed
- ❖ Avoid waterlogging
- ❖ Seed treatment with Thiophanate methyl @ 1.5 g/kg or captan 3g/kg seeds
- ❖ Seedling dip with *Trichoderma harzianum* 10 g/lit water

- ❖ Foliar Spray of Mancozeb @ 0.25% or Cabrio top @ 0.1 or Hexaconazole @ 0.1%.
- ❖ Soil application of *Trichoderma* spp. at 5 Kg enriched in 250 kg of FYM per ha. This may be repeated at 35 DAT and 65 DAT to effectively manage disease.

***Fusarium* Basal Rot/Basal Rot**

Fusarium basal rot is an important disease of *Allium* crops appearing at pre- as well as post-harvest. The disease is prevalent in all parts of the world where onion and garlic are grown causing sizeable crop losses.

Symptoms:

- ❖ Disease occurs in patches; leaves turn yellow and then dry up slowly.
- ❖ As infections progress, wilting and rapid die-back of leaves from the tips occurs.
- ❖ Affected roots are dark brown to dark pink.
- ❖ Whitish mould growth appears on the scale.
- ❖ The bulbs become soft and when cut a watering decay is noticed.
- ❖ Under dry conditions, stem plate tissues become pitted and show dry rot.
- ❖ Under storage the disease may continue if the conditions prevail as 30-40 °C temperature and above 70% relative humidity.

Causal organism: Fusarium basal rot caused by a complex set of *Fusarium* species, generally *Fusarium oxysporum* f.sp. *cepae,* which is a soil-borne pathogen that can survive in the soil for many years as chlamydospores or as saprophyte on crop residues. *Fusarium* also causes damping-off, wilting, root rot and seed infection and leads 30-40% storage losses of bulbs.

Favourable conditions: The disease generally appears when the soil temperature is 25-28 °C along with high soil moisture. Relative humidity is above 70%.

- ❖ Stress due to high temperature and drought increases the disease incidence.
- ❖ Basal rot is more severe in transplanted onion than direct seeded onion

Disease cycle: Pathogen perpetuates in soil through chlamydospores. Under favourable conditions, this inoculum can infect and colonize the host, resulting in disease symptoms. Primary infection of *Fusarium* spp. occurs when the fungus penetrates directly into roots or through wounds on roots or on the basal plate of bulb scales or bulbs by onion maggots (*Delia antique*) or other insects. The fungus may be disseminated by infected onion sets, movement of infested soil on equipment and irrigation water.

Management:

- ❖ Deep summer ploughing and soil solarization
- ❖ Follow long crop rotation with Maize or spring wheat
- ❖ Mixed cropping with tobacco, sorghum
- ❖ Avoid injuries during inter cultivation
- ❖ Flooding the soil in off-season.
- ❖ Green-manuring increases antagonistic microbial population in the soil
- ❖ Proper curing of onion and storing at cool temperature.

- Seed treatment or seedling dip with *T. viride + P. fluorescens* (5g/lit water) reduces basal rot incidence.
- Dipping of seedlings before transplanting in the suspension of carbendazim (0.1%)
- Soil application of *Trichoderma harzianum, T. viride, T. koningii, T. hamatum, T. pseudokoningii, Psuedomonas fluorescens* and *Bacillus subtilis.*
- Pre-harvest sprays of carbendazim (0.2%).
- Spraying of 0.1% carbendazim at 30, 20, 10 days before harvest reduce the post-harvest decay in storage.

White Rot / *Sclerotium* Rot

White rot of onion is found in destructive condition at onion growing regions. Under favorable environmental conditions, plants can become infected at any stage of growth. Onion and garlic grown in white rot infested fields can suffer plant losses of up to 20-40%.

Symptoms:

- The infected plants show yellowing and wilting of leaves. The tip of the leaves starts drying from the tips backward, droop down and appear blighted.
- At later stage of infection base of stem and leave sheath rots and collapsed.
- Yellowing and wilting of the leaves and the plants gradually declined and collapsed.
- Bulbs are decayed, watery, soft and are covered with white cottony mycelial growth of the fungus accompanied by the presence of small, circular, white, brown and black sclerotia interspersed among the mycelial growth and infected tissues.

Causal organism* and *Disease Cycle:

Sclerotium cepivorum is the causal fungus, which is polyphagous in nature and infects a large number of both monocotyledonous and dicotyledonous crops. The fungus has a broad host range. The disease is worst in warm summers or in the case of winter onions during warm spell in autumn or spring. Sclerotia persist in soil for longer period and it can over-winter in infected onion debris and in diseased onion sets. The primary inoculum consists of spherical small black sclerotia produced in infested fissure of *Allium* spp. during previous years. Sclerotia are transported from field to field by floodwater. The sclerotia that form on the decaying host will lay dormant until a host plant's root exudates stimulate germination, specifically root exudates that are unique to *Allium* spp. Cool-weather is also needed for germination of sclerotia and hyphal growth. The soil moisture levels optimal for host root growth are also optimal for sclerotia germination. Mycelium will grow through the soil, and once it encounters a host root the fungus will form appressoria, structures whose purpose is to aid in the attachment and penetration of the host. Mycelium can grow outwards from the roots of one plant to the roots of a neighbouring plant, and it is by this method that the pathogen can move down a planted row. Sclerotia are formed on the decaying host tissue, and once the host tissue completely decays the sclerotia are free in soil. If the bulbs survive long enough to be placed into storage, the pathogen may continue to decay the bulbs if there is high humidity and low temperatures. If the bulbs are stored dry then the disease may not spread but bulbs infected in the field will continue to decay.

Favourable conditions: This disease is most severe in cool and dry soils. Optimum soil temperature for infection ranges from 15-20 °C.

Management:

- Do not move infected bulbs, and soil from infested to non-infested fields.
- Cleaning of equipment before moving from one field to another.
- Soil solarisation with white polyethylene sheets in the nursery.
- Deep summer ploughing
- Use disease free set or bulbs for transplanting
- Soil application of *Trichoderma viride, T. harzianum Gliocladium zeae, Bacillus subtilis* and Arbuscular mycorrhizal fungi reduces the disease.
- Application of Iprodione @ 0.25% or copper oxychloride @ 0.3% reduces the disease incidence.

Botrytis Leaf Blight

Botrytis leaf blight is the major disease of onions in cool climate areas. Light infections do not affect yields but heavy infections causing major yield reductions. Botrytis leaf blight, often termed as “blast”, is a foliar disease common to onion growing regions in eastern and midwestern states. The disease causes leaf spotting and tip dieback, and can adversely affect the maturity and quality of the bulbs.

Symptoms:

- The disease develops in two stages: a leaf spotting phase followed by a leaf blighting phase.
- The disease appears first as leaf lesions 24 to 48 h after inoculation. Tissue maceration then occurs as a result of pectolytic enzymes produced over several days. The lesions on leaves are whitish, 1 to 5 mm in length, and generally surrounded by a greenish-white halo that first appears water soaked.
- As the lesion ages, the center becomes sunken, straw-colored, and sometimes develops a slit oriented lengthwise along the lesion.
- Older onion leaves are more susceptible than younger leaves
- Partial or complete leaf blighting generally occurs within 5 to 12 days after initial lesion development under optimum conditions for BLB development.
- Onion fields with severe infections often take on a yellowish cast as a result of coalescing lesions on the leaves, leaf tip dieback, and leaf blighting.
- The disease then spreads very rapidly and tops of the entire crop may be killed.
- Necrotic tissue plays an important role in the epidemiology of BLB, as it is the site for secondary conidial production by *B. squamosa* under moist conditions

***Causal organism* and *Disease cycle*:**

Botrytis squamosa is the causal organism, which overwinters as sclerotia formed on infected onion leaves and necks of onion bulbs that remain in the field as crop debris or in cull piles. Ascospores produced within apothecia, which develop from the sclerotia can infect onion leaves but are not considered a significant source of primary inoculum. In the areas of year-round onion cropping, onion leaves can also be infected by conidia produced on infected leaves of neighboring fields. Sclerotia of *B. squamosa* have the ability to produce conidia repeatedly, which results in production of initial inoculum over a prolonged period in *rabi* and early summer.

Favourable conditions**:** Optimum temperature 3 to 27°C, long leaf wetness period (8 and 22 hrs). Relative humidity > 70% for at least 6 h.

Management**:**

- Destruction of cull piles
- Crop rotation out of onions for at least 2-3 years
- Bulb treatment with Captan /Thiram @ 0.25%.
- Spraying of Mancozeb or Copper oxychloride @ 0.25% at 7-10 days interval helps is managing disease.

Pink Root Rot

The disease mainly a field disease and damaging effects are primarily on the growing plant, but losses can also occur during transport and storage. Pink root often occurs in association of *Fusarium* basal rot.

Symptoms:

- The fungus attacks onion from the seedling stage onwards.
- The roots are affected and turn yellow then pink or reddish and sometimes darken to a red or purple colour black spores form on the diseased roots which eventually shrivel and die.
- New roots are formed throughout the season and these may be infected and killed successively and the disease is confined to roots.
- Diseased plants can be easily pulled. The above-ground symptoms are stunting and yellowing tip burn and dieback of the leaves.
- Affected seedlings may be killed. Older plants are not normally killed but bulb formation is affected and yields are low.
- Bulbs are not attacked although the outer scales may be penetrated but the development of bulb retarded.

Favourable conditions**:**

- Optimum temperatures for growth of the pathogen and disease development 24-28 °C
- Plant stresses such as drought, cold, nutrient deficiencies/toxicities, insects and other diseases can increase the disease severity.
- Poorly drained soils that are low in organic matter
- High soil moisture

Causal organism* and *Disease cycle: Disease is caused by *Pyrenochaeta terrestris* and *Fusarium* spp. Pink-root fungus can persist in the soil, in diseased roots and on the debris of susceptible crops for several years. Dissemination results from movement of spores, infested soil and plant residue by agricultural tools, wind and surface irrigation or drainage water.

Management

- Long crop rotations should be practiced to prevent the build-up of inoculum in the soil.
- Soil Solarization or soil fumigation may help.
- Use healthy planting material in disease-free, well-prepared, well-drained, fertile soil.
- *Allium fistulosum,* leeks and chives are highly resistant.

Downy Mildew

Downy mildew is widely distributed in all continents, particularly temperate growing areas of the world. In cool and humid weather, the disease can be highly destructive, causing losses in both yield and bulb quality. In India downy mildew is still limited to Jammu & Kashmir and Uttarakhand states where it can cause up to 12-75% bulb yield losses.

Symptoms:

- The fungus causes both systemic and local infections.
- Plants raised from infected bulbs are showing systemic infection, which remain stunted, distorted and pale in colour.
- Local infection is caused by wind-borne conidia, which produce oval to cylindrical spots, which are violet to purple in colour. Under humid weather, greyish violet downy growth of the fungus can be seen on the affected portion.
- Affected leaves become pale green, fold over and collapse.
- Older leaves are attacked first and the infection spreads to sheath.
- Lesions on seed stems are circular to elongate, often affecting only one side of the stalk.
- They weaken the stalk so that it breaks over from the weight of the seed umbel, thereby causing the seeds to shrivel.
- The pathogen also may infect flower parts and maybe carried with the seeds.

Favourable conditions**:** The spores are formed at night when high humidity and temperatures of 4–25˚C occur, with an optimal temperature of 13˚C. The spores mature early in the morning and are disseminated during the day. Spores remain viable for about 4 days. Germination occurs in free water from 1– 28˚C with an optimal range of 7–16˚C. Rain is not needed for infection if heavy dews occur continuously during the night and morning hours.

Causal organism* and *Disease Cycle: Downy mildew is caused by *Peronospora destructor***.** The fungus attacks the seed stalks in a seed crop but true seeds do not help in carry over of the fungus from one season to the next. The main sources of perennation are the diseased bulbs used for propagating the crop. It is believed that the DM fungus over winters primarily as mycelium in infected onions that remain in onion fields or in nearby cull piles.

Management**:**

- Bulbs used for seed production should be selected from disease-free fields.
- 3-4 years crop rotation with non-host crops.
- Well-drained land should be used.
- Rows should be planted in the same direction as prevailing winds.
- Dense population of plants and windbreaks or other protection should be avoided.
- Use surface and drip irrigation rather than sprinkler irrigation.
- Infected crop debris and refuse heaps of onion culled from storage should be disposed properly.
- Late planting, higher doses of fertilizers and frequent irrigation should be avoided as these practices encourage high disease incidence.
- Bulb and seedling dip in Ridomil MZ @ 0.25% for 12 hours, followed by sprays of Mancozeb @ 0.25% starting 20 days after transplanting at 10-12 days interval gives effective disease control.

Black Mold

Black mold is a post-harvest disease that occurs in the field as well as storage conditions. In India after *rabi* harvest to *kharif* harvest i.e. from May to October, farmers prefer to store *rabi* harvested bulbs for sale and seed production as there is no production of onions in between.

***Symptoms*:**

- The primary symptom is a black discoloration of tissue and is easily detected with a black sooty mass and these powdery masses are arranged at the neck and beneath the outer scales in streaks, or spots of black.
- Fungal spores may develop between dry, dead outer scales and the first inner fleshy scales of the bulb neck and progress downward.
- Invaded scales initially become water-soaked, and spores often appear in a streaking pattern along veins.
- Occasionally, interior parts of the bulb may be affected with gray-to-black discoloration without showing external symptoms.
- Under dry conditions, diseased scales dry and shrivel, and black masses of spores are visible between outer scales.
- Affected parts may also be invaded by soft rot bacteria, causing the whole bulb to deteriorate into a watery soft rot.

Causal Organism:

Black mold of onion is caused by the fungus *Aspergillus niger*, which survives on decaying organic matter such as plant debris, and is a weak pathogen that generally does not affect uninjured bulbs. The fungus is widely distributed among soil environments as a saprophyte and the infection occurs when spores land and colonize the tissue through wounds, or cut necks at harvest and natural openings.

Favourable environment:

The fungus grows within all onion tissues as an endophyte, but only causes symptoms on plants when environmental conditions are favourable. It occurs on both onions and garlic, but is more of a concern in onion crops. Moisture for 6 to 12 hours on the onion surface and a temperature of 28-34 ^{o}C with a relative humidity of 80% is ideal for the disease to develop. This situation may occur, if bulbs are damp while storage.

Management: There are no fungicides for the direct control of black mold, hence cultural management will be effective and economical,

- Use healthy and clean seeds for cultivation and follow crop rotation.
- Avoid bruising and injury during harvest, handling, and transport
- Harvest onions promptly and do not delay drying.
- During harvesting the neck length should be 20mm.
- Maintain stable temperatures during transport, as well as when bulbs are going into and coming out of storage.
- Shade curing up to 21days and avoid high-temperature curing.

- Sorting of bulbs should be done at the field level, which eliminates pathogen inoculum during storage.
- After curing, bulbs can be stored at a low temperature (2-12 ^{o}C) and humidity (80%).
- Storage condition should be well ventilated. Avoid high temperature and high relative humidity during storage conditions.

__Chapter 7__

INTEGRATED PEST MANAGEMENT IN ONION AND GARLIC CULTIVATION

V. Karuppaiah*, Soumia P.S and Major Singh
ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra-410505
*Email: karuppaiahv2008@gmail.com

India is the world's second-largest producer of onions. Indian onions are famous for their spice, and it is in high demand internationally. However, productivity is very low compared to the global average due to various constraints. Amongst, insect pests are one of the significant constraints that cause significant economic loss. Onion thrips are India's most widespread and severe pest of onion, causing damage either directly by feeding injury or indirectly through viral disease transmission. The tobacco caterpillar, beet armyworm, black cutworm, green-looper, red spider mite, eriophyid mite, aphids and leaf tier are other foliage and bulb damaging insect pests that infest onion and garlic in India. This chapter gives an overview of these important pests, distribution, their biology, damage symptoms and various integrated management strategies for effective control of these pests to enhance the productivity of onions.

Onion Pests

Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)

Onion thrips, *Thrips tabaci* is a major onion pest, causing yield losses of up to 50% in a severe infestation. Thrips nymphs and adults suck the leaf sap resulting in silvery leaf spots and white blotches on leaves. Excessive damage reduces the plant's photosynthetic ability, which reduces bulb weight. Thrips also act as a vector for Iris Yellow Spot Virus (IYSV), a devasting viral disease of onion that can cause complete crop failure. In this article, we have summarized the available management options for the benefit of onion growers.

Fig 1: damage by Thrips in onion

Fig 2: Thrips (nymphs and adults)

Biology: Eggs are kidney-bean shaped, tiny in size, whitish when laid and measure roughly 0.2mm in length. Eggs are deposited singly and inserted into leaf tissues. Hatching takes between 4-10 days.

Nymphs or larva are elongate and slender-bodied insects that range in colour from pale yellow to yellow. The larval stage lasts about 5-7 days. The first two instars are active and feeding stages, while the third and fourth instars are inactive and non-feeding stages known as pre-pupa and pupa. The colour of the pupa ranges from pale yellow to brown. The duration of the pupa is 3-10 days. The adults are slender, yellowish-brown, and around 1 mm long. The life cycle takes 17-30 days to complete, and it varies with climatic conditions.

Damage symptoms: Both nymph and adult thrips cause damage by rasping the leaf surface and sucking sap from the cells. Feeding causes silvery leaf spots, white blotches, and silvery patches to appear on the leaves. Damaged tissues coalesces exhibiting blast like appearance. Affected tissue will dry up when the damage is severe. Leaves that have been damaged may become papery and distorted. Infested terminals lose their colour, roll, and eventually dry from the tip downwards. Thrips also feed on bulbs at storage. Silvery scars on the outer surface of bulbs affect the appearance and quality of the bulb and fetch poor consumer attraction and market price.

Seasonality: Thrips infestation in onions persists throughout the year and crop growing period. Usually, thrips population load and build-up are slow in *kharif* onion. This is due to the amount of rains prevailing during the season and other unfavourable climatic conditions. However, thrips are a more significant concern in late *kharif* and *rabi* onions, and the population load may reach >100 thrips per plant under favourable environmental conditions. Thrips reproduce sexually as well as asexually. Parthenogenesis reproduction under favourable climatic conditions facilitates rapid population growth in a short period.

IPM strategies

Clean cultivation: Field sanitation must be maintained to avoid early infestation immediate and damage. Removal of weed species such as parthenium, wild amaranthus, milkweed and lantana in and around the field may reduce infestation. These weed species provide shelter for the off-season survival of thrips. Residual debris of previous crops is also a source of infestation and adult thrips, so it should be destroyed.

Monitoring: Periodic field inspections are necessary to detect the infestation early and take management decisions. Monitoring the field twice a week is advised. Visual counts and sampling by gently tapping leaves with white paper and can use further counting. Thirty thrips per plant are taken as the economic threshold level (ETL) to take control measures. Yellow or blue sticky cards also can be used for monitoring and mass trapping of adult thrips.

Cultural control strategies: Crop rotations with non-host crops are recommended (corn and millets). Avoid planting onions and garlic in succession. Planting two rows of maize as a barrier along with the field border 7-10 days before transplanting is advised to avoid adult thrips movements from infested to an infested field. Sprinkler irrigation is also minimizing thrips population. However, it may aggravate disease incidence.

Botanical pesticides: Use neem powder, neem-based formulations @ 2- 3% advised when the thrips load is low. This will help to conserve the existing natural enemies, including parasitoids, *Ceraneus mense* and predatory thrips, anthocorid bugs, coccinellids, and *Chrysopa* species in the onion ecosystem.

Chemical control: Effective Insecticides are the principal means of controlling thrips on onion and garlic. Dipping of seedlings roots (1/3 of the bottom of the seedlings) in 0.025% Carbosulfan (2ml/l) two hours before transplanting is recommended to avoid an early thrips attack. Foliar spray of insecticides at 30 -60 days after transplanting is essential to avoid yield loss. Insecticides like profenofos 1ml/L, carbosulfan 2 ml/L, fipronil 1 ml/L, and spinosad 0.4ml/L are recommended for the population level above ETL which is 3-5 thrips/leaf or 30 nymphs/plant. Avoid spray before three to four weeks of harvest. To ensure reasonable control always add a spreader at 0.5 ml/L of spray solution.

Common cutworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

Pest description and identification: The young caterpillars are light green with a blackhead or black dots, seen in clusters. Pupae are pale yellow to brown and pupate in the soil. Adults are slender, yellowish-brown, approximately 1 mm long, and brown. The forewings are brown with wavy white patterns, possess a reniform spot, are brown, outlined with a white margin and have a marking of the letter "A" at the apex area; the orbicular spot is elongate, narrow, oblique, light brown and outlined with a white margin. Hind wings are white with a brown patch along the edges**.** Creamy white eggs are laid in masses and covered with silky hairs.

Symptom of damage: The larva is in the damaging stage. Larvae can be found in nursery beds and newly transplanted onion fields. Larvae feed gregariously on foliage and leave a papery appearance on the leaves.

Fig 3: *S. liura* larvae and damaged leaf

Beet army worm, *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae)

Pest description and identification: The early instar larvae are pale green, turning greyish with a blackhead. Older larvae have a broad striped pattern on both sides and are usually dark green or greyish-black in colour. Pupae are light brown and pupate in the soil. Adults are medium-sized, with mottled grey and brown forewings; the orbicular spot is round and light or yellowish-brown with a white margin surrounded by a thin black margin. Whereas, the hind wings are uniform grey or white. White eggs are laid in clusters towards the apex of the leaves and covered with scales.

Symptom of damage: The larva is in the damaging stage. Larva feeds gregariously for the first few days, especially in the growing tips of the onion, by scraping the mesophyll layer. As the larvae mature, they become solitary and feed on tubular leaves by boring irregular holes. At an advanced stage, larvae tunnel through small boreholes and feed on the outer layers of the bulb, and the damage is visible superficially. It also attacks the umbel and flower stalk of the seed crop. Causes extensive defoliation, heavily infested field is visible as white papery patches from a distance.

Fig 4: *S. exigua* damage

Fig 5: *S. exigua* larvae

Green looper, *Chrysodeixis acuta* Walker (Lepidoptera: Noctuidae)

Pest description and identification: Larvae are glossy green and have three pairs of abdominal legs (prolegs); form a characteristic loop or hump while crawling (semi-loop). The pupa is green and then turns brown; it also forms a white silken cocoon. Adult moths are brown; forewings bear a dark brown pattern with two distinctive silver spots and have tiny silver spots along the median region. Hind wings are also brown. The eggs are yellowish-white and deposited singly on the leaf surface.

Symptom of damage: The larva is the damaging stage. Larvae feed on the onion leaves; early instars scrape off the leaves, making them translucent and revealing caterpillars inside the onion's circular leaves; later instars produce feeding cuts.

Fig 6: *C. acuta* larva

Fig 7: *C. acuta damage in onion*

Black cutworm, *Agrotis ipsilon* (Lepidoptera: Noctuidae)
Pest description and identification: The larvae are light grey to black and have a greasy look. Pupae are brown, spindle-shaped, formed inside a soil puparium. Adult moths have dark grey colouration with a dagger-shaped pattern on the forewing. When disturbed, the larva coils up into a 'C' shape. *A. ipisilon* is a localized pest in areas where sugarcane, maize, potato, and other crops are grown.

Symptom of damage: The larva is the damaging stage. Larvae usually hide in cracks and crevices in the soil during the daytime. Larvae feed on the tender foliage of young seedlings. Later instars of larvae cut entirely through the stalks at ground level. Onion fields irrigated with a drip system are more prone where loose, moist soil conditions exist. The damage may occur in batches, and entire fields may damage in a severe attack.

Fig 8: *Agrotis* damage in onion

Head borer, *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae)

Pest description and identification: The colour of the larva varies from greenish to brown. Green with dark brown-grey lines laterally side the body, and lateral white lines with dark and pale bands. The fully-grown larva is greenish with dark brown-grey lines along the side of the body and measures about 35-45 mm in length. The pupa is brown and occurs in soil, within stalks and crop debris. The adult is a light pale brownish-yellow stout moth. Fore wing grey to pale brown with a "V" shaped speck. The hind wings are pale smoky white with a broad blackish outer margin. The eggs are spherical, creamy white and laid singly.

Symptom of damage: The larva is the damaging stage. Head borer is a pest of onion seed crop and occurs sporadically on onion grown for seed. Larva cuts the pedicel of the flower and feeds on the stalk. Single larva can damage many flower stalks. It causes defoliation, breaking of the umbel stalk, and the formation of umbels.

Fig 9: *H. armigera* larva

Fig 10: *H. armigera* damaged umbel

Management strategies: Pheromone traps for insects *viz*., *A. ipsilon*, *S. litura and H. armigera* @ 4-5/acre can be used. Fix the traps to the supporting pole at one foot above the plant canopy. Lures should be changed at 2–3-week intervals (regular intervals). Light light traps @ 1 trap/acre 15 cm above the crop canopy can be used to monitor and mass trap adult moths.

Chlorpyriphos @ 312 g a.i/ha, quinalphos @ 250 g a.i/ha and biopesticides, *Bt* formulations 1Kg/ha and NSKE 5% also found to be promising for *S. exigua* on onion. Application of chlorantraniliprole 18.5 % SC @ 0.15 ml/lit and spinosad 45 % SC @ 0.12 ml/lit can be effective for *Spodoptera* sp. Spinetoram 12% SC is significantly effective at 36 and 45 g a.i. ha-1 when sprayed thrice at 15 days interval to minimize leaf damage on onion plants and to increase the bulb yield. Cyantraniliprole 10% OD @ 0.9 ml/lit will be used against cutworms and green looper. Flood irrigation is advised once *A. ipsilon* infestation noticed. Spraying insecticides like chlorpyriphos @ 1lit/ha and neem-based formulation @ 3% is also recommended for cutworms.

Garlic pests

Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)

Pest description and identification: Nymphs are white to pale yellow and have elongated, slender bodies and the appearance of an adult but without wings. The pupa is a pale yellow to brown. Adults are slender, yellowish-brown and measure about 1 mm in length. Males are wingless, and females have long, narrow fringed wings.

Fig 11: Thrips damage in garlic

Fig 12: Yellow nymphs of thrips

Symptom of damage: Nymphs and adults are damaging stage. Leaves curl and twist, and white or silvery patches appear at later stages. The whole plant looks blemished and turns white.

Red spider mite *Tetranychus cinnabarinus* Boisduval (Acari: Tetranychidae)

Pest description and identification: Adult females are more or less elliptical in shape and reddish in colour. Eggs are laid singly on the underside of the leaves or attached to silky webs made by the adults. Larvae are pinkish and are slightly larger than the egg.

Symptom of damage: Nymphs and adults are damaging. Adults and nymphs feed primarily on the underside of leaves**.** Feeding punctures appear as small spots stippled on the upper surface of the leaves**.** Typically, mites feed-in "pockets". Mite infestation creates silk webbing, which is usually visible. Leaves become bleached and discoloured with time, and they may fall off eventually.

Eriophyid mite, *Aceria tulipae* Keifer (Acari: Eriophyoidea)

Pest description and identification: Eriophyid mites are cylindrical/cigar-shaped, tapering from head to rear, translucent white in colour and microscopic**.** Unlike most mites, eriophyid only has two pairs of legs located near the head**.** The adult mite is about 200 to 250 µm in length and 36 to 52 µm.

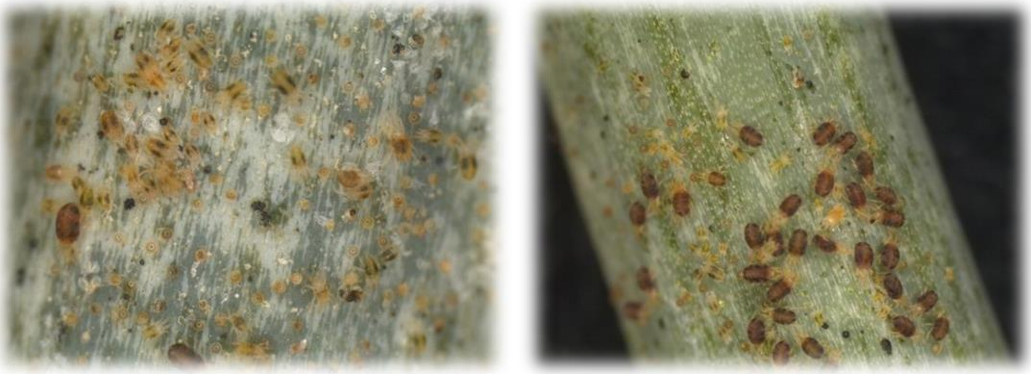


Fig 13: Red spider mites (larva, nymphs and adults)

Fig 14: Eriophyide infested garlic plant

Fig 15: Eriophyid mites

Symptom of damage: Nymphs and adults are damaging. Both adults and immature stages feed on the young leaves and infested leaves do not open completely**.** Stunting, twisting, curling and discoloration of foliage are some common symptoms. Whole plants will show curling symptom and yellow mottling on the edge of the leaves**.** Mites acts as vectors for various plant viral diseases in garlic.

Aphid *Aphis sp* and *Myzus sp* (Hemiptera: Aphididae)

Pest description and identification: *Myzus* sp nymphs are green to yellow in colour. Winged aphids have a black head and thorax, green abdomen with a large dark patch dorsally. *Aphis* sp nymphs vary from tan to gray or green, and often are marked with dark head and distal portion of abdomen dark green. Adults are light to dark green in colour.

Symptom of damage: Nymphs and adults are damaging. Both nymphs and adults suck leaf sap which causes the leaves to roll, twist and yellowing. Aphids also transmit the viral diseases in garlic.

Leaf tier *Archips machlopis* (Meyrick) (Tortricidae: Lepidoptera)

Pest description and identification: Larvae are greenish grey to whitish grey with a reddish brown head with a prominent brown prothoracic shield. Pupae are dark brown to black in colour; with a long tapering cremaster in a dense web of silk. Adult moths are cryptically coloured, with forewings grey, brown, rust, or tan coloured, have a prominent round-pointed apex with wings held in a characteristic a flattened roof shape at rest.

Fig 16: Leaf tier *Archips machlopis* damage in garlic and its larva

Symptom of damage: Larva is damaging. Larvae tie the adjacent leaves of plants together and feed the leaf tissue from inside by scraping action.

Management strategies:

- Late planting should be avoided since it has chances to harbour higher thrips population than an early sown crop.
- Avoiding successive onion and garlic planting will help to reduce the population buildup.
- All plant debris, crop residues of previous crops, weed host such as parthenium, amarathus must be adequately destroyed to prevent thrips from overwintering.
- Monitoring with blue/yellow sticky cards as well as mass trapping the adults isrecommended.
- Spray insecticides Profenofos @ 1 ml/lit, Carbosulfan @ 2 ml/lit or Fipronil @ 1 ml/lit or Spinosad @ 0.4 ml/lit when thrips population exceeds the economic threshold level for 30 thrips/plant
- Spray broad spectrum insecticide Profenofos @ 1 ml/lit against aphids.
- Apply sulphur @ 2 g/lit once the plant shows mite infestation symptoms. And repeating the spray after 15 days will provide substantial control of mite.

References

Karuppaiah, V., Soumia, P. S. and Major Singh. 2019. Occurrence of green semi-looper, *Chrysodeixis acuta* Walker in onion (*Allium cepa* L) (Amaryllidaceae). *Florida Entomologist*, 102(4): 783

Karuppaiah,V., Soumia, P.S, Thangasamy, A. and Mahajan, V. 2016. Incidence of black cutworm *Agrotis ipsilon* in Rabi onion. DOGR News, 20(2):6-7

Mala, J. (2013). Off seasonal survival of onion thrips, *Thrips tabaci* Lindeman infesting onion (*Allium cepa*). Insect Environment, 19(3):193-194

Rao D. V. S and Subbaratnam G V. 1999. Seasonal incidence and population dynamics of Spodoptera exigua (Hubner) in onion. *Pest Management and Economic Zoology*, 7: 39-45

Ravi, K.S., Kitkaru A.S and Winter, S. 2006. Iris yellow spot virus in onions: a new tospovirus record from India. *Plant Pathology,* 55(2):288 – 288

Satyagopal, K., Sushil, S.N., Jeyakumar, P., Shankar, G., Sharma, O.P., Boina, D., Sain, S.K., Ram Asre, Kapoor, K.S., Arya S., Kumar, S., Patni, C.S., Chattopadhyay, C., Pawar, S.A., Abhishekh Shukla, Usha Bhale, Basanagoud, K., Mishra, H.P., Suresh, Ekabote, D., Thakare, A.Y., Halepyati, A.S., Patil, M.B., Sreenivas, A.G., Sathyanarayana, N. and Latha, S. 2014. AESA based IPM package for onion. Department of Agriculture and cooperation, Ministry of Agriculture, Government of India. P 60

Soumia P.S, Karuppaiah V., Mahajan V. and Singh M. 2020. Beet armyworm, Spodoptera exigua: Emerging threat to onion production. *National Academy Science Letters*: doi.org/10.1007/s40009- 020-00892-5

Soumia, P.S., Karuppaiah, V and Singh, M. 2017. Managing *Thrips tabaci* - a pest of national significance. *Indian Horticulture,* 62(6): 55-56

Soumia, P.S., Karuppaiah, V and Singh, M. 2017. Managing *Thrips tabaci* - a pest of national significance. *Indian Horticulture,* 62(6): 55-56

Sreenivas, A.G., Sushila N., R Shankaramurthy, V., Raghavendra Y., Rani S., Patil, N., Ashrith, K. N. and Vinay S. Patted. 2016. Eco-friendly approaches for the management of defoliators on onion. *Progressive Horticulture,* 48(2). DOI : 10.5958/2249-5258.2016.00033.6

Srinivas, P.S., Singh. R.P. and Lawande, K.E. 2007. Integrated Pest and Disease Management in Onion and Garlic. Technical Bulletin No.17. ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra, p34

Chapter 8

ONION SEED PRODUCTION

Manjunathagowda, D.C.*, Abhishek Dilip Gavhane, Shivam Gaikwad, Sharad Veer Singh
ICAR-Directorate of Onion and Garlic Research, Pune-410505, Pune.
*Email: Dc.Manjunath@icar.gov.in

Seed is a prime input in successful onion production. It has major cost share in the inputs purchased. As it is a costlier commodity, the selection of right variety and also the right seed source are among the major farm decisions. Onion being a biennial crop, the seed production of onion takes place in two steps. Firstly, the onion bulbs are produced. Mostly the bulbs are sourced from *kharif* season with 15-25 days of rest or from the back rabi season. These bulbs are planted in rabi for season for seed. The seed demand for onion is about 10000 tonnes for a year. The onion seed chain shows presence of both the organized sector and unorganized sector. Where the organized sector includes private and government agencies engaged in seed production, the unorganized sector is made up of the farmers producing seeds.

Common package of practices for onion seed production developed by ICAR-DOGR:

1. Soil and Climate requirements

Well-drained medium to heavy soils along with pH range of 6.5 to 7.5 are considered good for onion seed production. Whereas, sandy, rocky and calcareous soils are not suitable for seed production. Flowering initiation in onion takes place at a comparatively cooler temperatures (15 to 25^{o}C.) whereas the pollen tube maturity and receptivity of stigma are greatly affected by higher temperatures. These higher temperatures are favorable only for seed ripening and maturity. Low temperature at the time of bulb planting (November-December), moderate temperature during stalk development, flowering and seed setting (January-February) and warm temperatures at seed maturity and drying (March-April) with bright sunshine free of cloudy weather is the best situation for seed production (Mahajan *et al*., 2017).

2. Field Preparation and planting:

Field preparation

Weed and soil borne pathogens are major constrains in success of onion seed production and field selection accordingly is advisable. Deep ploughing in summer is always helpful in reducing diseases, pests and weed population. A deep ploughing and incorporation of well decomposed farm yard manure @ 20 t/ha creates good soil tilth. Ridges and furrows are common planting method followed for mother seed planting.

Selection of mother bulb:

Akin to seed production, for mother bulb production also, the isolation distance is mandatory to avoid contamination of bulbs of another variety. This distance is kept about 5m. Harvest of rabi season already catches enough resting period, but the bulbs harvested in kharif need to give a resting period of about 15 to 20 days. The bulb selection is three step process. Firstly, the rotten, diseased, double, sprouted and small sized bulbs are removed. Secondly the thick necked, irregular shaped or colored bulbs are removed and lastly during the planting, the malformed, internally damaged, diseased bulbs are removed. Also, the single centred bulbs are chosen for planting. The ideal bulb selection should be based on following criteria;

1. Bulbs should be true to type
2. Uniform Colour
3. Uniform Shape
4. Medium to large in size (45-60mm diameter), preferably more than 80g of bulb weight
5. Preferably single center

Planting

Onion seed production is generally recommended by bulb to seed method, here bulbs are produced in first season/year and in second season selected bulbs are planted for seed production. This method gives higher yield, improves quality and maintains purity of seed. For kharif season variety this cycle is completed in one year while, rabi season varieties takes two years to complete one cycle. Bulbs are planted normally during October-November for seed production. The furrows should be opened at the 45 cm apart and bulbs are planted at 30 cm distance on one the sides of the ridges. For drip, spacing of 60×20 cm is followed. Broad Based Furrows (BBF) of 50 to 60 meters length and 1.2-meter width can also be used for with drip irrigation for seed production. BBF planting with drip irrigation increases seed yield and quality besides water saving. The top $1/3^{rd}$ portion of the bulbs should be cut before planting and treated with 0.2% carbendazim solution for 20 to 30 minutes. The treated bulbs need to be planted at 5 to 6 cm depth

Table 1. Planting of mother bulbs for raising seed crop

Spacing (cm)	Av. Bulb Weight (g)	Quantity of bulbs (q/ ha)
45 × 30	80	45
60 × 20 (on drip)	80	40

Fig 1. Planting of mother bulbs for raising of seed crop

3. Irrigation and fertilizer management:

Onion seed crop has shallow root system thus it demands frequent irrigation able to create constant and enough moisture into the soil about (65% of filed capacity). One should avoid excess irrigation to onion seed as it favors crop lodging and base rotting. The seed crop has a water requirement about 75-90 ha cm. throughout the crop duration (Mahajan *et al*., 2017). Generally, 12 to 15 irrigations starting from initial irrigation just after the planting are given to onion seed crop. The drip irrigation system has found suitable for onion seed production where a drip lateral of 16 mm diameter with inline drippers at 30-50 cm distance and 4 l/h discharges are required. Seed filling stage is critical and deficit water during this period reduces yield drastically.

For onion seed crop, 100:50:50:50 NPKS/ha is recommended. One third of recommended nitrogen (N) and full quantity of phosphorus (P), potassium (K) and sulphur (S) should applied as basal dose before planting. Application of remaining quantity of N should be applied in two equal splits at 30 and 45 days after planting. Applications of N, K and S are not recommended during flowering because these make the flower nectar unattractive to bees. Soil test-based approach for micronutrient application is useful, commonly micronutrient mixture @ 5 ml/l is recommended at 45, 60 and 75 days after transplanting. Boron helps in improving pollen germination hence may be sprayed after opening of flowers (Mahajan *et al*.2017).

4. Isolation and Rouging:

Onion being a highly cross-pollinated crop more care is needed for the isolation from the fields of seed crop of other verities or the bolters of bulb crops. Insects, primarily the honey bees are common pollinators of onion seed crop. The honeybees are able to travel a greater distance in search of nectar or pollen. Thus, an isolation distance more than 1000 m for commercial seed crop, 500 m for certified seed crop and 1000 m for foundation seed is recommended to maintain the genetic purity of the seeds. Generally, four rouging should be done for pure seed crop at before flowering, during seed stock development, during flowering and at harvesting. Otherwise, the off-type plants will continue to provide pollen and will affect the quality of seed. If bulb crop is cultivated around the seed crop, care should be taken to remove the bolters before flower opening.

5. Supplementary Pollination:

Onion although being hermaphrodite in nature, the anthers mature before the stigma and make the self-pollination uncommon. To ensure good pollination, 2 to 4 colonies of honeybees can be kept in one-acre seed plot at the time of flowering with a view to provide supplementary pollination and produce quality seeds (Mahajan *et al*, .2017). While keeping the honeybees; Insecticide sprays after opening of flowers and also after keeping honey bee boxes must be avoided.

6. Diseases and Pests

Purple Blotch, Stemphyllium Blight and Onion Yellow Dwarf are major diseases in onion seed crop. For managing these diseases effectively, healthy bulbs should be used and crop rotation of 2-3 years with non-related crops should be followed. The fungicides effectively manage purple blotch are Mancozeb (0.25%), Hexaconazole (0.1%) and Tricyclazole (0.2%). The alternate spray of these fungicides may be taken up at 15 days interval, if plants show persistent infection in the field. The sticker like triton/ sandovit should also be mixed in the spray solution. The spraying of chemical fungicides should be avoided after flowering as it affects the bee activity in the field. After flowering safer options such as efficient strains of *Fluorescence pseudomonas, Bacillus subtilis, Trichoderma viridae*, *T. harzianum* can be used. For yellow dwarf virus; it has been found to be transmitted mechanically as well as by insect vectors. The diseased plants should be removed and burnt. Healthy bulbs should be used for seed production.

Fig. 2 Successful Onion seed plot following good horticultural practices

Thrips and mites are common pest of onion seed crop, Thrips suck the cell sap from leaves and stalks leaving white patches, which make easy entry for pathogens. Thrips also suck the sap from pedicels of flowers after opening of flower parianth. Due to which the flower buds do-not develop and umbel becomes almost sterile. Sometimes 50-60% losses in crop are observed due to thrips attack. Before initiation of flowering, the insecticides such as Fipronil, Spinosad, Profenophos and Carbosulphan can be used for spraying (Mahajan *et al,* .2017). Generally, the spray of insecticides or other agrochemicals harmful to honeybees are avoided after flowering initiation to ensure proper honey bee activity.

7. Harvesting, Drying and Threshing:

There is no synchronous maturity in onion seed crop, therefore, three to four harvestings are required. Generally, opening of 10 to 15 percent seed capsules is considered right stage of maturity of umbels. Generally, the harvesting is performed manually by cutting the umbels by hand or by sickle. To avoid seed shattering during harvesting; the umbels are supported firmly by hands while cutting. Harvested umbels are dried in thresh yard free from any contamination. It should be spread in shallow layers of not more than 20 – 30 cm height and are exposed to the sun for 4-5 days. Regular turning of heaps is followed to ensure uniform drying.

Wooden mallets or sticks are used for beating the umbels gently. After cleaning seeds using winnower; the seeds are further graded using sieves. Before packing the seeds are made free from weed seeds, light seeds, and chaff. The quality parameters for foundation and certified class of seeds as prescribed by Indian Minimum Seed Certification Standard are as follows:

Table 3. The Minimum Seed Certification Standards

Parameters	Standard for	
	Foundation Seed	Certified Seed
Seed purity	98.0%	98.0%
Inert matter (Maximum)	2.0%	2.0%
Other crop seed (Maximum)	5/kg	10/kg
Weed seed (Maximum)	5/kg	10/kg
Germination (Minimum)	70%	70%

A well-managed seed plot can yield about 500-800 kg seed per hectare. As much as 1000 to 1200 kg seed per hectare can be obtained under best management and climatic conditions.

Fig 3. Sun-drying of harvested umbel for seed processing

8. Packing and Storage:

Generally, seed drying unto the moisture reach of 8% is required prior bagging or packing the seeds in cloth or jute bag. Onion seed loses viability after 12 months if they are packed improperly. Packing in a polythene bag (400 gauge) of 1 to 5 kg capacity is recommended for longer viability, but the moisture level of seeds before packing should be less than 6%. Under cold storage at 12-15^{o}C and 35-45% humidity seed can be stored for 3-4 years provided initial seed moisture is maintained at 6% level.

The Seed Standards:

A quality seed to present a seed certificate needs to follow some criteria prescribed by Indian Minimum Seed Certification Standards. for Onion seed production the standards prescribed are as:

I. **Land Requirements**

Seed production of onion plot should be free from volunteer plants

II. **Field Inspection**

2.1 Bulb production stage - Minimum of two inspections

2.2 Seed production stage - Minimum of four inspections

A. Mother bulb production stage

1. The first inspection shall be made after transplanting of seedlings in order to determine isolation, volunteer plants Off-types including bottlers and other relevant factors.

2. The second inspection shall be made after the bulbs have been lifted to verify the true characteristics of bulbs.

B. Seed production stage

1. The first inspection shall be made before flowering in order to determine isolation, volunteer plants Off-types including bottlers and other relevant factors.
2. The second and third inspections shall be made during flowering to check isolation, Off-types and other relevant factors
3. The fourth inspection shall be made at maturity to verify the true nature of plant and other relevant factors.

III. Field Standards

A. General requirements

1. Isolation

Onion seed fields shall be isolated from the contaminants shown in the below table by the distances specified in columns, isolation distance for seed production is kept between two varieties or two plots of the same variety

IV. General Requirements

Table 4. General isolation requirements

Isolation	Minimum distance (meters)			
Requirements	Bulb production stage		Seed production stage	
Class	**Foundation**	**Certified**	**Foundation**	**Certified**
Fields of other varieties	5	5	1000	500
Fields of the same variety	5	5	1000	500

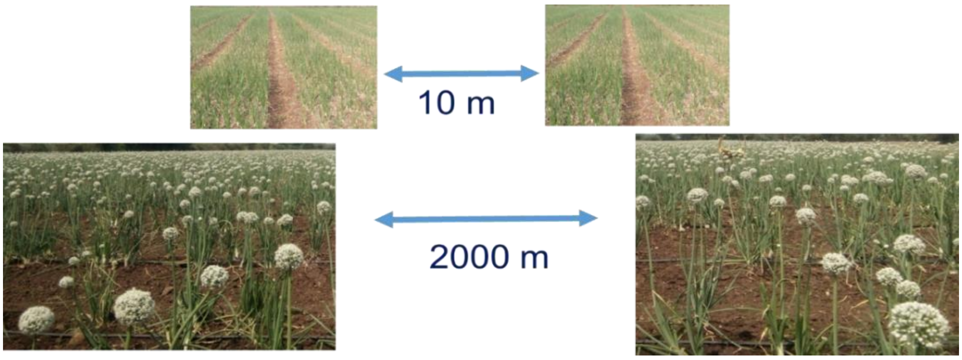


Fig 4. Isolation distance for breeder mother bulbs production and breeder seed production

V. Specific requirements

Table 5. Specific Purity requirements

Specific Requirements	Foundation	Certified
*Bulbs not conforming to the varietal characteristics	0.10%	0.20%
**Off-types	0.10%	0.20%

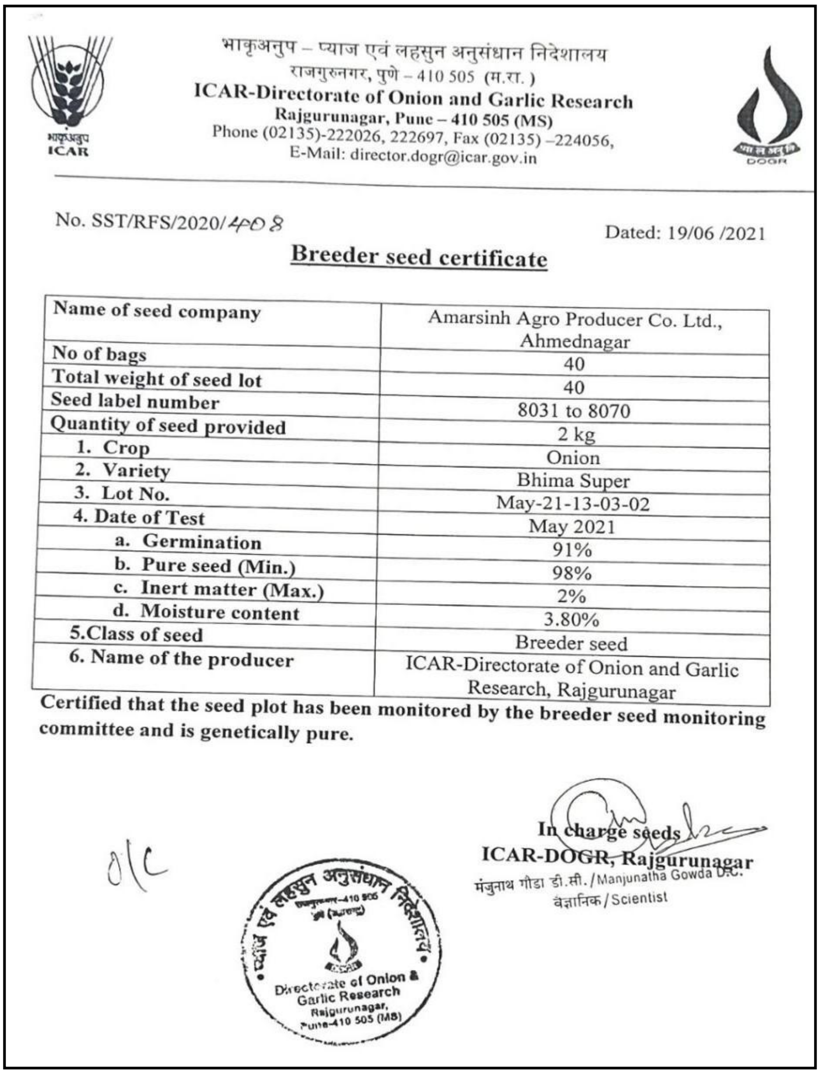
*Maximum permitted at second inspection at mother bulb production stage

**Maximum permitted at and after flowering at seed production stage

VI. Seed Standards

Table 6. Minimum and maximum limits of particulars for seed certification

Class	Foundation	Certified
Pure seed (minimum)	98.00%	98.00%
Inert matter (maximum)	2.00%	2.00%
Other crop seeds (maximum)	5/kg	10/kg
Weed seeds (maximum)	5/kg	10/kg
Germination (minimum)	70%	70%
Moisture (maximum)	8.00%	8.00%
Vapour-proof containers (maximum)	6.00%	6.00%



भाकृअनुप – प्याज एवं लहसुन अनुसंधान निदेशालय
राजगुरुनगर, पुणे – 410 505 (म.रा.)
ICAR-Directorate of Onion and Garlic Research
Rajgurunagar, Pune – 410 505 (MS)
Phone (02135)-222026, 222697, Fax (02135) –224056,
E-Mail: director.dogr@icar.gov.in

No. SST/RFS/2020/408

Dated: 19/06 /2021

Breeder seed certificate

Name of seed company	Amarsinh Agro Producer Co. Ltd., Ahmednagar
No of bags	40
Total weight of seed lot	40
Seed label number	8031 to 8070
Quantity of seed provided	2 kg
1. Crop	Onion
2. Variety	Bhima Super
3. Lot No.	May-21-13-03-02
4. Date of Test	May 2021
a. Germination	91%
b. Pure seed (Min.)	98%
c. Inert matter (Max.)	2%
d. Moisture content	3.80%
5.Class of seed	Breeder seed
6. Name of the producer	ICAR-Directorate of Onion and Garlic Research, Rajgurunagar

Certified that the seed plot has been monitored by the breeder seed monitoring committee and is genetically pure.

In charge seeds
ICAR-DOGR, Rajgurunagar
मंजुनाथ गौडा डी.सी. / Manjunatha Gowda D.C.
वैज्ञानिक / Scientist

Fig 5: Minimum and maximum limits of particulars for breeder seed certification

Conclusion:

The successful onion seed production needs to follow the prescribed steps. The highly cross-pollinated crop requires the purity maintenance as a prime managerial task. FPOs and farmer collectives need to step in the onion seed production. Aiding government initiatives, it is easy to skill the farming population and generates a common decision for selection of a single variety for seed production in proximity. The new concept like ‘seed village’ are getting popular where farmers are fetching benefits of cooperative structuring collaborating their marginal lands to generate commerce able quantity of seed along with maintenance of varietal purity. Directorate of onion and garlic research engaged in development of improved onion varieties also advancing seed licence for its 10 improved verities.

References

Mahajan, V., Gupta, A.J., Thangasamy, A., Gawande, S.J. and Singh, M., Quality seed production of onion. Indian Horticulture, 62(6) (2017).

www.dogr.icar.gov.in

www.icar.org.in

www.nhrdf.org

__Chapter 9__

HARNESSING THE BENEFITS OF PPV&FRA FOR TRADITIONAL GROWERS OF ONION AND GARLIC

Amar Jeet Gupta*, Vijay Mahajan and Major Singh
ICAR-Directorate of Onion and Garlic Research, Pune-410 505
*Email: guptaaj75@yahoo.co.in

In India, about seventy-two onion and twenty-eight garlic varieties have been released from different public sector organizations and their number is expected to increase in future. Onion and garlic varieties attain acceptance when the farmers get genetically pure seeds/ cloves of high standards as well as yield and quality performance. For this purpose, each onion and garlic variety should be properly defined with suitable descriptors so as to maintain its identity during seed/ bulb production through field inspection and certification. Apart from characterization of onion and garlic varieties, their protection is also required under Plant Variety Protection (PVP) legislation through varietal testing for Distinctiveness, Uniformity and Stability (DUS) which is the basis for grant of protection of new plant varieties under the PPV&FR Act 2001. The Act has the provision to compare the novel candidate variety with the varieties of common knowledge on a set of relevant characteristics prescribed in the DUS Test Guidelines of onion and garlic (PPV&FR Authority 2009) which is commonly accepted for this purpose at the time of filling of application.

Process for protection of onion and garlic varieties

Under protection of plant varieties and farmers right act, registration of plant varieties is essential. DUS testing report from competent authority is required for registration. The Govt. of India has identified authorities for crop-wise DUS testing in 172 commercial crops. ICAR-DOGR, Pune has been designated as authority for DUS testing of onion and garlic varieties.

Breeders or farmers who wants to register their varieties can apply to competent authority in the Ministry for registration. Applicant will have to supply minimum 100 g good quality onion seed or 1200 bulblets for each year (vegetative propagated multiplier onion) of each variety along with full details of characters in general and distinct characters in particular. In case of garlic at least 2000 viable cloves for each year are required. Applicant will have to indicate geo-graphical areas where the multi-location testing has been done and/ recommendation of variety by AINRPOG. Specific areas for testing in case of onion and garlic can also be mentioned by the applicant which are photo and thermo sensitive for bulbing.

The minimum duration of tests should normally be two independent similar growing seasons with reference to the ecosystem of the variety submitted for DUS test. The test should be normally conducted at two test locations. If any important characteristics of the variety cannot be seen at these places, the variety may be tested at additional place. The test should be carried out under conditions ensuring normal growth with minimum of 600 plants across three replications. DUS test fee for onion and garlic is Rs. 40,000/- per entry and registration charges is Rs. 7000 (Individual)/ 10000 (Educational)/ 50000 (Commercial) for Essentially Derived Varieties (EDV)/ New Varieties/ Extant

Varieties (VCK); Rs. 2000 for Notified Extant Variety; and No registration fee is required for Farmers' Variety. Duration of protection of registered varieties is for15 years.

DUS Test Characteristics of Onion

Thirty-four characteristics have been notified by PPV&FRA for DUS Test of onion varieties and 32 characteristics have been notified by PPV&FRA for DUS Test of garlic varieties.

a. **Common onion varieties:** Number of leaves per pseudo-stem, Foliage length (from pseudo-stem to tip of leaf), Time of maturity (from date of sowing), Bulb height and Bulb diameter.
b. **For bulb propagated/ multiplier onion varieties:** Total number of leaves/hill, Total number of shoots/plant, Foliage length from pseudo-stem to tip of leaf, Bulb time of maturity from date of sowing, Compound bulb-polar diameter, Compound bulb- equatorial diameter, Bulblet polar diameter, Bulblet equatorial diameter and Number of bulblets per bulb.
c. **For all varieties:** Foliage attitude, Leaf diameter (maximum), Foliage waxiness, Intensity of green colour, Foliage cranking, Pseudostem length (up to last emerged green leaf), Pseudostem diameter (at midpoint of length), Bulb thickness of neck, Bulb general shape (in longitudinal section), Bulb basic colour of dry skin, Adherence of skin after harvest, Thickness of rings (average of all the rings), Firmness of flesh, Colour of epidermis of fleshy scale, Position of root disc, Predominant number of axes, Bulb cross section, Degree of splitting into bulblets (with dry skin around each bulblet), Total soluble solids and Male sterility.

DUS Test Characteristics of Garlic

Density of leaves, Number of leaves per pseudostem, Foliage attitude, Leaf intensity of green colour, Leaf waxiness, Leaf length (longest leaf), Leaf width (widest leaf), Leaf shape in cross section (in middle of the longest leaf), Pseudostem length (up to first emerged green leaf), Pseudostem width of the base, Intensity of anthocyanin colouration at base, Flowering stem curvature, Flowering stem length (special characteristics for temperate condition), Bulbils, Time of maturity (from date of planting), Bulb size (diameter), Bulb shape in longitudinal section, Bulb shape in cross section, Position of cloves at tip of bulb, Position of root disc, Bulb shape of base, Compactness of cloves, Ground colour of dry external scales, Anthocyanin stripes on dry external scales, Number of cloves, Distribution of cloves, External cloves, Skin adherence of dry external scales, Clove size (diameter), Colour of scale and Colour of flesh.

Maintenance of Onion and Garlic Varieties

ICAR-DOGR is maintaining 47 *rabi* and 11 *kharif* varieties of onion and 31 varieties of garlic (Table 1a-1c). Eleven *kharif* onion varieties are Agrifound Dark Red, Arka Kalyan, B-780, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Shweta, Bhima Safed, Bhima Super, Bhima Dark Red and N-53. Rest of onion varieties are maintained during *rabi* season. However, Bhima Raj, Bhima Red and Bhima Shweta are maintained in both *kharif* and *rabi* seasons. Out of these varieties, all the long day onion and garlic varieties are being maintained at ICAR-CITH, Srinagar and multiplier type onion varieties are being maintained at TNAU, Coimbatore. All the short-day varieties of onion and garlic are being maintained at ICAR-DOGR, Rajgurunagar, Pune as well as ICAR-IARI, New Delhi. The onion varieties are being maintained as per the mandate during *kharif* and *rabi* seasons whereas garlic varieties were maintained during *rabi* season.

Table 1a; Common Onion (*Allium cepa* L.) (No. of varieties: 61)

Name of the Varieties	**Source of Varieties**
Pusa Red, Pusa White Round, Pusa White Flat, Pusa Madhavi, Pusa Ridhi, Pusa Sona, Early Grano* and Brown Spanish*	ICAR-IARI, New Delhi
Arka Niketan, Arka Pitambar, Arka Pragati, Arka Bindu, Arka Kalyan and Arka Bheem	ICAR-IIHR, Bangalore
Bhima Super, Bhima Red, Bhima Raj, Bhima Kiran, Bhima Shakti, Bhima Dark Red, Bhima Light Red, Bhima Shweta, Bhima Shubhra and Bhima Safed	ICAR-DOGR, Pune
VL Piaz-3*	ICAR-VPKAS, Almora
B-780, Phule Samarth, Phule Safed and Phule Suvarna	MPKV, Rahuri
Agrifound Dark Red, Agrifound Light Red, Agrifound White, Agrifound Rose, NHRDF Red, NHRDF Red-2, NHRDF Red-3, NHRDF Red-4 and NHRDF Fursungi	NHRDF, Nasik
Hissar-2, Hissar-3 and HOS-4	HAU, Hissar
N-2-4-1 and N-53	Agril. Dept., MS
Punjab Naroya and PRO-6	PAU, Ludhiana
PKV White	PDKV, Akola
Udaipur-102	RAU, Udaipur
GWO-1, GWO-2, GJWO-3 and GJRO-11	GAU, Junagadh
Kalyanpur Red Round	CSAUA&T, Kanpur
Palam Lohit*	CSKHPAU, Palampur
RO-1, RO-59 and RO-252	SKNAU, Durgapura
Phursungi Local, Sukhsagar, Pilipatti Junagadh, Talaja Red and Telagi Local	Farmer’s Varieties

* Maintained at CITH, Srinagar

Table 1b: Multiplier Onion (*Allium cepa* L.) (No. of varieties: 5)

Name of the Varieties	**Source of Varieties**
CO-1, CO-2, CO-3, CO-4 and CO-5	TNAU, Coimbatore

Table 1c: Garlic (*Allium sativum* L.) (No. of varieties: 32)

Name of the Varieties	**Source of Varieties**
Bhima Omkar and Bhima Purple	ICAR-DOGR, Pune
VL Garlic-1* and VL Garlic-2*	ICAR-VPKAS, Almora
GG-2, GG-3 and GG-4	GAU, Junagadh
GJG-5, GAG-6 and GAG-7	AAU, Anand
Godawari, Phule Baswant and Phule Neelima	MPKV, Rahuri
G-1 (Yamuna Safed), G-41 (Yamuna White), G-50 (Yamuna Safed-2), G-282 (Yamuna Safed-3), G-323 (Yamuna Safed-4), G-189 (Yamuna	NHRDF, Karnal

Safed-5), G-384 (Yamuna Safed-8), G-386 (Yamuna Safed-9), G-404 (Yamuna Purple-10) and Agrifound Parvati*	
CITH-G-1*	ICAR-CITH, Srinagar
PG-17 and PG-18	PAU, Ludhiana
Rani Bennur Local, Sikkim Local, Silkuei Local, Chunar Local, Navapur Local and Ooty Local	Farmer's Varieties

* Maintained at CITH, Srinagar

Farmers' Rights in the PPV&FR Act, 2001

The Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act) seeks to address the rights of plant breeders and farmers on an equal footing. It affirms the necessity of recognizing and protecting the rights of farmers with respect to the contribution they make in conserving, improving and making Plant Genetic Resources (PGR) available for the development of new plant varieties. The PPV&FR Act recognizes the multiple roles played by farmers in cultivating, conserving, developing and selecting varieties. With regard to developing or selecting varieties, the Act refers to the value added by farmers to wild species or traditional varieties/ landraces through selection and identification for their economic traits. Accordingly, farmers' rights encompass the roles of farmers as users, conservers and breeders.

Benefits Sharing

The benefit sharing is one of the most important ingredients of the farmers' rights. Section 26 provides benefits sharing and the claims can be submitted by the citizens of India or firms or non-governmental organization (NGOs) formed or established in India. Depending upon the extent and nature of the use of genetic material of the claimant in the development of the variety along with commercial utility and demand in the market of the variety, breeder will deposit the amount in the Gene Fund. The amount deposited will be paid to the claimant from National Gene Fund. The Authority also publishes the contents of the certificate in the PVJI for the purpose of inviting claims for benefits sharing (PPV&FRA 2015).

Protection of onion and garlic varieties

After initiation of DUS test in 2012 at ICAR-DOGR and ICAR-IARI, 14 varieties of onion and 8 varieties of garlic have been registered with PPV&FRA for its protection (Table 2). From ICAR-DOGR, nine onion varieties *viz.*; Bhima Kiran, Bhima Red, Bhima Raj, Bhima Light Red, Bhima Shubhra, Bhima Safed, Bhima Shakti, Bhima Dark Red and Bhima Super as well as one garlic variety Bhima Omkar have been registered with PPV&FRA. One onion variety Bhima Shweta and one garlic variety Bhima Purple are under registration with PPV&FRA.

Table 2: Registered varieties of onion and garlic under PPV& FR Act, 2001

Crop	Variety	Category	Source	Reg. No.
Onion (14)	NHRDF Red (L-28)	Extant	NHRDF, Nashik	260 of 2015
	NHRDF Red-2 (L-355)	Extant	NHRDF, Nashik	261 of 2015
	Bhima Raj (B-780-5-2-2)	Extant	DOGR, Pune	262 of 2015
	Phule Samarth	Extant	MPKV, Rahuri	97 of 2016

	Bhima Kiran (DOGR-597)	Extant	DOGR, Pune	341 of 2016
	Bhima Red (B-780-5-3-1)	Extant	DOGR, Pune	342 of 2016
	Arka Bindu	Extant	IIHR, Bengaluru	173 of 2018
	Arka Pitamber	Extant	IIHR, Bengaluru	174 of 2018
	Bhima Safed	Extent	DOGR, Pune	115 of 2019
	Bhima Shubhra	Extant	DOGR, Pune	120 of 2019
	Bhima Light Red	Extant	DOGR, Pune	261 of 2020
	Bhima Shakti	Extant	DOGR, Pune	REG/2014/984
	Bhima Dark Red	New	DOGR, Pune	REG/2014/985
	Bhima Super	Extant	DOGR, Pune	REG/2015/2018
Garlic (8)	JG-99-213 (Gujarat Garlic)	Extant	JAU, Junagadh	811 of 2014
	Yamuna Safed-4 (G-323)	Extant	NHRDF, Karnal	259 of 2015
	Agrifound Parvati-2 (G-408)	Extant	NHRDF, Karnal	344 of 2016
	Yamuna Safed-8 (G-384)	Extant	NHRDF, Karnal	345 of 2016
	Bhima Omkar (AC-200)	Extant	DOGR, Pune	427 of 2016
	Agrifound Parvati (G-313)	Extant	NHRDF, Karnal	208 of 2017
	Yamuna Safed-5 (G-189)	Extant	NHRDF, Karnal	175 of 2018
	Phule Baswant (PB Sel-2)	Extant	MPKV, Rahuri	REG/2019/116


Bhima Super


Bhima Red


Bhima Raj


Bhima Dark Red


Bhima Kiran


Bhima Shakti

Bhima Light Red

Bhima Shubhra

Bhima Safed

Bhima Omkar

Fig. 1: Registered ICAR-DOGR varieties of onion and garlic

Fig 2: Maintenance of onion and garlic varieties under DUS Project

(a) Variability in DUS onion varieties

(b) Variability in DUS garlic varieties

Fig3: **Variability in DUS onion and garlic varieties.**

Chapter 10

ABIOTIC STRESSES IN ONION AND GARLIC PRODUCTION

Kiran P. Bhagat[*1], R. B. Kale, Ashwini Benke, Manjunathgowda D. C., Pranjali H. Ghodke, Dhananjay V. Shirsat, Kuldeep Jawalekar, Vijay Mahajan and Major Singh

ICAR- Directorate of Onion and Garlic Research, Pune, [1]ICAR- Directorate of Floricultural Research, Pune.

[*]Email : kiranbhagat.iari@gmail.com

Global climate abnormalities due to different anthropogenic and natural activities typically increased different biotic and abiotic stress on crop plants which affect plants genetic potential of growth and economic production adversely (Ramegowda and Senthil-Kumar, 2015). Abiotic stresses include various environmental aspects such as moisture stress, temperature stress, salinity stress etc. which also influence occurrence of different biotic stress *i.e*. pathogens, insects and weeds at different crop growth stages (Peters *et al.,* 2014). The root system is the descending (growing downwards) portion of the plant axis. When a seed germinates, radicle is the first organ to come out. It also plays another vital role of absorbing water and mineral salts from the soil and transporting them upwards. It elongates to form primary or the tap root. It gives off lateral branches (secondary and tertiary roots) and thus forms the root system. It branches through large and deep areas in the soil and anchors the plant very firmly.

The root systems are mainly of two types- (a) Tap root system: It is the root system that develops from the radicle and continues as the primary root (tap root) which gives off lateral roots. They provide very strong anchorage as they are able to reach very deep into the soil. It is the main root system of dicots; (b) Fibrous root system: In this root system, the primary root is short lived. A cluster of slender, fiber-like roots arises from the base of the radicle and plumule which constitute the fibrous root system. They do not branch profusely, are shallow and spread horizontally, hence cannot provide strong anchorage. Fibrous root system is the main root system of monocots. Transportation of water in plants is governed by water potential differences and hydraulic conductances. Both the conductances and the driving forces may vary greatly in short or long-time scales. Carminati *et al*. (2010) used neutron radiography to measure water content in the soil at the very proximity of the root surface. The major roles of roots in plants are well known as they are involved in the acquisition of water and nutrients, anchorage of the plant, synthesis of plant hormones, and storage functions. This study indicated that changes in the soil properties around roots, apparently due to exuded mucilage, that affected the hydraulic properties of the soil on drying or wetting processes by changing the soil water retention characteristics differently on drying or wetting (and accordingly its hydraulic conductivity), a phenomenon known as hysteresis (*i.e.*, affected by the change direction). These changes moderated the drop of moisture around the root in a drying soil. It took about 40 years to cover the gap in our understanding of how plant roots are adapted to live in a drying soil (Moshe, 2013). A major difference between plant and animal development is that positional information rather than cell lineage determines cell fate in plants (Singh and Bhalla, 2006). For roots, it has been reported that different root zones contribute to different extents to the overall uptake of water (North and Nobel, 1991).

Plant development is essentially driven by stem cells localized in apical regions of shoots and roots, and referred to as apical meristems. This particular characteristic allows plants, which are sessile organisms, to adapt their morphology and organ development to the encountered environmental conditions. Another vital area with respect to plant roots are symbiotic association with other living organisms. Interactions of roots with their biological environment, both micro- and macro-organisms, were a subject to many studies. The spatial configuration of the root system (number and length of lateral organs), so-called root architecture, vary greatly depending on the plant species, soil composition, and particularly on water and mineral nutrients availability (Malamy, 2005). It was demonstrated by several studies that the root and its bacterial associates act as a functional unit- the roots exude substances on which the bacteria are fed (Badri and Vivanco, 2009). In roots, auxin is involved in lateral root formation, maintenance of apical dominance and adventitious root formation. All these developmental events require correct auxin transport and signaling. The different stages of root development are controlled and regulated by various phytohormones with auxin playing a major role (Leyser, 2006). Auxin also plays a major role in lateral root initiation and development. Lateral root development can be divided in different steps: primordium initiation and development, emergence, and meristem activation. Furthermore, it is also involved in the growth and organization of lateral root primordia and emergence from the parent root (Laskowski *et al.* 2006). Auxin local accumulation in Arabidopsis root pericycle cells adjacent to xylem vessels, triggers lateral root initiation by re-specifying these cells into lateral root founder cells (Dubrovsky *et al*. 2008). Auxin transport into the regions where lateral root initiate also seems crucial for the regulation of root branching (Casimiro et al. 2001). This induction is mediated by ARF proteins that bind to the auxin responsive elements (AuxREs) in the promoters of auxin-responsive genes, and activate or repress transcription through interaction with specific Aux/ IAA proteins (Liscum and Reed, 2002). When auxin reaches the target tissue it induces a transcriptional response. Several auxin-responsive genes and gene families involved in auxin signaling have been identified, of which the Aux/IAAs and ARFs are the best studied. Auxin induces expression of Aux/IAA proteins, which in many cases reduces the sensitivity of cells toward auxin.

In contrast to auxin, exogenous cytokinin application suppresses lateral root formation, and transgenic Arabidopsis plants with decreased cytokinin levels display increased root branching and enhanced primary root growth (Werner *et al.*, 2003). The notion that cytokinin negatively regulates root growth has also been verified by studies of cytokinin perception and signaling (Hodge *et al*., 2009). Although auxin plays a fundamental role in root growth and development, several other phytorhomones modulate auxin action and consequently affect root development and architecture.

Modification in onion roots under drought stress and water-logging conditions

Unlike life in water, roots of terrestrial plants had to adapt to a wide range of abiotic stress conditions such as water deficit and excess moisture condition. Onion crop is not an exception from these abiotic stress conditions. Availability of water and nutrients to plants under terrestrial conditions depends on resources supplied by the soil. And roots are the essential organ which supplies water and required nutrients to the plant for its proper growth and development. Though, the research on onion root study under such adverse conditions are merely reported and therefore, ICAR- Directorate of Onion and Garlic Research, Pune has taken a leading step to study the performance of onion roots under water deficit and excess moisture conditions. Root is the first plant interface with soil and is the organ that mainly receives stress arising to substrate characteristics (Polverigiani*et al*., 2014). Less is known about the drought adaptations of roots than of shoots, simply because shoots are more accessible. That is, although early studies already pointed out inherent gaps in our knowledge on the root-soil system: As soil dries, its volume must be reduced. Also, there might occur shrinkage of roots when exposed to a drying soil (Huck *et al*., 1970). Based on these facts, Taylor and Klepper (1975) concluded that, under drying soil conditions, soil water flow to the root surface should drop with soil moisture decrease, since a gap between the soil and the root surface should develop due to both root and soil shrinkage (Waraich *et al*., 2011). In fact, the change in water flow to roots grown in drying soils does not indicate the occurrence of such a gap (often referred to as the Klepper-Taylor paradox). Furthermore, measurements made on water uptake by desert plants, resulted in a relatively small drop in water flux to roots under drying soil conditions, although the roots shrank under water deficit (Nobel and Cui, 1992; North and Nobel, 1997). Responses include root biomass adjustments, anatomical alterations, andphysiological acclimations.

The molecular mechanisms under lying these responses are characterized to some extent, and involve stress signaling and the induction of numerous genes, leading to the activation of tolerance pathways. In addition, mycorrhizas seem to play important protective roles (Brunner *et al*., 2015). Also, relatively little water was lost from the root as a flow-back to the drying soil, as water potential gradient apparently should cause. They also showed that certain desert plants can fill the gap formed due to the root shrinkage by root gel-like exudates, so a continuation of the soil-root system was maintained, as was supported by McCully (1999). Xylem conduits are assumed to narrow from the roots to the stem and further to the branches and leaf petioles, in order to achieve an optimal structure for the functioning of the vascular elements (Tyree and Zimmermann, 2002). Conduit tapering is commonly believed to control water distribution. By having the lowest conductivities in the minor branches at the end of the flow path, a plant can control the distribution of water regardless of the transport distance. As the most distal organs belowground, fine roots can be sacrificed in response to drought, similar to leaf fall, as observed in various temperate and boreal forests (Chenlemuge *et al*., 2013; Hertel *et al*., 2013). This assumption was confirmed in recent studies, where the xylem conduit diameters in roots and in aboveground parts of temperate, boreal, and tropical tree species were investigated (Schuldt *et al*., 2013). Therefore, Root architecture and plant phenotyping is an important selection tools for onion under drought stress condition. Morphologically, number of onion roots gets reduced in response to limited water supply whereas root length tends to increase in search of water beneath soil horizon. The desirable root traits especially the root length plays a significant role in drought condition. It was revealed that the entries with desirable root traits especially the root length plays a significant role under drought condition. Such findings can be used as an important criterion while selecting desirable entries in varietal development program in drought prone areas. Thickness of roots reduces under such limited water condition.

Additionally, average root length, average root area and average root volume enhance better performance in drought tolerant onion genotypes as compared to susceptible onion entries under moisture deficit stress. Roots are the primary plant part which affects directly under water logging or soil flooding conditions. The water logging tolerant onion entries grow better proportion of root growth as compared with susceptible onion entries under excess moisture condition. Morphologically, the tolerant onion entries enhance the root volume by increasing root length, and more prominently root thickness under such water logging condition. This may be due to storage of oxygen in aerenchymatic cells. The aerenchyma cells allow gas (notably oxygen) to be transported from the shoot to the root either via simple diffusion, or possibly under pressure flow. Aerenchyma cells are, therefore, essential for the internal ventilation of roots in an anaerobic environment. However, there may be a trade-off between root mechanical strength and aerenchyma formation particularly in plant species that lack a multiseriate ring of tissue for mechanical protection in the outer cortex (Striker *et al*., 2007).

The movement of oxygen from the shoots to the roots also has important consequences for rhizosphere micro-organisms, as some oxygen is released from the root (termed radical oxygen loss (ROL)) into the zone immediately surrounding the root. Root dimorphism and suberization of both exodermis and endodermis cells were shown significant differences under water logging. Altogether, the entries with desirable root traits especially the improved root density plays promising role under excess moisture condition. The desirable root traits especially root density and root volume play a significant role in water logging tolerant mechanisms. Such type of observations can further be utilized and used as an important stress indicator while selecting promising entries for breeding program in response to excess moisture condition. The development of a root system advantageously involves that are common to the development of all plant organs, as well as certain aspects that are unique to roots. Despite the importance of roots and roots related developmental characteristics, the study of root morphogenesis has not received as much attention as the development of aerial plant organs (Schiefelbein and benfey, 1991). This addition expressed their view that plant roots are poorly understood, while the aboveground parts of plants were studied thoroughly for several centuries studies of roots grown in soil are still well behind. One of the leading researchers on root study, Waisel *et al*. (2002) added to the main title of their book, 'Plant Roots', a sub-title: 'The Hidden Half'.
Hence, the physiological mechanisms of plants under various abiotic stress conditions must understand thoroughly with the help of advanced technologies for the improvement of growth and development in abiotic stresses exposed plants to attain maximum economic yield from plants.

References

Badri DV and Vivanco JM, 2009. Regulation and Function of Root Exudates. *Plant Cell and Environment*, **32**(6): 666-681. (doi: 10.1111/j.1365-3040.2009.01926.x).

Brunner I, Herzog C, Daves MA Arend M and Sperisen C, 2015. How tree roots respond to drought. Frontiers in Plant Science, **6**: 1-16. (doi: 10.3389/fpls.2015.00547).

Carminati A, Moradi AB, Vetterlein D, Vontobel P, Lehmann E, Weller U, Vogel HJ and Oswald SE, 2010. Dynamics of Soil Water Content in the Rhizosphere," *Plant and Soil*, **332**(1-2): 163-176. (doi:10.1007/s11104-010-0283-8).

Casimiro I, Marchant A, Bhalerao RP, Beeckman T, Dhooge S, Swarup R, Graham N, Inzé D, Sandberg G, Casero PJ and Bennett P, 2001. Auxin transport promotes Arabidopsis lateral root initiation. *Plant Cell*, **13**: 843–852.

Chenlemuge T, Hertel D, Dulamsuren C, Khishigjargal M, Leuschner C and Hauck M, 2013. Extremely low fine root biomass in *Larix sibirica* forests at the southern drought limit of the boreal forest. *Flora*, **208**: 488–496. (doi: 10.1016/j.flora.2013.08.002).

Dubrovsky JG, Sauer M, Napsucialy-Mendivil S, Ivanchenko MG, Friml J, Shishkova S, Celenza J and Benkova E, 2008. Auxin acts as a local morphogenetic trigger to specify lateral root founder cells. *Proceedings of the National Academy of Sciences, USA*, **105**: 8790–8794. (doi:10.1073/pnas.0712307105).

Hertel D, Strecker T, Müller-Haubold H and Leuschner C, 2013. Fine root biomass and dynamics in beech forests across a precipitation gradient- is optimal resource partitioning theory applicable to water-limited mature trees? *J. Ecol.* **101**: 1183-1200. (doi:10.1111/1365-2745.12124).

Hodge A, Berta G, Doussan C, Merchan F, Crespi M, 2009. Plant root growth, architecture and function.*Plant Soil*, **321**:153–187. (doi:10.1007/s11104-009-9929-9).

Huck MG, Klepper B and Taylor HM, 1970. Diurnal Variations in Root Diameter. *Plant Physiology*, **45**(4): 529-530. (doi:10.1104/pp.45.4.529).

Laskowski M, Biller S, Stanley K, Kajstura T and Prusty R, 2006. Expression profiling of auxin-treated Arabidopsis roots: toward a molecular analysis of lateral root emergence. *Plant and Cell Physiology*, **47**: 788–792. (doi:10.1093/pcp/pcj043).

Leyser O, 2006. Dynamic integration of auxin transport and signalling. *Current Biology*, **16**: R424–R433. (doi:10.1016/j.cub.2006.05.014).

Liscum E and Reed JW, 2002. Genetics of Aux/IAA and ARF action in plant growth and development. *Plant Molecular Biology*, **49**: 387–400. (doi:10.1023/A:1015255030047).

Malamy JE, 2005. Intrinsic and environmental response pathways that regulate root system architecture. *Plant and Cell Environment*, **28**: 67–77. (doi:10.1111/j.1365-3040.2005.01306.x).

McCully ME, 1999. Roots in Soil: Unearthing the Complexities of Roots and Their Rhizospheres," *In*: R. L. Jones, Ed., *Annual Review of Plant Physiology and Plant Mo- lecular Biology*, **50**: 695-718.

Moshe S, 2013. Root Study: Why Is It behind Other Plant Studies? *American Journal of Plant Sciences*, **4**: 197-202. (doi: http://dx.doi.org/10.4236/ajps.2013.42026)

Nobel PS. and Cui M, 1992. Hydraulic Conductances of the Soil, the Root-Soil Air Gap, and the Root: Changes for Desert Succulents in Drying Soil. *Journal of Experimental Botany*, **43**(248): 319-326. (doi:10.1093/jxb/43.3.319).

North GB and Nobel PS, 1991. Changes in hydraulic conductivity and anatomy caused by drylng and rewetting roots of Agave deserti (Agavaceae). *American Journal of Botany*, **78**: 906-915.

North GB and Nobel PS, 1997. Drought Induced Changes in Soil Contact and Hydraulic Conductivity for Roots of *Opuntiaficusindica*with and without Rhizosheaths. *Plant and Soil*, **191**(2): 249-258. (doi:10.1023/A:1004213728734).

Peters K, Breitsameter L, Gerowitt B., 2014. Impact of climate change on weeds in agriculture: A review. *Agriculture and Sustainable Development*, **34**: 707-721.

Polverigiani S, Kelderer M and Neri D, 2014. Growth of 'M9' apple root in five Central Europe replanted soils. *Plant Root*, **8**: 55-63. (doi:10.3117/plantroot.8.55).

Ramegowda V, Senthil-Kumar M., 2015. The interactive effects of simultaneous biotic and abiotic stresses on plants: mechanistic understanding from drought and pathogen combination. *Journal of Plant Physiology*, **176**: 47-54.

Schiefelbein JW and Benfey PN, 1991. The Development of Plant Roots: New Approaches to Underground Problems.*The Plant Cell*, 3: 1147-1154.

Schuldt B, Leuschner C, Brock N and Horna V, 2013. Changes in wood density, wood anatomy and hydraulic properties of the xylem along the root- to-shoot flow path in tropical rainforest trees. *Tree Physiol.* **33**: 161-174. (doi: 10.1093/treephys/tps122).

Singh MB and Bhalla PL, 2006. Plant stem cells carve their own niche. *Trends in Plant Sciences,* **11**: 241–246. (doi:10.1016/j.tplants.2006.03.004).

Striker GG, Insausti P, Grimoldi AA and Vega AS, 2007. Trade–off between root porosity and mechanical strength in species with different types of aerenchyma. *Plant, Cell and Environment*, **30**: 580-589.

Taylor HM and Klepper B, 1975. Water Uptake by Cotton Root Systems: An Examination of Assumptions in the Single Root Model. *Soil Science*, **120**(1): 57-67. (doi:10.1097/00010694-197507000-00009).

Tyree MT and Zimmermann MH, 2002. *In*: Xylem Structure and The Ascent of Sap. Berlin:Springer. (doi: 10.1007/978-3-662-04931-0).

Waisel Y, Eshel A and Kafkafi U, 2002. Plant Roots- The Hidden Half. Third Edition, Marcel Dekker Inc., New York, 2002.

Waraich EA, Ahmad R, Saifullah, Ashraf MY and Ehsanullah, 2011. Role of Mineral Nutrition in Alleviation of Drought Stress in Plants. *Australian Journal of Crop Science*, **5**(6): 764-777.

Werner T, Motyka V, Laucou V, Smets R, Van Onckelen H and Schmülling T, 2003. Cytokinin-deficient transgenic Arabidopsis plants show multiple developmental alterations indicating opposite functions of cytokinins in the regulation of shoot and root meristem activity. *Plant Cell*, **15**: 2532–2550. (doi:10.1105/tpc.014928).

__Chapter 11__

OPPORTUNITIES IN PROCESSING, STORAGE AND VALUE ADDITION OF ONION AND GARLIC PROCESSING

Bhushan Bibwe*, Rajkumar Dagadkhair and Kalyani Gorrepati
ICAR-Directorate of Onion and Garlic Research, Pune-**410505**
*Email: bhushan.bibwe@icar.gov.in

Onion and garlic, members of Alliaceae family, are cultivated throughout the world for food, therapeutic and medicinal value. In India, onion and garlic have been under cultivation for the last 5000 years. In India, major area under onion and garlic cultivation is in tropical areas as compared to the high yielding countries where maximum areas under these crops fall under temperate regions. Onion and garlic are known to have natural health-promoting properties due to its rich nutritional composition. With the increase in consumer awareness regarding the health-promoting attributes of onions, their consumption is increasing day by day. Processing of onion and garlic into ready-to-eat or ready-to-use form would increase the consumption. Processing of onion and garlic into various products will allow the effective utilization of worthless onions that fail to meet the quality standards required for marketing, besides adding value to the vegetable. Entrepreneurship is one of the key drivers for economic development. During an economic crisis, the importance of entrepreneurship development increases. Entrepreneurship has been linked to improved growth, increased wealth and quality of life. Entrepreneurship development appears to be the best substitute to find employment opportunities, income generation, poverty reduction and improvements in nutrition, health and overall food security in the national economy.

The change in contemporary life-style demands availability of fast-food alternatives without compromising freshness and sacrifice of nutrient quality. Processing is a way to add value to the product without altering quality. Different methods of processing have been devised to suit a range of applications and needs. It is important to choose appropriate method based on the requirement. The important post harvest unit operations for garlic and onion are curing, grading, storage, processing (minimally processed, dried flakes, puree and paste, picle, vinegar, oil etc.) and value addition. The various methods and techniques useful for the processing, storage and value addition of onion and garlic are discussed here under to highlight the opportunities in the valorization sector.

Post-harvest unit operations

Curing: It is a drying process intended to dry off the necks and outer scale leaves of the bulbs to prevent the loss of moisture and the attack by decay during storage, eliminating the chances of microbial infection in storage.

- **Field curing:** by windrow method for 3-5 days till foliage turn yellow is recommended.
- **Shade curing:** after field curing is essential to remove the field heat and excess moisture from the surface of bulbs before packing, transportation or storage operation



Fig 1. Curing of Onion and garlic

Grading: Onions are graded before they are stored or transported to the market. The thick necked, bolted, doubles, injured, and decayed bulbs are picked out.

- Onion size grading: Large >60mm, medium 40-60 mm, Small 20-40 mm diameter
- Garlic size grading: Sizes: <2 inches, 2 to 2.5 inches, 2.5 to 3 inches, and >3 inches, Premium bulbs are those 2.5 inches and larger.

Storage: The present storage capacity for onion is about 4.6 lakh tonnes. This is quite inadequate compared to our total production. Even most of the structures available are traditional and unscientific. If 40 % of the stocks are earmarked for scientific storage the potential for new storage structures is about 12.6 lakh tonnes. However, it has been projected bythe Expert Committee on Cold Storage and Onion Storage that about 1.5 lakh tonnes on-farm capacity in production areas and 3.0 lakh tonnes capacity at APMCs and other market places are required in next 5 years. Thus there remains a vast potential to be tapped. The desired requirements for storage of onion is storage at cool and dry with storage Temp 25-30°C and relative humidity of RH 60-70% . The different types of onion storage structures established in various part of country are enlisted below.

Different storage structures for onion

- Traditional single row storage structure
- Traditional double row storage structure
- Top and bottom ventilated storage structure
- Bottom ventilated single row storage structure
- Low-cost bottom ventilated single row storage structure

- Modified bottom ventilated storage structure
- Modified bottom ventilated storage structure with chain link on side

(a) Single Row **(b) Double row**

Fig 2. Storage Structures of Onion

Sprouting and rooting are major challenges of onion storage. Sprouting is controlled by temperature while rooting is controlled by relative humidity. A temperature below 10-25°C increases sprouting and the higher the relative humidity the higher rooting occurrence. Sprouting can be preserved if maleic hydrazide at 2500 ppm is sprayed at 75-90 days after transplanting to field. Weight loss is higher when temperature is above 35°C. Onions are stored at a temperature of 25-35°C with relative humidity of 65-70% but for cold storage, onions are kept under temperature between 0-2 °C at relative humidity of 60-70%. Storage rot can be prevented through proper cleanliness in the store and crops can be sprayed with 0.1% carbendazim after 90 days if transplanting and just before harvest.

Need of Processing

- To reduce post-harvest losses like physical weight loss, rotting and sprouting of onion bulbs during storage
- The worthless onions like double grown, bolted onion bulbs etc that fails to meet the quality standards required for marketing and because of that these onions are sold at lowest price. Such onion can be utilized in processing.
- Onion is mostly grown in three seasons, kharif and late kharif with production of 20% each and rabi season with 60% of onion production. The crop harvested during rabi season hits the market from March onwards. The same crop must continue to meet the consumer demand till the month of October every year before the kharif crop is harvested and brought to the market. Hence it is very important to supply onion in market without breaking supply chain is very high throughout the year because of that fluctuations in market prices are continuously observed.
- It is very difficult to maintain the quality and quantity inadequate availability as compared to demand during slack period.

Processing of Onion

Onion offers a huge potential for value creation through processing. Advances in the field of processing makes it possible to produce different value-added products from onion i.e., minimally processed ready to use or ready to cook fresh onion, onion paste, dehydrated onion flakes, onion powder, onion oil, onion vinegar, onion sauce, pickled onion, onion wine and beverages etc.

Minimally processed onions: Minimally processed vegetables are defined as vegetables that are altered physically from its original form, yet retaining freshness. Pre-sliced fresh onions are most preferred by consumers who desire a healthy life-style and have a little time for food preparation. Onions are peeled and/or cut onions for ready to use that retain its freshness, packed in suitable packaging material and stored at refrigerated conditions or frozen conditions. To avoid undesirable physiological changes (Increase in respiration, etc) occurs due to minimally processing, modified atmosphere packaging (MAP) storage and controlled atmosphere (CA) storage with or without pretreatments augment storage-life and maintain physical and nutritional characteristics of the minimally processed onions. CO_2 enriched atmosphere delay onion deterioration and microbial development, particularly psychrotroph flora; 2% O_2 / 10% CO_2 enriched atmosphere is optimal to maintain sensory quality of diced onions (Blanchard *etal*.,1996).

Fig 3. Processed Onion

Dehydrated Onion Products:

Onion flakes and powder:

Dehydration is the oldest method of food preservation practiced by mankind. It is for producing concentrated product, which would have longer shelf life when packaged properly, and can be simply reconstituted without any substantial loss of flavour, taste, color and aroma. Onions are generally dried from an initial moisture content of about 86% (wet basis) to 7% or less for efficient storage and processing. In onion dehydration raw onions are peeled and cleaned. Peeled onion bulbs are cut into Slices having thickness up to 1/8-1/4" with the help of vegetable cutter. Onion slices are blanched at 80°C for 5 min. After blanching onion slices are deep in a brine solution having concentration 1-3% for 30 min. Tray drying of onion slices at 50-70°C is carried out for 8-10 hrs. After drying, onion flakes can be pack using suitable packaging material or can be pulverize by using pulveriser to form a fine onion powder and pack in a suitable packaging material and stored in cool and dry place.

(a) Dehydrated onion flakes   Red onion powder   White onion powder

Fig 4. Onion flakes and powder

Onion Puree and Paste: Onion is one of the main ingredients in every curry preparation of Indian households. Availability of onion in the form of ready to use paste would curtail inconvenient process of cutting onions, and thereby reduce total time for food preparation. Onion paste is a semi-solid product which retains original color and flavour of onions. Preparation of onion paste is simple process, but it entails proper packaging and storage condition to retain its colour, flavour besides microbial safety. During onion paste preparation raw onion is peeled off and pulp is prepared with the help of pulp making machine. Onion pulp is heated up to 110°C with addition of preservatives like 2% NaCl and 0.1% Citric acid. The TSS of onion paste should be 32°Brix. Filling of pulp is carried out at temperature 70-80°C in suitable packaging material. After packing material is allowed to cool down at room temperature and stored at 4°C for further use.

Fig. 5. Onion puree and paste

Onion Pickle: Our ancestors have explored pickling process to preserve surplus food supplies for long winters, famine and other times of need. It is a global culinary art. Pickles add a special test to many snacks and meals. Onion pickle is prepared by selecting good quality onion (20-25 mm diameter). Remove neck and bottom part of onion. Blanching of onion for (1-2 min) in boiling water or under steam for 4 minutes is carried out. Onions are cooled immediately by dipping them in cold water and peeling off the outer scales carefully. Onions are dipped in a brine solution having 500 ml water, 500 ml, ofvinegar, and 100 g salt for 1 kg onion) for 24-36 hours. Drain out pickling solution and transfer material for surface drying at 55°C for 2-3 hours in a ventilated oven.

Fig. 6: Onion Pickle

After drying different spices are mixed with little amount of oil in surface dried onions to prepare pickle. Spices quantity added for 1 kg of fermented onion 16 g of mustard, 13 g of turmeric powder, 25 g of sugar, 30 g of garlic paste, 15 g of chilli powder, 0.7 g of roasted fenugreek and 300 ml of oil. Pre-sterilized jars were used with oil up to 1/5 to of its volume and then adding the above mixture to jars containing oil, pressing the onion slightly to the bottom with the help of a spatula to eliminate air pockets. Cover onion with thin layer of oil, leaving headspace of 5-10 mm. Finally Pasteurizing the product in pasteurizer for 10 min at 85°C or in boiling water for 10 minutes (Place the jars in water at 70°C to avoid cracking). Allow the jars to get cool to room temperature then label it and store at cool and dry place.

Onion Oil: The odor and flavor properties of onion oil and its components have been used in the food industry to add traditional flavors in novel foods. Alk(en)yl sulfides, the main constituents of onion oil, are perceived as odorants like sulfur, fried onion, garlic, and/or cooked cabbage. Generally, 1 g of onion oil is equivalent to the flavor of 4.4 kg of fresh onions or 500 g onion powder. Onion oil can be incorporated into carriers (salt, carbohydrates, or other edible material) to get dry soluble, fat-based soluble, encapsulated, and liquid soluble spices. Onion oil has been used as a food additive to improve the sensorial, antioxidant, and microbiological quality of a treated product

Fig.7: Onion Oil

Onion Vinegar: Onions are considered to be a promising source of vinegar as they are rich in sugar and many nutrients. Onion outer layer of dry skin is removed. Onion is subjected to microwave shock treatment at 530-560W to inactivate allinase. Further onions pulp is prepared with the help of pulp making machine and small amount of sugar is added in pulp under the intervention of antioxidant SO_2 to adjust sugar degree to 15-20% (W/W). Inoculation of activated wine yeast for alcoholic fermentation is done (Fermentation quantity: 0.2-1%, temperature: 18-25°C, time: 5-7 days). By separating slag from liquid to obtain onion raw vinegar and alcohol content is adjusted. Inoculation of acetic acid bacteria is done for acetic fermentation (fermentation quantity: 0.2-1%, temperature: 30-40°C, time: 3-7 days) with adjusting the acidity. Ageing process is followed at normal temperature for 1-2 months. After ageing vinegar is filtered finely and degerming is carried out (Fu and Dong, 2011).

Fig.8 Onion Vinegar

Different value-added products from garlic

Garlic can be processed into different value-added products like minimally processed ready to use peeled garlic cloves, dehydrated flakes, powder, paste, pickles, oil etc.

Minimally processed peeled garlic

'Though garlic is regularly used in the Indian house hold, peeling of garlic is time taking and cumbersome. With increase in the number of working women, the demand for ready to use minimally processed foods is also increasing. Peeled garlic offers convenience to use and retain the fresh characteristics of the garlic. Although peeled garlic offers convenience, due to the removal of protective layer by peeling, storage life will be dwindled. The storage life of peeled garlic depends on the type of variety and length of storage and storage conditions (ce temperature and relative humidity (RH)) of garlic bulbs before peeling. The major visible quality changes that are perceived in peeled garlic are sprouting, rooting and discoloration apart from the invisible nutritional quality changes. Garlic can be peeled either manually or mechanically. Selection of packaging 'material is very important to reduce weight loss by controlling the respiration rate and to augment the storage life. Storage at 0 to 5°C is imperative to maintain good quality of peeled garlic, storage temperatures above 5°C will result in pink and brown discoloration on the damaged areas and also favors root and sprout development (Cantwell, 2016). Modified atmosphere packaging (MAP) may also be effective in preserving quality of stored garlic cloves. A reasonable expected storage-life of commercially peeled and modified atmosphere packaged garlic is 3-4 weeks at 0°C, 2-3 weeks at 5°C; and 1-2 weeks at 10°C and pungency (thiosulfinate and pyruvate Concentrations) decreases with time and the decrease is greater at higher storage temperatures (Tanamati, 2016). Hot water dip treatments at 55°Cfor 10 min is effective in reducing sprout and adventitious root growth in cloves stored at 10°C and >95% RH. Hot water dip treatment at 60°C for 2.5 min is also effective in inhibiting sprout and foot growth without any injury (Cantwell *et al*., 2003).

Dehydrated garlic flakes

Dehydration also extends the shelf-life by retaining sensorial characteristics compared to those of fresh products. Dehydration decreases the water activity of the material, reduces microbiological activity, and minimizes physical and chemical changes during its storage. Although garlic is semi-perishable crop, its availability in the form of flakes and powder augment the value besides increasing its shelf life. Garlic flakes are prepared by peeling, cutting, pre-treating and drying using different drying, techniques (sun/solar, hot air/ vacuum oven, microwave, fluidized bed, freeze drying, infra-red etc.) Pre-treatment before drying improves the quality of dried product, prevents browning, accelerates drying rate and also retains volatile compounds. Pre-treatment of garlic by immersing in 0.5% metabisulfite solution before drying improves the quality of the dried product by preventing the browning reactions. Steam blanching of garlic prior to the drying at 100°C for 4 min increases the drying constant.

Garlic powder

Garlic powder is mainly used as a condiment in food preparation, also serves as a carminative and gastric stimulant in many medicinal preparations. It is easy and convenient to use and store and can be transported without any difficulty. Dehydrated garlic in its powder form is highly hygroscopic. It picks up moisture even at 20% RH for a typical garlic powder (moisture 6%), the equilibrium relative humidity at 25° is about 13%. The critical point for garlic powder as regards caking is 10.6% moisture level, and the danger point is 9.5%. The shelf life of the garlic powder at 3 months of storage at ambient condition is better in aluminum laminate and brown glass bottle (Ambrose *et al*., 1998). Polypropylene (PP) is not suitable as a packaging material for storage of garlic powder. Garlic powder can further be developed into different value added products like ready to use garlic bread mix, curry masala mix, soup mix etc. by adding different spices in the optimized quantity Powder prepared using hygienic and quality preserving drying technologies is also used in the medicinal composition preparations.

Garlic paste

Garlic paste can be prepared by peeling and grinding. As the paste contains high moisture, proper packaging and storage conditions are required to store for longer duration without any microbial spoilage. Addition of preservatives or thermal treatments can be followed to store it for longer duration. Generally, garlic paste should have light tan to cream color but greening of garlic products during preparation and storage has been recognized as a major quality problem. The greening process is known to be triggered by the action of the enzyme allinase which yields a thiosulfinate known as a color developer. This color developer reacts chemically with an amino acid to form a pigment precursor. Both temperature and duration of storage had effect on total color of garlic paste. Greening depends on both type of variety and manufacturing conditions. Optimal solutions for garlic greening prevention should be sought on a case-by-case basis.

Garlic pickle

‘Among the different garlic-based products on the market, pickled blanched garlic appears to be fairly well-accepted by consumers. Pickled blanched garlic possess good organoleptic properties besides benedicial health effects because of the organo sultur compounds present in it. Optimum blanching treatment to inhibit potential formation of green colouration and remove pungent flavor is 80°C for 1.1 min (Rejano *et al*., 2004). For its long-term storage, blanched garlic is normally packed in small containers using acidized brine as, cover liquid with the optional addition of spices and/or olive oil.

Pasteurization or the addition of sorbates/benzoates plus refrigeration is done to make it microbial safe during storage.

Garlic oil

Garlic bulbs contain 0.06% to 0.1% of volatile oil whose active constituents are propyl disulphide, alliin and alticin. Garlic oil contains sulfur organic compounds such as allyl sulfides, produced by the action of an enzyme (alliinase) on precursor amino acids. The oil is used not only as a flavor agent, but also as a nutraceutical (Andreatta *et al*., 2014). Garlic essential oil is effective in scavenging free radical and has the potential to be powerful antioxidant. Garlic oil can be extracted from fresh garlic bulbs using traditional hydro-distillation or steam stripping processes or alternatively by applying new techniques such as high-pressure extraction with near- critical fluids. Carbon dioxide is the preferred near-critical solvent, because it has a low critical temperature, it is non-toxic, non-flammable, easily available and relatively cheap. The oil extracted with liquid CO_2, has the typical flavor of fresh garlic, while the oils obtained by hydro-distillation and steam stripping have the characteristic smell of cooked garlic. (Andreatta *et al*., 2014),

Aged black garlic

Garlic is being used as a medicinal ingredient in folk remedies since the old times due to bio- functional properties that are good for health. However, it is not enjoyed by many due to its peculiar smell. Black garlic (BG) such product that is prepared by aging whole garlic at high temperature and in high humidity, causing the garlic to turn black because of browning compounds BG does not exude a strong off flavor, like fresh garlic which removes the peculiar pungent odor (Choi *et al*., 2014), Its produced by ageing. Whole garlic at high temperature (70 ^{o}C) and high (90% RH) humidity (Lee *et al*., 2009). During this process compound allicin, which is responsible for the pungent odor changes into water soluble antioxidant compounds such as S-allylcysteine, tetrahydro-é-carbolines, biologically active alkaloids, and flavonoid-like compounds (Choi *et al*., 2014)

Epilogue

Consumption of onion and garlic which are rich in medicinal properties is good for health benefits. The onion based value added products such as paste, powder, flakes or vacuumed packed o are part and parcel of daily consumption pattern both in rural and urban India. These products fall under commonly consumed culinary products across households. Therefore, demand for onion paste, powder, flakes are always are prevalent across length and breadth of the country throughout the year. Urban organized platforms such as departmental stores, malls, super markets can be attractive platforms to sell well packaged and branded onion products. Processors can also have tie-up with hotels and restaurants for supply. Availability of onion and garlic in processed form for ready use would be helpful in its regular consumption. Processing and valorisation of onion and garlic into different value-added products with better storage life will also be helpful in reducing the postharvest losses.

References

Adreatta AE, Foco G, Mabe G and Bottini S 2014. Extraction of garlic oil with quasi- critical solvents. 2nd Mercosur Congress on Chemical Engineering 4th Mercosur Congress on Process Systems Engineering

Ambrose DCP and Sreenarayanan VV 1998. Studies on the dehydration of garlic. *J Food Sci Tech Mys*. 35: 242-244

Blanchard, M., Castaigne, F., Willemot, C., & Makhlouf, J. 1996. Modified atmosphere preservation of freshly prepared diced yellow onion. *Postharvest Biology and Technology*, 9(2), 173-185

Cantwell MI, Kang J, & Hong G. 2003. Heat treatments control sprouting and rooting of garlic cloves. *Postharvest biology and technology, 30*, 57-65 doi:10.1016/S0925-5214(03)00060-7

Cantwell M 2016. http:// www.ba.ars.usda.gov/hb66/garlic.pdf

Choi IS, Cha HS and Lee YS 2014. Physicochemical and antioxidant properties of black garlic. *Molecules*. 19: 16811-16823

Fu P and Dong Y. 2011. Preparation method of onion vinegar. *Patent publication no:CN102154088 (A)*. [Applicant: Shandong Haizhibao Seafood Co Ltd]

Kejano L, De Castro A, Sanchez AH, Casado FJ and Montano A 2004. Thermal kinetics of pungency loss in relation to the quality of pickled garlic. *Int J Food Sci Tech*. 39: 311-317

Lee Y, Gweon O, Seo Y, Im J, Kang M, Kim M and Kim J 2009. Antioxidant effect of garlic and aged black garlic in animal model of type 2 diabetes mellitus. *Nutr Res Pract*. 3(2): 156-161

Tanamati F, Hong G and Cantwell MI. 2016. Impact of storage temperatures and modified atmospheres on quality of fresh-peeled garlic cloves. *Acta Hortic*. 1141, 221-228.

Chapter 12

MEDICINAL AND NUTRACEUTICAL PROPERTIES OF ONION AND GARLIC

R A Dagadkhair*, Bhushan R Bibwe and Kalyani Gorrepati
ICAR-Directorate of Onion and Garlic Research, Pune-410505
Email: rajkumar.dagaarkhair@icar.gov.in

Onion

The onion is one of the important vegetable crops in India and is an integral component of Indian culinary. Being an essential food item, it is also a highly politically sensitive commodity because it has one of the major export potential, therefore, it is very pertinent to assess the performance of onion products export in post liberalized regime in order to take corrective measures and devise future strategies to achieve greater levels of export. India ranks second in global onion production after China and with an annual production of 16 to17 million tonnes accounts for around 20% of global production. In overall cropping pattern, onion occupies about 0.1 per cent of gross cropped area and about 7 per cent of total area under all vegetable crops. Onion production has shown a steady upward trend, in response to increase in planted area and to a lesser account due to improvement in productivity.

Types Of Bioactive Compounds

Onion is a perfect blend of valuable bioactive compounds such as FOS, flavonoids, ascorbic acid, and OSCs, and these compounds have shown various health benefits to humans. Onion is a prime source of OSCs and flavonoids known for their antioxidant properties, whereas, onion by-products possess a significantly higher amount of total phenols, flavonoids, and minerals compared to the edible bulb.

Thio-sulfinates and organosulfur compounds

Like other Allium species, onion is the major source of flavoring OSCs, including thiosulfinates. Enzyme alliinase forms thiosulfinates by catalytic action which produces lachrymatory compounds and onion flavor. Total thiosulfinates may differ according to the color of onion cultivars. As per a high-performance liquid chromatography (HPLC) analysis, the red, yellow, and white onions had 0.20, 0.35, and 0.14 µmol/g FW of thiosulfinates, respectively. Depending on the reaction conditions, thiosulfinates can convert into several sulfur compounds, such as diallyl, vinyldithiins, diethyl mono, di, tri, tetra, penta, hexa sulfides, methyl allyl, and (E)- and (Z)-ajoene. From the chemical point of view, the OSCs of onion include diallyl monosulfide (DMS), diallyl disulfide (DADS), diallyl trisulfide (DATS), and diallyl tetrasulfide (DTTS). Onion also contains other sulfur-containing compounds, such as S-propyl-l-cysteine sulfoxide, S-methyl-l-cysteine sulfoxide, and S-propenyl-l-cysteine sulfoxide. In addition, sulfoxides, such as (+)-S-(1-propenyl)-L-cysteine sulfoxide (PRENCSO) and (+) S-methyl-L-cysteine sulfoxide (MCSO) are also known as sulfur-containing compounds. Indeed, S-alk(en)yl-l-cysteine sulfoxides (ACSOs) are formed from (+)-S-(trans-1-propenyl)-L-cysteine and S-alk(en)yl-cysteines, such as (+)-S-allyl-L-cysteine (SAC), which are parts of γ-glutamyl peptides. All these molecules are responsible for the peculiar flavor (pungency) of onion and formed on the disruption of onion tissues triggering the conversion reaction. Proelyn-L-cysteine sulfoxide is a precursor of lachrymatory and flavor attributes of onion which irritate few animals. In their study, investigated onion for ACSOs and found isoallin concentration ranging from 8.42 to 0.18 mg/g dry weight (DW). examined four onion varieties, namely, Alife Onion, Montoro Onion, tapered shape Vatolla onion, and spinning top Vatolla onion from the Italian Mediterranean area. They recorded 963.90 ± 69.88, 1322.79 ± 253.22, 1368.63 ± 127.60, and 1393.15 ± 156.48 mg/kg concentration of OSCs (DW basis), respectively investigated three types of onions, that is, "onion," "Storey onion'," and "Welsh onion" for OSCs and they obtained the highest amount in "Storey onion" (962.20 μg/g FW) followed by "onion" (634.65 μg/g) and "Welsh onion" (606.48 μg/g). Nevertheless, the variation in the content of different OSCs is related to growing conditions, cultivar types, and geographical locations. In addition, onion color also affects the level of OSCs (41)

Phenolics and flavonoids

Onion is a source of phenolics that derive through cinnamic or benzoic acid. Phenolics are found either in free or bound form and are responsible for the colour, taste, bitterness, and aroma of plants. Hydroxycinnamic acids (HCs), monocyclic phenylpropanoids having a C6–C3 skeleton, are found in plants and exemplified by ferulic, sinapic acids, p-coumaric, and caffeic acid. In onion, HCs are found in the form of protocatechuic, ferulic acid, 1-O-ß-D-glucoside, p-coumaric, and vanillic acids either free or conjugated (Lachman et al., 2003). In this regard, purple, red, yellow, and green cultivars of onion were evaluated for total phenols and it was noted that the purple cultivar contained the highest content of phenols (47.3 mg/100 g FW) followed by red (44 mg/100 g FW) and yellow (34.7 mg/100 g FW), whereas green cultivar had the lowest phenolics content (30 mg/100 g FW) investigated 34 Indian genotypes of white, pink, and red coloured onions and recorded the highest phenolics in red cultivars (867.8 mg/kg FW) followed by pink (702.0 mg/kg FW) and white (165.0 mg/kg FW). analysed the skin of fifteen Indian cultivars and found that total phenolics content values in dark red (289.04 mg GAE/g DW), pink (231.73 mg GAE/g DW), and white (19.74 mg GAE/g DW) cultivars were in agreement with other studies, and these results confirm that the concentration of phenols is positively correlated with the colour of onion cultivars. The extraction solvents and experimental conditions such as time, temperature, and pressure may also affect the level of phenolic compounds.

Quercetin

Quercetin is made up to five hydroxyl groups, which is responsible for possible number of derivatives and biological activity of the compound. Major groups of quercetin derivatives are ethers and glycosides, while prenyl and sulfate substituents are present in fewer amounts.

Kaempferol

It is a tetrahydroxyflavone having four hydroxyl groups present on 3, 5, 7, and 4′ positions. Being a tetrahydroxyflavoneand 7-hydroxyflavonol, it falls under flavonols family. It comes from kaempferol oxoanion as conjugate acid. Luteolin. It is a tetrahydroxyflavone same as kaempferol but it contains four hydroxyl groups located at 3′, 4′ 5, and 7. According to the structure, it is also known as 3′-hydroxyflavonoid.

Anthocyanins

Anthocyanins are generally found in epidermal layer of plant cell. It is composed of a molecular region with three aromatic rings that has one or more attached sugar moiety. The basic structure of anthocyanins has flavylium cation (2-phenylbenzopyrilium) links with methoxyl (-OCH3) or hydroxyl (-OH) and one or more sugar units. It comprises mainly 3-glucosides that is categorized into the sugar free anthocyanin glycosides and anthocyanidin aglycones. 2.3 Ascorbic acid Onion has also been reported to contain ascorbic acid (vitamin C). Red and yellow Korean onions were assessed for ascorbic acid content and red cultivar showed higher concentrations (28.34 mg/100 g FW) than yellow ones (19.20 mg/100 g FW), and it was shown that color variation in cultivars affects ascorbic acid levels. measured ascorbic acid content and values ranged from 60–2703 mg/kg to 390–5000 mg/kg DW for onion bulb and leaves, respectively. Physical treatment also affects ascorbic acid content. For example, raw onion bulbs had a higher quantity of ascorbic acid (35 mg/kg DW) in comparison with microwaved onion (1 min at 1000 W), which contained 29 mg/kg DW.

Fructooligosaccharides

FOS are the main nonstructural carbohydrate storage in onion. Among 60 different vegetables, onion was reported to contain the highest amount of FOS, which has been shown to increase the healthpromoting gut microflora. In onion, FOSs are composed of several fructofuranosyl sucrose subunits, that is, 1-kestose, neokestose, nystose, other linear (inulin), and branched (inulin neoseries) polymers. The analysis of different varieties showed that the intense color of onion can be correlated with higher content of FOS. Different studies reported a variation in FOS content of different onion varieties. In red onion cultivars, total FOSs averaged 27.1 mg/g FW and in yellow cultivars, it was found between 24.2 and 26.3 mg/g FW, whereas white cultivar and welsh onion had 3.1 and 1.1 mg/g FW of FOS, respectively investigated FOS in five Spanish onion cultivars and reported a content ranging from 23.3 to 141.9 g/kg.

Garlic

Natural products of animals, plants and microbial sources have been used by human being for thousands of years either in the pure forms or crude extracts to treat many diseases. Garlic (*Allium sativum L.*) is one of those plants that were seriously investigated over several years and used for centuries to fight infectious diseases. The taxonomic position of garlic and related genera had been a matter of controversy for long period of time. The most recent classification scheme of garlic was class Liliopsida, subclass Liliidae, superorder Liliianae, order Amaryllidales, family Alliaceae, subfamily Allioideae, tribe Allieae and genus Allium which is mainly based on the sequences of nuclear ribosomal DNA. The early Egyptians used garlic to treat diarrhoea and its medical power was described on the walls of ancient temples and on papyrus dating to 1500 BC. It was used by Greek physicians Hippocrates and Galen to treat intestinal and extra-intestinal diseases; ancient Japanese and Chinese used it to treat headache, flu, sore throat and fever. In Africa, particularly in Nigeria, it is used to treat abdominal discomfort, diarrhoea, otitis media and respiratory tract infections. In Europe and India, it was used to treat common colds, hay fever and asthma. Garlic is nicknamed as Russian penicillin for its widespread use as a topical and systemic antimicrobial agent; it is commonly used in many cultures as an excitement and reputation of healing power.

Potentially Active Chemical Constituents Of Garlic

Garlic contains at least 33 sulfur compounds, several enzymes and the minerals germanium, calcium, copper, iron, potassium, magnesium, selenium and zinc; vitamins A, B1 and C, fiber and water. It also contains 17 amino acids to be found in garlic: lysine, histidine, arginine, aspartic acid threonine, swine, glutamine, proline, glycine, alanine, cysteine, valine, methionine, isoleucine, leucine, tryptophan and phenylalanine. It has a higher concentration of sulfur compounds than any other Allium species which are responsible both for garlic's pungent odour and many of its medicinal effects. One of the most biologically active compounds in garlic is allicin (diallyl thiosulfinate or diallyldisulfide). The most abundant sulfur compound in garlic is alliin (Sallylcysteine sulfoxide), which is present at 10 and 30 mg/g in fresh and dry garlic, respectively.

Typical garlic food preparation such as chopping, mincing and crushing disturbs S-allyl cysteine sulfoxide and exposed it to the allinase enzymes, then quickly converted it to diallyl thiosulfinate, which give off garlic's characteristic aroma. The allinase enzyme responsible for diallyl thiosulfanate conversion becomes inactivated below a pH of 3.5 or with heating. Although allicin is considered the major antioxidant and scavenging compound, recent studies showing that other compounds may play stronger roles; such as polar compounds of phenolic and steroidal origin, which offer various pharmacological properties without odor and are also heat stable.

Role Of Garlic In Health

Garlic can rightfully be called one of nature's wonderful plants with healing power. It can inhibit and kill bacteria, fungi, lower (blood pressure, blood cholesterol and blood sugar), prevent blood clotting, and contains anti-tumor properties. It can also boost the immune system to fight off potential disease and maintain health. It has the ability to stimulate the lymphatic system which expedites the removal of waste products from the body. It is also considered an effective antioxidant to protect cells against free radical damage. It can help to prevent some forms of cancer, heart disease, strokes and viral infections. Garlic alone can provide us with over two hundred unusual chemicals that have the capability of protecting the human body from a wide variety of diseases. The sulfur containing compounds found in garlic afford the human body with protection by stimulating the production of certain beneficial enzymes.

Treat cardiovascular disease

Disorders of the heart and the circulatory system claim more lives than any other diseases. It is the obstruction or clogging of the coronary arteries which causes more deaths than any other factors. The arteries, which supply the heart with blood and oxygen, become increasingly narrower as plaque builds up over time. When blood supply becomes restricted, a certain portion of the heart is deprived of oxygen and leads to heart attack. The two greatest means of heart disease are high blood pressure and high blood serum cholesterol levels; which are directly impacted by the therapeutic action of garlic. The relevant role of garlic in coronary heart disease was done on rabbits and found that even pre-existing atherosclerotic deposits and lesions could actually be reversed if garlic was consistently consumed.

From a study conducted in India, 432 coronary artery patients were randomly grouped into two groups and half of them were supplied with garlic juice in milk, whereas the other group patients were not supplied with garlic juice. The result showed that within the three years of the study time, nearly twice as many patients had died in the group not supplied with garlic juice. It is well reported to scavenge oxidants, increase superoxide dismutase, catalase, glutathione peroxidase, glutathione levels, inhibit lipid peroxidation as well as it reduces cholesterol synthesis by inhibiting 3-hydroxy-3-methylglutaryl-CoA. It has been shown to reduce platelet aggregation, arterial plaque formation, decrease homocysteine, lower blood pressure, and increase microcirculation. It may also help prevent cognitive decline by protecting neurons from neurotoxicity and apoptosis, thereby preventing ischaemia or reperfusionrelated neuronal death and by improving learning and memory retention.

Reduces high blood pressure/hypertension

Garlic has probably been most popularized as a complementary therapy for blood pressure control. A recent in vitro study has confirmed that, the vasoactive ability of garlic sulfur compounds whereby red blood cells convert garlic organic polysulfides into hydrogen sulfide, a known endogenous cardio-protective vascular cell signalling molecule. Using 2400 mg garlic tablet containing 31.2 mg allicin has high dose reduced diastolic pressure by 16 mmHg after 5 h of administration.

A meta-analysis made on pooled data from 415 patients showed also reduction of 7.7 mmHg diastolic pressure. As natural blood thinner Platelets and fibrin play great role in blood clotting and higher amount of fibrin in blood can cause heart attack. Garlic constituents can reduce fibrin formation and also help reduce the fibrin existing in the blood even better than aspirin. Ajoene, a sulfur compound found in garlic seems to be responsible for its anti-clotting effect; but ajoene is only viable at room temperature or above, it is not present in raw or freezedried garlic. It is believed that the addition of garlic to a diet can help to increase the breakdown of fibrin from 24 to 30% in people.

As natural immunity booster

With the arrival of frightening viral diseases like HIV/AIDS, boosting immunity system is receiving a new attention. Because these types of diseases have no effective cures or treatments, strengthening the body's ability to fight off infection has become even more important. Garlic has abundant sulfur containing amino acids and other compounds that seem to initiate increased activity in the immune system. It is one of the impressive conductors of the body's immune system; which stimulates immune function by making macrophages or killer cells more active. We are constantly beaten by inadequate nutrition, cigarette smoke, physical injury, mental tension and chemical pollution. In light of the enormous pressures, which our immune systems sustain, supplemental nutrients like garlic are clearly needed.

Its remarkable content of germanium alone offers excellent immune stimulation. In addition to germanium, garlic contains thiamine, sulfur, niacin, phosphorous, and selenium. Preliminary studies in humans, using an alliin standardized garlic powder preparation, have demonstrated positive effects on immunoreactions and phagocytosis. In aged subjects, the administration of 600 mg garlic powder per day for 3 months induced significantly (p10.0 g/day) the risk of prostate cancer than those in the lowest category.

The reduced risk of prostate cancer was independent of body size, intake of other foods and total calorie intake and was more pronounced for men with localized prostate cancer than with advanced prostate cancer. Prostate specific antigen serum markers had significant decreases during short term ingestion, but returned to baseline after 4 weeks. A very important epidemiological study for Americans has been published in which the intake of 127 foods (including 44 vegetables and fruits) was determined in 41,387 women (ages 55 to 69) followed by a five year monitoring of colon cancer incidence. The most striking result of this "Iowa Women's Health Study" was the finding that garlic was the only food which showed a statistically significant association with decreased colon cancer risk. For cancers anywhere in the colon, the modest consumption of one or more servings of garlic (fresh or powdered) per week resulted in a 35% lower risk, while a 50% lower risk was found for cancer of the distal colon. Dermatologic applications A study examined 43 persons for their topical use of two different garlic extracts for wart and corn treatment. Of these persons, 15 volunteers utilized a water extract of garlic, while 23 volunteers applied lipid extract to appropriate areas twice a day. Five controls applied only a neutral solvent. All lipid extract volunteers experienced complete resolution of wart and 80% of corn within one to two weeks. The water extract seemed to be less potent, with complete dissolution of smaller warts and corns, and only partial dissolution of larger ones. Controls showed no improvement from baseline. The lipid extract did cause some burning, redness, blistering and skin darkening, which was resolved after conclusion of use.

Antimicrobial

The antimicrobial properties of garlic were first described by Pasteur (1958), and since then, many researches had demonstrated its effectiveness and broad spectrum antimicrobial activity against many species of bacteria, viruses, parasites, protozoan and fungi. Garlic is more effective with least side effects as compared to commercial antibiotics; as a result, they are used as an alternative remedy for treatment of various infections. Out of the many medicinal plants, garlic has an antimicrobial property which protects the host from other pathogens highlighting the importance of search for natural antimicrobial drugs. Previously conducted researches confirmed that garlic is not only effective against Gram positive and Gram negative bacteria but also possess antiviral and antifungal activities.

Antiviral

Garlic and its sulfur constituents verified antiviral activity against coxsackievirus species, herpes simplex virus types 1 and 2, influenza B, para-influenza virus type 3, vaccinia virus, vesicular stomatitis virus, human immunodeficiency virus type 1 and human rhinovirus type 2. The order of compounds found in garlic for virucidal activity was, ajoene > allicin > allyl methyl thiosulfanate > methyl allyl thiosulfanate; no activity was found for the polar fractions, alliin, deoxyalliin, diallyl disulfide, or diallyl trisulfide. Several laboratory tests have shown that garlic is an effectual treatment for both the influenza B virus and herpes simplex virus. Two independent researchers in Japan and Romania have found that garlic is able to protect living organisms from the influenza virus. Most recently, a double blind placebo controlled study has shown significant protection from the common cold virus. As conducted by The Garlic Centre, published in Advances in Therapy, this is the first serious work to show prevention, treatment and reduction of reinfection benefits from taking Allimax Powder capsules once daily.

Antibacterial

Garlic extract inhibits the growth of Gram positive and Gram negative bacteria, such as Staphylococcus, Streptococcus, Micrococcus, Enterobacter, Escherichia, Klebsiella, Lactobacillus, Pseudomonas, Shigella, Salmonella, Proteus, and Helicobacter pylori. Its antibacterial activity is mainly due to the presence of allicin produced by the enzymatic activity of allinase on alliin. Allicin is considered to be the most potent antibacterial agent in crushed garlic extracts, but it can be unstable, breaking down within 16 h at 23°C. However, the use of a water-based extract of allicin stabilizes the allicin molecule due to the hydrogen bonding of water to the reactive oxygen atom in allicin or there may be water soluble components in crushed garlic that destabilize the molecule. The disadvantage of this approach is that allicin can react with water to form diallyl disulphide, which does not exhibit the same level of antibacterial activity of allicin.

Antifungal

Ajoene is an active compound found in garlic which plays a great role as topical antifungal agent. Garlic has been shown to inhibit growth of fungal diseases as equally as the drug ketoconazole, when tested on the fungi *Malassezia furfur, Candida albicans, Aspergillus, Cryptococcus* and other Candida species. A report from a Chinese medical journal delineates the use of intravenous garlic to treat a potentially fatal and rare fungal infection of the brain called Cryptococcus meningitis. In the report, the Chinese compared the effectiveness of the garlic with standard medical treatment which involved a very toxic antibiotic called AmphotericinB. The study revealed that, intravenous garlic was more effective than the drug and was not toxic regardless of its dosage. A study found that Candida colonies were substantially reduced in mice that had been treated using liquid garlic extract. The study also revealed that garlic stimulated phagocytic activity. This implies that infections such as Candida may be controlled because garlic stimulates the body's own defences. Garlic oil can be used to treat ringworm, skin parasites and warts if it is applied externally. Lesions that were caused by skin fungi in rabbits and guinea pigs were treated with external applications of garlic extract and began to heal after seven days.

Antiparasitic

Many herbalists worldwide recommend garlic as a treatment for intestinal parasites. In some cultures, children infested with helminths are treated with enemas containing crushed garlic. One of the traditional Chinese medical treatments for intestinal diseases is an alcoholic extract of crushed garlic cloves. Allicin exhibits antiparasitic activity against major human intestinal parasites such as *Entamoeba histolytica, Ascaris lumbricoides* and *Giardia lamblia*. Entamoeba histolytica, the human intestinal protozoan parasite, is very sensitive to allicin, as only 30 μg/ml of allicin totally inhibits the growth of amoeba cultures. Moreover, researchers have found that at lower concentrations (5 μg/ml), allicin inhibited 90% the virulence of trophozoites of E. histolytica as determined by their inability to destroy mono-layers of tissue-cultured mammalian cells in vitro. Role of garlic against multi-drug resistant bacteria Garlic is active against microorganisms that are resistant to antibiotics and the combination of garlic extracts with antibiotics leads to partial and total synergism. The emergence of multi-drug resistant strains of Gram negative (*Pseudomonas, Klebsiella, Enterobacter, Acinetobacter, Salmonella spp,* etc) and Gram positive (*Staphylococcus, Enterococcus, Streptococcus spp.*, etc) bacteria is troubling for human and Gebreyohannes and Gebreyohannes 405 animals. The emergence of epidemic methicillin resistant Staphylococcus aureus (MRSA) resistant to mupirocin has led many authors to suggest that the use of mupirocin should be controlled more strictly, especially as there is a lack of alternative agents. Consequently, garlic is an alternative agent for the treatment of MRSA and in a great demand.

Role of garlic against multi-drug resistant tuberculosis (MDR-TB)

Scientific evidence from randomized clinical trials supports the use of garlic and enhances access for MDRTB infected people, through the public health system. Its use can allow an effective MDR-TB management, due to its affordability and the absence of toxic effects. In view of the increased incidence of MDR-TB, the research of new anti-tubercular drugs based on affordable and more effective treatments has already begun. Studies on innovative alternative plant extracts of medicinal values need to be emphasized, as plants are an important source of new antimicrobial agents, with little toxicity, able to replace drugs to which Mycobacterium resistance has occurred. As garlic is concerned, the in vitro tests undertaken about the inhibitory effect on MDR-TB are at an advanced stage whereas few researches in vivo have been conducted. The concentration of garlic extract required was in the range of 1.34 to 3.35 mg/ml suggesting that there is only a slight variation in the susceptibility of the strains to allicin. The anti-tuberculosis activity in vivo of garlic oil preparation was demonstrated in a study of guinea pigs which were given an intra-peritoneal dose of 0.5 mg/kg. However, when garlic oil was used, a reduced causative process was noted in the organs involved, indicating that garlic oil administration causes less marked lesions in the viscera of the animals inoculated with tubercle bacilli. The high potential of garlic extract was revealed to inhibit the growth of *Mycobacterium tuberculosis* H37Rv and M. tuberculosis TRC-C1193, susceptible and resistant to isoniazid (first-line anti-tuberculosis medication), respectively. The minimum inhibitory concentration (MIC) of garlic was between 80 and 160 μg/ml for the susceptible strain and 100 and 200 μg/ml for the resistant strain. In addition, water extract of garlic was proven to inhibit the incorporation of 14C glycine into the whole cells, indicating that the primary mechanism of action is by inhibition of protein synthesis. An interesting in vitro test about the anti-tubercular activity of garlic was performed in Nigeria using disc diffusion method and compared with standard antibiotics. The anti-tubercular activity of garlic on multiple-drug resistant Mycobacterium was investigated among Nigerian HIV-infected-persons and it exhibited maximal activity against all isolates even at reduced concentrations. Only two of the standard anti-tubercular antibiotics used, streptomycin and rifampicin, showed significant activity against isolates tested. Antioxidant Whole garlic and aged garlic extract exhibit direct antioxidant effects and enhance the serum levels of two antioxidant enzymes, catalase and glutathione peroxidase. Garlic extract, allicin is efficiently scavenged exogenously generated hydroxyl radicals in a dose dependent fashion, but their effectiveness was reduced about 10% by heating to 100°C for 20 min. Other garlic constituents, such as S-allyl cysteine, also confirmed significant antioxidant effects.

The sulfur compounds found in fresh garlic appear to be nearly 1000 times more potent as antioxidants than crude, aged garlic extract. Garlic (both the homogenate of 10% in physiological saline solution and its supernatant) was able to reduce the radicals present in cigarette smoke. Drug toxicities and pharmacokinetics Glutathione is a compound necessary for liver to facilitate detoxification of substances. It has been hypothesized that garlic organo-sulfur compounds may be able to prevent glutathione depletion. Patients who experience increasing in reactive oxygen induced stress on liver function may be protected by garlic ingestion. It was found in E. coli cultures that aged garlic extract, S-allyl cysteine, diallyl sulfide and diallyl disulfide do not interfere with the antibiotic activity of gentamycin but may improve gentamycin-induced nephrotoxicity. Aged garlic has also been shown to reverse oxidant effects of nicotine toxicity in rat studies. More researches are required in the future garlic may be a unique choice to help minimize the toxic effects of therapeutic drugs.

Reduces stress

Among the many uses of garlic, it appears to have the fortunate capacity for protecting against the negative effects of stress that affects the autonomic nervous and neuroendocrine system. Rats that were trained with endurance exercises to physical fatigue enjoyed improved parameters of aerobic glucose

metabolism, attenuated oxidative stress, and vasodilation's, when given garlic at a dosage of 2.86 g/kg for 30 min before exercise. In rats exposed to psychologically stressful situations, aged garlic extracts significantly prevented the decreases in spleen weight seen in control animals. Additionally, the garlic significantly prevented reduction of hemolytic plaque forming cells in spleen cells. Moreover, garlic was able to block lipopolysaccharide induced immune cytokine and plasma corticosterone and catecholamine changes following cold water immersion stress. Aged garlic extract is also effective to prevent adrenal hypertrophy, hyperglycemia and elevation of corticosterone in hyperglycemic mice induced by immobilization stress. Given the extreme chronic stress many people now face in their daily life, garlic may prove useful to counter the negative impact of this stress on human physiology.
Adverse effects of garlic

The main adverse effect commonly associated with garlic intake is breath odour, especially when raw forms of the herb are used. Nausea and vomiting are other major adverse effects and care should be taken in consuming high quantities. Although an entire bulb produces little juice, it is potent and can act as a strong emetic, even in small quantities. Although garlic generally poses little in terms of safety issues, there are isolated cases of topical garlic burns and anaphylaxis. Rare garlic allergy has been attributed to the protein allinase, which has induced immunoglobulin E (IgE) mediated hypersensitivity responses from skin prick testing. As a result, the literature has generally cautioned against using garlic while using anticoagulant therapy. There is a reported case of spontaneous spinal or epidural hematoma in an 87 years old man, with associated platelet dysfunction related to excessive garlic ingestion.

Conclusion

In conclusion, onion is very beneficial to human health. Medical properties of onion exceed those in many drugs, which normally have side effects. Several parts of the plant have a place in traditional medicines. Health benefits of onion include substantial relief from number of diseases such as common cold, asthma, bacterial infections, respiratory problems, angina, and cough. World Health Organization confirms that onions are best for people with less appetite and those suffering from atherosclerosis. Health experts acknowledge the fact that onions do provide great respite to patients having chronic asthma, allergic bronchitis, common cough and cold syndrome. Health benefits of onion are available due to presence of sulphur compounds, quercetin and mineral components. To stay healthy and prevent the onset of these diseases, eating an onion a day can keep the doctor away by cleansing and detoxifying the body to prevent and treat ailments from diabetes to heart disease boosting your health. Garlic, from crushed to capsules, is consumed throughout the world. This review paper demonstrated some of the benefits of garlic for its potential uses in preventing and curing different diseases, and acting as antioxidant for many radicals. Fresh and powdered garlic are popular for food flavor and should continue to be used. Today, with the ever-growing resistant organisms, taking of garlic extract remains a powerful antimicrobial agent. Clearly more studies are needed to refine the use and improvement of the efficacy of this important medicinal plant.

References

El-Aasr, M., Fujiwara, Y., Takeya, M., Ikeda, T., Tsukamoto, S., Ono, M., Nakano, D., Okawa, M., Kinjo, J., Yoshimitsu, H. and Nohara, T., 2010. Onionin A from Allium cepa inhibits macrophage activation. Journal of natural products, 73(7), pp.1306-1308..

Eidi, A., Eidi, M. and Esmaeili, E., 2006. Antidiabetic effect of garlic (Allium sativum L.) in normal and streptozotocin-induced diabetic rats. Phytomedicine, 13(9-10), pp.624-629..

Galeone C, Pelucchi C, Levi F, Negri E, Franceschi S, Talamini R, Giacosa A and La Vecchia C. 2006. Onion and garlic use and human cancer. American Journal of Clinical Nutrition, 84 (5). 1027-1032.

Griffiths G, Trueman L, Crowther T, Thomas B and Smith B. 2002. Onions--a global benefit to health. Phytother. Res. 16(7): 603-615.

Harde P. 2012; Antidiabetic Herbal drugs- A Review. Pharmacophore- An International Research Journal 3(1): 18-22.

http://bioweb.uwlax.edu/bio203/s2008/gallant_kirk/Habitat%20and%20Geography.htm

http://cms.cnr.edu.bt/cms/files/docs/File/vegetable%20production/Study%20guides/garlic %20cms.pdf

https://lpi.oregonstate.edu/mic/food-beverages/garlic

Jaime L, Cabrejas MAM, Mollá E, Andréu FJL and Esteban RM. 2001. Effect of Storage on Fructan and Fructooligosaccharide of Onion (Allium cepa L.). J. Agric. Food Chem. 49 (2): 982–988.

Kemper J, Kathi. Garlic (Allium stivum). 2000; The Longwood Herbal Task Force - The center for Holistic Pediatric Education and Research 8: 36-72. 6

Kim JH 1997 Anti-bacterial action of onion (Allium cepa L.) extracts against oral pathogenic bacteria.J. Nehon University Sch Dent. 39: 136- 141.

Lawson LD, Hughes BG.1992; Characterization of the formation of allicin and other thiosulfinates from garlic. Planta Med; 58(4):345-350. (PubMed)

Lawson LD, Wang ZJ.2005; Allicin and allicin-derived garlic compounds increase breath acetone through allyl methyl sulfide: use in measuring allicin bioavailability. J Agric Food Chem. 53 (6):1974-1983. (PubMed)

Lawson LD. 1998; Garlic: a review of its medicinal effects and indicated active compounds. In: Lawson LD, Bauer R, eds. Phytomedicines of Europe: Chemistry and Biological Activity. Washington, D. C.: American Chemical Society; 177-209.

Minami T, Boku T, Inada K, Morita M, Okasaki Y. 1989; Odor components of human breath after the ingestion of grated raw garlic. J Food Sci. 54:763-765.

Rosen RT, Hiserodt RD, Fukuda EK, et al. 2001; Determination of allicin, S-allylcysteine and volatile metabolites of garlic in breath, plasma or simulated gastric fluids. J Nutr. 131(3s):968S-971S. (PubMed)

Slimestad R, Fossen T, Vagen IM. 2007. Onions: A source of unique dietary flavonoids. J. Agricult. Food Chem. 55(25): 10067-10080.

Suarez F, Springfield J, Furne J, Levitt M. 1999; Differentiation of mouth versus gut as site of origin of odoriferous breath gases after garlic ingestion. Am J Physiol. 276(2 Pt 1):G425-430. (PubMed)

Tattelman E. 2005; Health effects of Garlic. Complementary and Alternative medicine 72(1): 103-106.

Thomson M. 2007; Anti-diabetic and hypolipidaaemic properties of Garlic (Allium sativum) in strepozotocin induced diabetic rats. International Journal of Diabetes & Metabolism 2007; 15: 108-115.

Tsuboki J, Fujiwara Y, Horlad H, Shiraishi D, Nohara T, Tayama S, Motohara T, Saito Y, Ikeda T, Takaishi K, Tashiro H, Yonemoto Y, Katabuchi H, Takeya M and Komohara Y. 2016. Onionin A inhibits ovarian cancer progression by suppressing cancer cell proliferation and the protumour function of macrophages. Sci. Rep.: 29588.

Yang J, Meyers KJ, Van Der Heide J, Liu RH. 2004. Varietal differences in phenolic content and antioxidant and antiproliferative activities of onions. J. Agric. Food Chem. 52(22): 6787 6793.

Chapter 13

MECHANIZATION IN ONION AND GARLIC VALUE CHAIN

Bhushan Bibwe*, Ashwini Benke, Yogesh Khade and R.B. Kale
ICAR-Directorate of Onion and Garlic Research, Pune-410505
*Email: bhushan.bibwe@icar.gov.in

Onion and garlic, members of Alliaceae family, are cultivated throughout the world for food, therapeutic and medicinal value. In India, onion and garlic have been under cultivation for the last 5000 years. In India, major area under onion and garlic cultivation is in tropical areas as compare to the high yielding countries where maximum areas under these crops fall under temperate regions. Onion is grown in 1.6 Mha with production of 26.7 MT and productivity of 16.0t/ha, whereas, garlic s grown in 0.363 Mha with production of 0.65 MT and productivity of 4.32 t/ha in India. Maharashtra is the leading state in onion production followed by Gujarat, Odisha, Karnataka, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Bihar, Punjab and Rajasthan, while garlic is grown commercially in Madhya Pradesh, Gujarat, Odisha, Rajasthan, Uttar Pradesh and Maharashtra (NHRDF, 2021). India ranks second to China in area and production in both onion and garlic, but ranks 102nd for onion and 74th for garlic in terms of productivity (FAOSTAT, 2021). India's share in global exports of agriculture products has increased from 1.7% a few years ago, to 2.1% in 2019 (APEDA, 2021). Onion and garlic are closely spaced (10 cm × 15 cm), shallow-rooted crop with sparse foliage, slow growth and subjected to more weed competition. Due to this, labor requirement is also high in onion and garlic cultivation, leading to high cost of production. Hence the package of modern technology, improved seed and fertilizers, use of efficient and economical farm implements, machines and suitable form of farm power and proper storage facilities after harvest is very important. Mechanization enables the conservation of input through precision metering, ensuring better distribution, reducing quantity needed for better response and prevention of losses of inputs applied. Mechanization reduces unit cost of production through higher productivity (Ashwini Talokar et al., 2014). India is a traditional grower and exporter of both the crops and it assumes number one position in onion export in the world. Both the commodities are going to continue their importance in trade and India has to remain always in competitive situation. But, be competitive, we need to improve our productivity level by gearing up with application of proper mechanization techniques at pre and post-harvest stages of onion and garlic. In case of research and development, a critical analysis of what has been done and what has to be done is always required for strategic planning. Hence in this chapter, information is given about mechanization in onion and garlic production, its constrains and solutions.

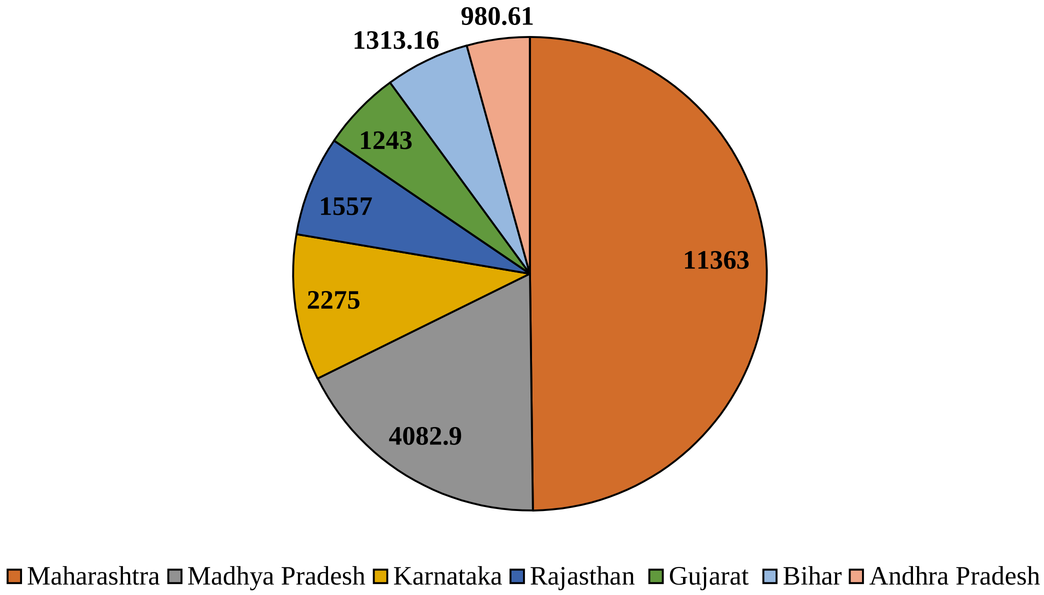
Mechanization in India

Agricultural mechanization is the process whereby equipment, machineries and implements are utilized to boost agricultural and food production. Indian Agriculture is characterized by small holdings due to higher population density. Nearly two-third of its population residing in the rural areas coupled with unabated land fragmentation. Major sources of farm power include both animate (human and draught animal) as well as inanimate sources such as diesel engines, tractors and electric motors. The technological improvements in Indian agriculture have brought revolutionary increase in agriculture production. There has been increase in the use of farm machinery in Indian agriculture as it has contributed to the increase in output due to timeliness of operation and increasing precision in input application. Moreover, farm machinery reduces risks caused by weather and non-availability of labour. Timely marketing is also made possible by quick mechanical transportation, cleaning and handling. Farm mechanization may improve employment opportunities both on farms and in non-farm sectors through increase in area under plough, multiple cropping, development of agro-industries and related services. Mechanization in Indian agriculture increased steadily and contributed greatly in land and labour productivity.

Onion and Garlic Production Technology and Mechanisation

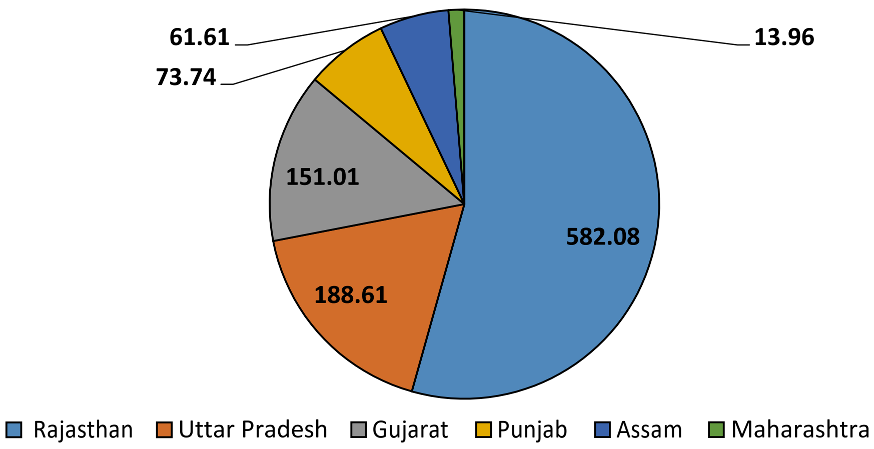
Onion: The details regarding seasonal production of Onion crop in year 2019-20 are kharif season 38.43 lakh tonnes, late kharif 16.68 lakh tonnes and rabi season 213.45 lakh tones and State wise production is given in Figure 1.

Garlic: The low productivity of garlic in India is one of the major issues of concern. There are many reasons for low yield including short day length conditions available in India, sub-optimal standards of cultivation, climatic fluctuations, and non-availability of virus-free quality planting material and use of local low yielding varieties. State wise garlic production is depicted in fig. 12.2



(Source: As reported by State Directorates of Horticulture for 2019-20)

Fig. 1. State wise onion Production (‘000 tones) in year 2019-20



(Source: APEDA agriexchange)

Fig. 2. State wise garlic Production ('000 tones) in year 2017-2018.

Various unit operations (on field and off field) in the production of onion and garlic value chain are given below**.**

Table 1: Pre and Post-harvest operations

Pre-harvest unit operations	**Post-harvest unit operations**
1. Field preparation: Ploughing, harrowing, roto tilling, land leveling etc	1. Curing (field / shed curing)
2. Bed preparation	2. Detoping/ Neck cutting
3. Nursery preparation (seedling raising)	3. Sorting and grading
4. Methods of planting 4.a) seed sowing: i) Broadcasting or drilling of seeds directly in the field, ii) Planting bulbs directly in the field 4b) Transplanting	4. Storage 5. Onion processing : Washing, peeling, cutting , slicing, a). Minimal processing, b) Drying and dehydration c) paste making d) pickle making e) Fermentation (vinegar) f) oil extraction
5. Irrigation and fertilizer application	5. Garlic processing: Bulb breaking, peeling, bulb separation etc a) Drying and dehydration c) paste making d) pickle making e) oil extraction
6. Intercultural operations, spraying, weeding etc	6. Packaging
7. Harvesting	7. Storage and marketing

Pre-Harvest Mechanization for Onion and Garlic value chain

The pre-harvest mechanization is followed from the time of land preparation till the harvest time. During this many operations are followed such as land preparation, sowing, planting, cultural operations, irrigation, harvesting etc. some important are discussed below.

Field preparation: The first primary tillage operation is ploughing the field which is carried out by using tractor operated plough and making it ready for secondary tillage but there is best option in which both primary and secondary tillage both are carried out called as roto tillage or roto tilling. The equipment used for roto-tilling is rotavator. The rotavator is powered by tractor/power tiller. It helps in saving 60-70% in operation time and 55-65% in fuel consumption compared to conventional method of bed preparation with separate ploughing and harrowing operations, besides conservation of moisture due to destruction of capillaries. The use of laser operated land levelers for land leveling is also getting popularity.

Bed Preparation: Beds farming adopted in agriculture at large scale in developed countries have proven to be an excellent option for increasing the productivity of crops. Broad bed formed by moving soil from the furrows to the area of the bed helps in raising its surface level. The furrows serve as irrigation channels, drains and traffic lanes. Planting of onion and garlic on broad beds increases yield, fertilizer and irrigation use efficiency, reduced weed incidence, facilitate better field management by providing passage to mobility in cropped field, fertilizer and irrigation water. Various machines like raised bund former, rolling type broad bed former are developed by research institutes (IARI, CIAE), SAUs (MPKV, PDKV) and by private agro implement manufactures (Maschino, Mahindra etc) can be used for bed preparation.

Onion seed drill/ seeder: For sowing of the onion seeds directly into the field the push type, pull type, bullock as well as tractor drawn onion seed drill are available in various research organizations/ SAUs and also in the market. It consists of a hopper box, rectangular frame, drive mechanism, depth wheels, furrow openers, metering plates, seed tubes and other accessories. The inclined plate edge drop mechanism is used for seed metering. Provision of vertical rotors for fertilizer metering is optional. Depth wheels are used for adjusting depth of operation. Row spacing is adjustable with lateral shifting of furrow openers on the frame. The seed box is divided into compartments, each for individual furrow opener.

Fig 3. Onion seed planter (Bullock drawn and Tractor drawn)

Onion transplanter: The most widely adopted method for onion seedling planting in the field or on beds is transplanting method. The onion transplanting is laborious and time consuming unit operation. Usually transplanting is carried out manually however, various research organizations (IARI, CIAE, MPKV Rahuri etc) also developed the semi-automatic transplanting machines. The work of development of automatic onion transplanting machine is also in progress at ICAR-CIAE, Bhopal. The tractor drawn semi-automatic onion transplanter (Fig 4) is developed a progressive farmer, Shri. Pandharinath More, Ahmednagar. It can perform three functions at a time viz. onion transplanting, fertilizer application and irrigation channels making. When the tractor moves forward, the star wheel type metering mechanism gets the drive to release the fertilizer in the tubes. The seedlings are delivered manually in the delivery chutes for planting. The inter-row and inter-plant spacing can be adjusted in the machine to a finer level. Two depth controlling wheels fitted on either ends of the equipment maintain uniform depth of onion planting, which is kept at 1 cm. A channel forming ridger plough is mounted offset to the right end of the transplanter to form the irrigation channel simultaneously

Garlic planter: A single-row manually-operated planter (Fig 5) developed at the Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana, India, was evaluated for sowing of garlic cloves. The machine consists of a planting mechanism and hopper mounted over a wheel hand hoe. The planting mechanism consists of a vertical disc with spoons on its face. The weight of the machine is approximately 12.0 kg. The machine is operated by 2 persons and another person is required for supplying the seed. It is highly labour-saving equipment as it requires only approximately 83 man hours/ha in comparison to approximately 520 man hours/ha.

Fig. 4. Tractor drawn Onion transplanter **Fig. 5. Tractor operated garlic planter**

Irrigation Equipments

Drip irrigation: Drip irrigation is a method of delivering slow and frequent application of water to the soil using a low pressure distribution and spatial flow control outlets. The labour requirement for drip-irrigation is lower and the system can be readily automated. Reduced percolation and evaporation losses result in a greater economy of water use.

Sprinkler irrigation: In sprinkler irrigation, water is sprayed into the air and allowed to fall on the ground surface simulating rainfall. It is versatile means of applying water to any crop, soil and topographic conditions where surface irrigation may be inefficient or expensive. Low rates of water may be applied as required for seed germination, frost protection and cooling of crops in hot weather.

The overall irrigation efficiency of this method is as high as 75-80% compared to 25-30% of surface method of irrigation.

Intercultural Equipments

Weeding: Different types of weeding tools which can be used for weeding in onion or garlic crop are given below.

(a) **Grubbler:** Manual, pull type implement suitable for weeding and intercultural operations of upland row crops in black soil regions.
(b) **Peg type dry land weeder:** Manually operated push-pull type of weeder.
(c) **Wheel Hoe:** Manually operated push-pull type of single wheel hoe.
(d) **Star weeder:** Manual push-pull type weeder

Plant Protection Equipments

(a) **Low volume Disc Sprayer:** Battery operated knapsack sprayer
(b) **CDA Crop Sprayer:** A tractor mounted sprayer suit able for application of herbicides, fungicides and insecticides.
(c) **Aero Blast Sprayer:** The machine consists of a tank of 400 litres capacity, pump, fan, control valve, filling unit, spout adjustable handle and spraying nozzles to release the pesticide solution in to a stream of air blast produced by the centrifugal blower

Harvesting Equipments

Onion crops are mature and ready to be harvested when at least half of the tops have fallen over and begun to dry. Mature onions should be harvested before heavy rain or prolonged periods of moisture. Rain on mature onions encourages the development of rot-causing fungi and bacteria while complicating manual and mechanical harvesting practices. For these reasons, harvest should be done as quickly as possible in dry climatic conditions to avoid poor weather and to prevent damage to onions. Tractor operated root crop harvesters developed by MPKV, Rahuri, PAU, Ludhiana are useful for harvesting of root crops. Effective field capacity of the Pau root harvestor (Fig 5) equipment was reported to be 0.107 ha/h with 77.60% field efficiency for onion harvesting. There is saving of 172 man hours/ha by using this machine over conventional method in onion harvesting.

Fig. 6. Tractor operated onion harvester

Post-Harvest Mechanization for Onion and Garlic

Curing: It is a drying process intended to dry off the necks and outer scale leaves of the bulbs to prevent the loss of moisture and the attack by decay during storage, eliminating the chances of microbial infection in storage.

- **Field curing:** by windrow method for 3-5 days till foliage turn yellow is recommended.
- **Shade curing:** after field curing is essential to remove the field heat and excess moisture from the surface of bulbs before packing, transportation or storage operation

Detopping/ neck cutting

The cutting of the onion or garlic leaves to separate the bulb is carried out after curing. Generally the detoping is carried out manually using sickle and it is also a laborious and time consuming unit operation. For detoping, the motorized detopper machine (capacity: 150 kg/h) and power operated onion de-topper cum grader (capacity: 400 kg/h) machines are developed by ICAR-IIHR, Bangalore. MPKV Rahuri also developed the power operated detopping machine of capacity 230-250 kg/h with detopping efficiency of 85.71%

Storage structures

Onion storage is widely practiced worldwide in accordance to their cultural and economical practice. In India, method of storage adopted mostly depends on the traditional knowledge. Commonly practiced methods are bag, pucca/room, tat storage, bamboo, chawl structure (Fig 6). The storage losses associated with these practices are quite higher. Sprouting, desiccation and rotting are often observed during storage. To minimize the storage losses, ICAR-DOGR has developed different storage structures as mentioned below. The ICAR-DOGR and Kala Biotech have designed and developed a controlled storage structure under Public Private Partnership mode to curtail storage losses in onion. The storage structure was designed to maintain temperature above 25°C and below 30°C and relative humidity (RH) of 60-65% with an air circulation system with 20 tonnes capacity. The temperature and RH were maintained by using a Heating Ventilation and Air Conditioning (HAVC) unit. A post-harvest and storage loss of onion was able to reduce up to 15% with the help of control storage structure.

Different storage structures for onion

- Traditional single row storage structure
- Traditional double row storage structure
- Top and bottom ventilated storage structure
- Bottom ventilated single row storage structure
- Low cost bottom ventilated single row storage structure
- Modified bottom ventilated storage structure
- Modified bottom ventilated storage structure with chain link on side

(a) Bottom and side ventilated double row structure, (b) Controlled Onion Storage Structure
Fig. 7. Onion storage structures developed by ICAR-DOGR

Onion graders

The size grader developed by ICAR- Directorate of Onion and Garlic Research, Pune are becoming popular among farmers and traders. The grader has two sets of counter rotating double rollers, which grades onion on the basis of diameter. It has provision of grading onion in five grades (80 mm). It can be moved across the fields with its caster wheels. The manually operated grader has a capacity of 0.5 tons/hr/person while motorized version (Figure 7) of the grader has a capacity of 1.5 to 2.0 t/hr.

Fig.8. Onion grader developed by ICAR-DOGR

Onion Processing:

Minimally processed onions: Minimally processed vegetables are defined as vegetables that are altered physically from its original form, yet retaining freshness. Pre-sliced fresh onions are most preferred by consumers who desire a healthy life-style and have a little time for food preparation (Brice et al., 1995). Onions are peeled and/or cut onions for ready to use that retain its freshness, packed in suitable packaging material and stored at refrigerated conditions or frozen conditions. CO_2 enriched atmosphere delay onion deterioration and microbial development, particularly psychrotroph flora; 2% O_2 / 10% CO_2 enriched atmosphere is optimal to maintain sensory quality of diced onions (Blanchard et al., 1996).

Dehydrated Onion flakes and powder: Dehydration is the oldest method of food preservation practiced by mankind. Peeled onion bulbs are cut into slices having thickness up to 1/8-1/4” with the help of vegetable cutter. Onion slices are blanched at 80°C for 5 min. After blanching, onion slices are deep in a brine solution having concentration 1-3% for 30 min. Tray drying of onion slices at 50-70°C is carried out for 8-10 hrs. After drying, onion flakes can be packed using suitable packaging material or can be pulverized by using pulveriser to form a fine onion powder and pack in a suitable packaging material and stored in cool and dry place.

Onion Puree and Paste: Onion paste is convenient to use. It is a semi-solid product which retains original color and flavor of onions (Ahmed and Shivhare, 2001). Preparation of onion paste is a simple process, but it entails proper packaging and storage condition to retain its colour, flavour besides microbial safety. During onion paste preparation raw onion is peeled off and pulp is prepared with the help of pulp making machine. Onion pulp is heated up to 110°C with addition of preservatives like 2% NaCl and 0.1% Citric acid. The TSS of onion paste should be 32°Brix. Filling of pulp is carried out at temperature 70-80°C in suitable packaging material. Packing material is allowed to cool down at room temperature and stored at 4°C for further use.

Onion Pickle: Onion pickle is prepared by selecting good quality onion (20-25 mm diameter). Remove neck and bottom part of onion. Blanching of onion for (1-2 min) in boiling water or under steam for 4 minutes is carried out. Onions are cooled immediately by dipping them in cold water and peeling off the outer scales carefully. Onions are dipped in a brine solution having 500 ml water, 500 ml, of vinegar, and 100 g salt for 1 kg onion) for 24-36 hours. Drain out pickling solution and transfer material for surface drying at 55°C for 2-3 hours in a ventilated oven. After drying, different spices are mixed with little amount of oil in surface dried onions to prepare pickle. Spices quantity added for 1 kg of fermented onion 16 g of mustared, 13 g of turmeric powder, 25 g of sugar, 30 g of garlic paste, 15 g of chilli powder, 0.7 g of rosted fenugreek and 300 ml of oil. Pre-sterilized jars were used with oil up to 1/5 to of its volume and then adding the above mixture to jars containing oil, pressing the onion slightly to the bottom with the help of a spatula to eliminate air pockets. Cover onion with thin layer of oil, leaving headspace of 5-10 mm. Finally pasteuriz the product in pasteurizer for 10 min at 85°C or in boiling water for 10 minutes (Place the jars in water at 70°C to avoid cracking). Allow the lars to get cool to room temperature then label it and store at cool and dry place (Anonymous 2013).

Onion Oil: The odour and flavour properties of onion oil and its components have been used in the food industry to add traditional flavors in novel foods. Alk(en)yl sulfides, the main constituents of onion oil, are perceived as odorants like sulfur, fried onion, garlic, and/or cooked cabbage (Blank, 2002). Onion oil has been used as a food additive to improve the sensorial, antioxidant, and microbiological quality of a treated product.

The machines required for onion and garlic processing and value addition are given below.

i) Onion peeling machine
ii) Onion slicing/ cutting/ dicing machine
iii) Pre-treatment unit
iv) Cabinet dryer/ tray dryer/ tunner dryer/ de-humidified dryer/ solar dryer
v) Dry grinding machine and Paste making /wet grinding machine
vi) Packaging machine
    - Sealing machine/ pack and fill machine/ paste filling machine/ bottle filling machine
    - Vacuum pack/ modified atmosphere packaging machine

Fig. 8. Onion peeling machine

Fig. 9. Onion slicer/ cutter

(a) Cabinet Dryer **b) Solar Dryer**

Fig. 10. Dryers

(a) Dry grinding machine **(b) Paste making/ Wet grinding**
machine

Fig. 11. Grinding machines

Fig. 12. Onion Paste/Pouch Filling Machine **Fig. 13. Oil extraction machine**

Garlic Processing

Dehydrated garlic powder: Dehydrated garlic powder is the dry powder obtained from garlic bulbs. It is characterized by a pungent and pleasant flavour, due to the compound *allicin*. It is a homogenous product, 95 % of which passes through a sieve of an apertures size of 250 µm.

Dehydrated garlic flakes or pieces: It is a product prepared by cutting garlic cloves into slices and removing broken pieces smaller than 4 mm. These are products passing through a sieve apertures size from 1.25 mm to 4 mm. Skin of individual cloves is not removed. The particles have an irregular shape and size. No blanching or other treatments are applied. The product spread evenly on drying trays. Dry until brittle moisture content should be within 6.5%. The finished product should be cool down to room temperature for half an hour before packing and stored in a dark place. Dehydrated garlic is packed in material which has enough barrier effect against moisture transfer.

Fig. 14. Garlic bulb breaking machine **Fig. 15. Garlic peeling machine**

Garlic Paste: Garlic paste is a product of high demand on market. This product has the same flavour as fresh garlic. The cleaned bulbs are broken into cloves, peeled and boiled carefully to obtain a homogeneous paste. To ensure a pleasing appearance and good shelf-life an addition of 0.1 % SO2, 15 % NaCl and 0.05 % ascorbic acid is recommended. There are many methods for garlic paste making. A vacuum packaging process increases the shelf life and freshness of the product

Pickled Garlic: Whole, sliced, cubed garlic is pickled in vinegar or brine or vegetable oil or their combinations. Pickles are high salt and acid products high acidity in pickles prevents spoilage from harmfull food poisoning microorganisms. Acids is directly added as vinegar or lemon juice or created by natural fermentation process. The acidity or salinity of the pickle solution gives it an environment in which microorganisms do not easily grow.

- Types of garlic pickles 1. Oil pickles 2. Fresh pack or quick processes pickle 3. Brained pickle/ fermented pickle
- Ingredients: Garlic, salt, vinegar, sugar, spices, water, packaging containers

Garlic Oil: Garlic oil is derived by steaming crushed garlic and capturing the resultant oil released. The yield of garlic oil is around 0.46-057 per cent on moisture free basis (quite expensive).The specific gravity and refractive index of garlic oil at 25°C is 1.091-1.098 and 1.5740-1.5820, respectively. It is reddish brown over powdering liquid. One gram of oil is equivalent in flavouring terms to 900 g fresh or 200 g dehydrated garlic powder. The high pungency of garlic oil makes difficult to use it.

Reference:

Ahmed, J., & Shivhare, U. S. 2001. Thermal kinetics of colour degradation and storage characteristics of onion paste. LWT-Food Science and Technology, 34(6), 380-383.

Anonymous, 2010. National Horticultural and Research Development Foundation (NHRDF) Database. Available at http://www.nhrdf.com/Content

Anonymous. 2013. http://www.areu.mu/fruit/processing/onion%20process.pdf, accessed on May 14, 2013.

Blanchard, M., Castaigne, F., Willemot, C., & Makhlouf, J. 1996. Modified atmosphere preservation of freshly prepared diced yellow onion. Postharvest Biology and Technology, 9(2), 173-185.

Blank, I., 2002. Sensory Relevance of Volatile Organic Sulfur Compounds in Food. Heteroatomic Aroma Compounds. American Chemical Society, pp. 25–53.

Brice, J. R., Bisbrown, A. J. K., & Curd, L. 1995. Onion storage trials at high ambient temperatures in the Republic of Yemen. Journal of agricultural engineering research, 62(3), 185-192.

Chapter 14

SAFETY MEASURES IN PLANT PROTECTION OPERATIONS

Soumia, P. S*., Karuppaiah, V., Yogesh, P. Khade, Dhananjay V. Shirsat and Major Singh
ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra-410505
*Email: soumiaps@gmail.com

Pesticides are chemicals or biological agents that repel, incapacitate, kill, or otherwise discourage pests such as insects, nematodes, diseases, weeds etc. Pesticides is a broad term named according to their intended use such as herbicide, insecticides, nematicide, molluscicide, piscicide, avicide, rodenticide, bactericide, insect repellent, antimicrobial, fungicide, lampricide and fumigants. Proper technique of application of pesticide and the equipment used for applying pesticide are vital to the success of pest control operations. The use of pesticides involves knowledge not only of application equipment, but of pest problem and its management. The basic goal of pesticide application technique is to cover the target with maximum efficiency and minimal effort in order to maintain the pest under control without affecting non-targets. Pesticides, the most dangerous type of agrochemicals, are consequently subject to stringent controls in many industrialized developed countries. These countries have either banned or restricted the use of such hazardous pesticides. Everyone involved in the manufacturing, import, storage, and sale of agrochemicals does have a role to play in ensuring their safety and health.For more than two decades, safety and health in the use of agrochemicals has been a top priority for international organisations. Excessive pesticide usage, on the other hand, not only leaves residues in the soil, water, and air, but also has negative consequences for non-target creatures including pollinators, parasitoids, predators, and wild animals. This had a negative impact on the ecological balance, resulting in pest recurrence, development of pest resistance, and pollution. However, if proper precautions are taken, they can be used safely.

Pesticide formulations

Pesticide formulation contains two parts such as an active ingredient and inert material. The active ingredients, in “pure” (technical grade) form, are not suitable for direct application, as they are extremely toxic. In their concentrated form, these compounds either do not mix well with water, or remain unstable, and some are difficult to handle, transport, or store. So, the manufacturers usually add inert chemicals to end-use pesticide products to solve these issues. Some inert substances act as diluents or carriers and have no pesticidal effect. Generally, inert ingredients make the final product safer, easier to use and deploy, and/or more effective.

Mode of Action

The chemical structure of an insecticide generally defines its target site and its mode of action. Target site is defined as the physical location within an organism where the insecticide acts. Whereas, the mode of action is defined as the action (physiological disruption) of an insecticide at its target site. Therefore, insecticide class, target site and mode of action are intertwined concepts.

Mode of entry

Many agricultural workers die and many more are poisoned or injured each year by such harmful agrochemicals entering the body; the main routes of absorption are through the respiratory tract (inhalation), through the skin (dermal absorption) and through the digestive tract (ingestion).

Inhalation: Breathing agrochemicals into the lungs is more likely to happen if they are in the form of gases, fine spray droplets, dust, fumes and smoke.

Ingestion: This type of contamination is due to accidental swallowing of agrochemicals, or unhygienic practices like chewing, smoking drinking and cleaning of blocked sprayer nozzle by blowing during spraying operations.

Skin absorption / contact: This is one of the most common poisoning routes. These substances can easily penetrate either through the intact human skin or cuts, abrasions or skin disease while spraying, accidental spilling or handling. Some parts of the body absorb pesticides extremely fast (within a few minutes) and need extra protection. For example, ear canal, fore head and body area between the navel and above mid-thigh. If any pesticide is spilled in these areas, clean the area immediately and change the clothing. Wearing the right Personal Protective Equipment (PPE) is the best way to avoid direct contact with pesticides as recommended on the label of the pesticide.

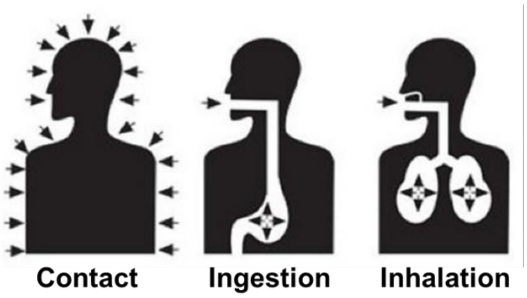


Fig. 1: mode of entry of pesticide into the body

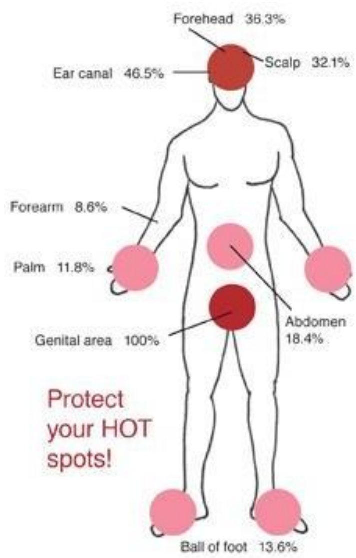


Fig. 2: Percentages indicate relative amount of absorption of pesticide over a 24-hour period. (Feldman and Maibach, 1974. Percutaneous penetration of some pesticide and herbicides in man. Toxicology and Applied Pharmacology 28, pp. 399-404)

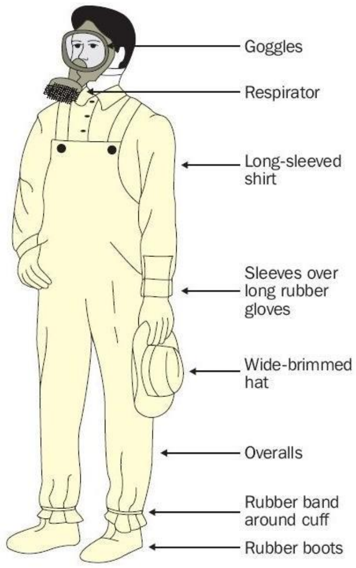


Photo courtesy: https://slideplayer.com/slide/10968632/

Fig. 3: Parts of Personal Protective Equipment (PPE)

Steps to be taken before, during and after pesticide application

All pesticides are potentially harmful, particularly for those who work with them on a daily basis because of the potential for being exposed to large doses and the likelihood of chronic exposure. Many pesticide accidents occur when the chemicals are being mixed for use. A few common sense rules can make mixing and loading safer, thereby helping you to avoid the leading cause of pesticide-related illnesses:

Precautions while pesticide purchase

- Always purchase pesticides / biopesticides only from registered pesticide dealers having valid Licence
- Before handling a pesticide, **READ THE LABEL**
- Do not buy in bulk, purchase only **JUST required quantity** e.g. 100, 250, 500 or 1000 ml for single application in specified area
- Do not purchase leaking containers, loose, unsealed or torn bags
- Do not purchase pesticides without proper / approved LABELS
- See Batch No., Registration Number, Date of Manufacture / Expiry on the labels

Pesticide labels:

The pesticide label is more than just a piece of paper; it is a legal document recognized by courts of law. Label formats vary according to pesticide type, registration, toxicity, and manufacturer. Pesticide labels contain detailed information on how to use the product correctly and legally. Labels contains the following information

- Brand name or trade name of the product
- Ingredient statement; percentage or amount of active ingredient(s) by weight
- Net contents of the container
- Name and address of the manufacturer
- Warning label: contains specific information about the product such as its toxicity level
    1. **“CAUTION”** means that it is slightly toxic. Oral lethal dose >5000 mg/kg
    2. **“DANGER”** means that it is moderately toxic. Oral lethal dose 501–5000 mg/kg

3. **“POISON”** means that it is highly toxic. Oral lethal dose 51–500 mg/kg
4. **“POISON** +  ” means that it is extremely toxic. Oral lethal dose 1–50 mg/kg

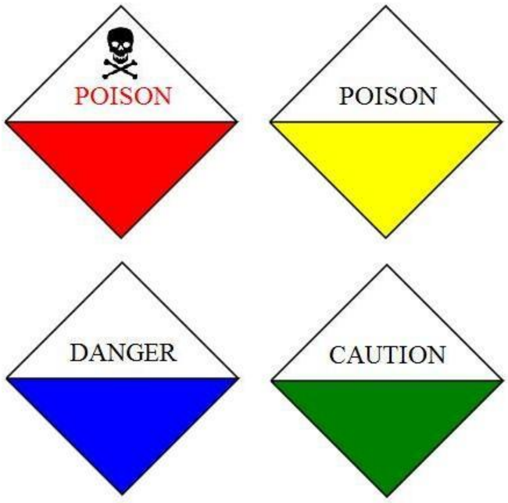


Fig 4: Warning labels

Other required parts of the label are:

- Registration and establishment numbers
- First aid statement
- Environmental hazard statement
- Use classification statement;
- Directions for use;
- Re-entry statement, if necessary
- Harvesting and/or grazing restrictions, if applicable
- storage and disposal statements

Precautions while transportation

- Avoid carrying pesticides on public transport
- Avoid carrying bulk - pesticides (dusts / granules) on head, shoulders or on the back
- Do not transport pesticides together with food products, fodder, or other commodities
- Make sure that pesticides are adequately packaged and do not spill or leak out. If the pesticide spills or leaks, wash the vehicle with bleaching lime paste (1 kg of lime for every 4 litres of water)

Precautions while storage

- Do not keep pesticides in the house premises. Preferably, store pesticides in a separate room which is well-ventilated and is away from direct sunlight or rain water
- Keep only in original container with intact seal
- Keep them away from food, animal feed and fodder, and containers of potable water
- Keep away from the reach of children and livestock
- Be careful of cross-contamination. Store herbicides separately from other pesticides
- Reseal containers after partial use

Precautions while pesticide application

- Check the application equipment and calibrate it according to the manufacturer's instrauction. Look for leaking hoses or connections, plugged or worn nozzles, and examine the seals on the filter openings to make sure they will prevent spillage of the chemicals.
- Use only appropriate containers for measuring, mixing, and applying pesticides. Never use food preparation utensils for this purpose. Mix the pesticides outdoors, in a place where there is good light and ventilation
- Apply pesticides only at the correct time and under acceptable weather conditions. Avoid applying pesticides when temperatures are extremely high or low. Further, apply pesticides in the early morning or late evening to avoid excessive drift (wind is normally lower during these time periods), and to prevent exposing beneficial insects like bees and ladybugs to the effects of them.
- Never smoke, drink, or eat while applying pesticides.
- Wear the appropriate personal protective equipment. Or else, mouth and nose should be covered with a simple device such as a disposable paper mask, a surgical-type disposable or washable mask while applying pesticides.
- The discharge from the sprayer should be directed away from the body.
- Use extreme care to prevent the pesticide from contaminating unintended target sites (e.g., streams, ponds, lakes or other bodies of water)
- Do not smell the sprayer tank.
- Don't blow/clean clogged- nozzle with mouth. Use old tooth- brush tied with the sprayer and clean with water
- Immediately after spraying, take a bath and change your clothes. All clothes must be washed separately immediately after spraying.

Precautions while Disposal

- Never leave pesticide in sprayers and dusters
- Clean equipment with soap, detergent, or soda solution and fresh water
- Left over spray solution should not be drained in ponds or water lines etc. 'throw it in barren isolated area, if possible
- The used/ empty containers should be crushed with a stone / stick and buried deep into soil away from water source. Do not use them to store food, water, or as cooking utensils.
- Do not go into a treated field until the recommended

Pesticide poisoning

Pesticide poisoning occurs when chemicals intended to control a pest affect non-target organisms such as humans, wildlife, or bees. There are three types of pesticide poisoning; (1) When a single and short-term very high level of exposure occurs to an individuals who intentionally consumes pesticide to commit suicide (2) long-term high-level exposure, which can occur in pesticide formulators and manufacturers and (3) long-term low-level exposure, which individuals are exposed to sources such as pesticide residues in food as well as contact with pesticide residues in the air, water, soil, sediment, food materials, plants and animals.

Symptoms of pesticide poisoning

Acute poisoning: This happens when someone has been exposed to a high dose of pesticide either through drenching of pesticide on the person or by-stander while mixing the solution or accidental ingestion of the chemical.

Chronic poisoning: This happens when a person being exposed to a small amount of pesticide over a long period of time. Chronic poisoning may happen when the operator repeatedly use the pesticide improperly, especially without wearing protective clothing during spraying and handling such chemicals.
Mild poisoning symptoms: Headache, blurred vision, sweating, diarrhoea, irritation of skin, nose, throat and eyes, nausea, fatigue, insomnia, loss of appetite, weakness, dizziness, restlessness etc.
Severe poisoning symptoms: Vomiting, Convulsions, Loss of reflexes, Unconsciousness, Inability to breathe, Fever, Muscle twitching, Constriction of eye pupils, breathing difficulties, Impaired metabolism, Hormonal effects, Damage to various organs, Cancer, Coma and Death

General Antidotes:

1. Removal of Poison: by inducing vomiting
2. The "Universal Antidote": A mixture of 7 g of activated charcoal, 3.5 g of magnesium oxide and 3.5 g of tannic acid in half a glass of warm water may be used to absorb or neutralize poisons.

Specific antidotes:

- Organochlorines and Carbamates: Phenobarbital
- Organophosphates: Atropine etc

Key points to remember when administering first aid during a pesticide emergency:
Dermal exposure:

- Remove the contaminated clothes
- Drench with clean water to dilute the pesticide and to prevent skin absorption
- Skin burns: cover the area loosely with a clean, soft cloth. No ointments (unless prescribed)
- Wash body with mild soap/water
- Avoid chills/overheating

Eye exposure:

- Wash quickly (eye wash or water)
- Rinse eye with cool, clean water 15 for more minutes
- Do not use chemicals or drugs in the wash water unless instructed to do so by a medical professional
- Cover the eye with a clean piece of cloth and seek medical attention immediately

Inhalation exposure:

- Carry the victim to fresh air
- Have the victim lie down and loosen his or her clothing
- If the victim is convulsing, protect his or her head, turn the head to the side, and watch that breathing continues. Do not attempt to insert anything into the person's mouth during a seizure
- Give artificial respiration (if needed)

Oral exposure:

- Rinse the mouth with water. Then, give the victim large amounts (up to 1 quart) of milk or water to drink
- Induce vomiting (if label says so). Several pesticides cause more harm when vomited than if they remain in the stomach

Do NOT induce vomiting if the victim:

- ✓ is unconscious/convulsions
- ✓ swallowed corrosive poison
- ✓ swallowed emulsifiable concentrate or oil solution product
- ✓ label prohibits

References:

1. Damalas, C. A. and Koutroubas, S. D. 2016. Farmers' exposure to pesticides: toxicity types and ways of prevention. Toxics, 4(1): 1.
2. Feldman and Maibach, 1974. Percutaneous penetration of some pesticide and herbicides in man.
3. Toxicology and Applied Pharmacology, 28: pp. 399-404 https://slideplayer.com/slide/10968632/ accessed on 05/04/2022
4. Mooventhan, P., R. K. Murali Baskaran, Jagdish Kumar and Pankaj Kaushal. 2020. Technical Bulletin on Current Status and Guidelines for Safe Use of Pesticides in Agriculture. ICAR-National Institute of Biotic Stress Management, Raipur, Chhattisgarh, India, 32 p.
5. Nebraska Extension publications: 2022 http://extensionpubs.unl.edu/ accessed on 5 April 2022

Chapter 15

FARMER PARTICIPATORY VALUE CHAIN IN ONION AND GARLIC: CHALLENGES AND OPPORTUNITIES

Rajiv Baliram Kale, S S Gadge, Abhishek Dilip Gavhane, Sharad Veer Singh, Shivam Gaikwad, and Rohini Bhat

ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra-410505

*Email: rajiv.kale@icar.gov.in

Onion is one of the largest cultivated, produced and consumed vegetables in India. Being a staple partner of many culinary preparations, onions not only provide flavor, but also supply the nutrients and health-promoting phytochemicals. Along with tomatoes and potatoes, onions are valued equally important and are grown in 170 countries over an area of 54.8 lakh hectares, producing 1046.18 million tonnes of onions in 2020-21. In the same year, India grew onions across 16.28 lakh ha and produced 269.1 lakh tonnes, making it the leader in both area and production. India is the world's top producer of onions by area and volume, but productivity of 18.64 tonnes per hectare places it at 83rd position.

In addition to production, the global economy is greatly impacted by onion trade. In 2020, the total value of its export for 84.51 lakh tonnes was 3612.46 million dollars. The export of onions has increased during the past decade. The Netherlands leads the world in exports with 17.51 lakh tonnes and a value of 797.42 MUSD. India is the second-largest exporter of onions in the world, sending out 14.49 lakh tonnes of onions that worth 346.64 MUSD. Indian onions are famous for their distinctive pungency. Bangladesh, Malaysia, the United Arab Emirates, Sri Lanka, Nepal, and Indonesia are major export partners for Indian onions.

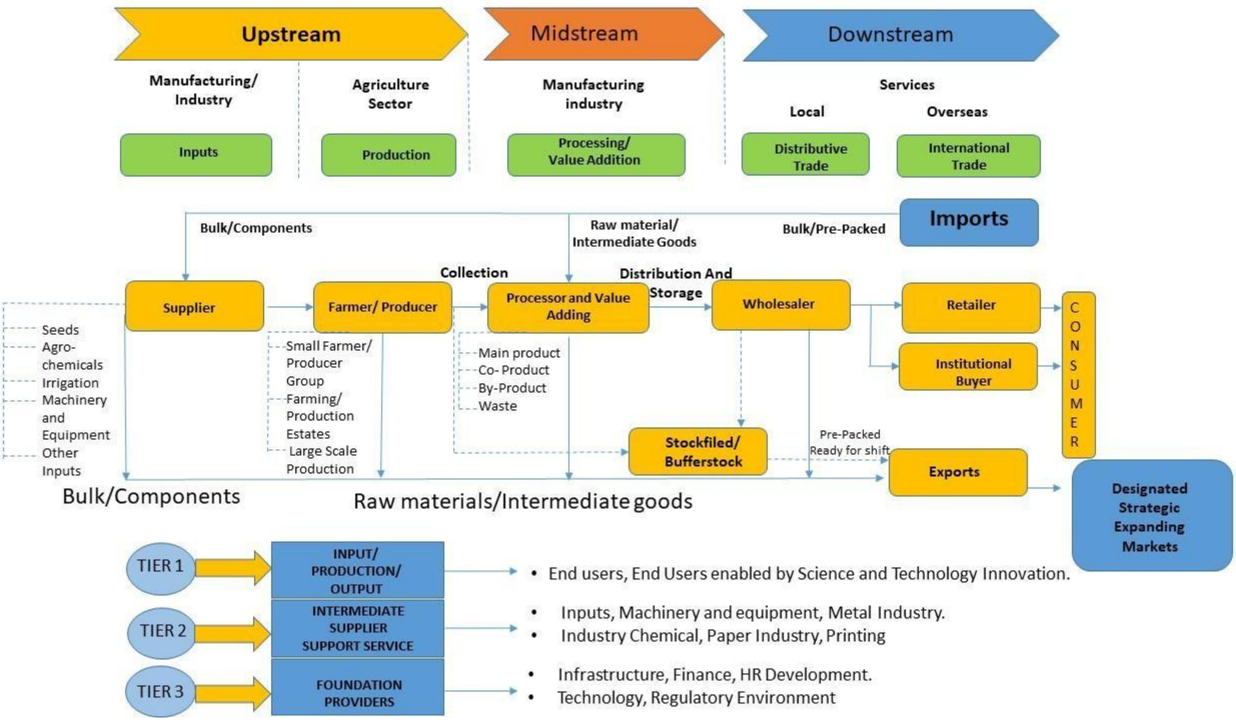
India enjoys diverse crop climates and seasons that enables tri-seasonal cultivation of onion. State of Maharashtra is the onion hub of the country. It alone contributes for more than 39% of the nation's total onion production, followed by Madhya Pradesh, Karnataka, Gujrat, and Rajasthan.

Being an integral part of Indian diets, there is a steady increase in the demand for onion across India as well as the world. But the supply shocks which makes the prices vulnerable to violent fluctuations is major concern of policy makers and stakeholders. Price fluctuations not only create the domestic crises in food economy, but also raise the export irregularities. Onion crop has received greater attention with extreme price volatility which brings tears to either the farmers or the consumers. In case of extreme price rise, the farmers shift the onion cultivation from other competing crops. Such decisions leads glut in the next season, where the farmers sometimes are not able to recover even the cost of production. Despite leading onion producer, we have not been able to do justice to our farmers. The answer lies in value chain fragmentation, price volatility, quality and quantity losses and low levels of processing that characterize the market for onion in India.

The fragmented supply chain, lack of adequate storage and perishable nature of onion, high marketing margins, and dominance of few traders, are significant challenges in the value chain and need measures to overcome them.

Agriculture Value chain:

A 'value chain' in agriculture identifies the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product (FAO, 2005). An agricultural value chain might include wide range of activities: development and dissemination of plant and animal genetic material, input supply, farmer organization, farm production, post-harvest handling, processing, provision of technologies of production and handling, grading criteria and facilities, cooling and packing technologies, post-harvest local processing, industrial processing, storage, transport, finance, and feedback from markets. The terms "value chain" and "supply chain" are often used interchangeably. A value chain is a set of linked activities that work to add value to a product. It consists of actors and actions that improve a product while linking commodity producers to processors and markets. Value chains work best when their actors cooperate



to produce higher-quality products and generate more income for all participants along the chain

Source: (Wong, 2016)

Fig 1. Structure of onion value chains

In Horticulture sector, there is dual nature of value chain. One informal or traditional, and the other formal or modern value chain. Small holders are frequently involved in informal chains that deliver products to local middlemen and then to small local stores. Formal value chains can deliver the same product, usually in better or more uniform quality, from larger farms or more organized groups of small farmers to more commercial wholesalers and from there to supermarkets or exporters. This duality has been accentuated by the explosive growth of supermarkets in developing countries.

It can limit many small producers to markets characterized by low-quality products, and low prices and low returns for them hence a frequent concern is to find ways to integrate small producers into more modern value chains, both domestic and export-oriented. In unorganised agricultural value chain, the producer's share in consumer's retail price is mere 25% to 30% depending on the commodity. Intermediaries in value chain reduces farmers income.

Issues and challenges in current value chain of Onion in India:

- **Low productivity**
  Though India is leading country in area and production of onion, the productivity is among the lowest. Limited adoption of improved varieties and improve package of practices, inadequate availability of certified seeds, poor seed replacement ratio (< 20%) are the main reasons for the low productivity.
- **Seasonality of production**
  In India average consumption of onion is estimated at 1.5 million tonnes every month, and to fulfill this demand, the crop is cultivated in three seasons – Kharif (planted between July-August and harvested in October-December); late Kharif (planted between October-November and harvested in January-March); and Rabi (planted between December-January and harvested in March-May). These seasons contribute 20%, 20% and 60%, respectively, to the total onion production. During kharif season due to climatic vagaries production is uncertain and productivity also very low. Generally the June to October demand is fulfilled by the stored rabi produce.
- **Increasing biotic and abiotic risks**
  The impact of heavy rainfall is mainly arising during kharif or in rabi season due to unseasonal rainfalls. Heavy rainfall in August, September and October, causes more losses as this period coincides with bulb development phase of kharif and the nursery of late-kharif and rabi crop. Additionally, heavy rainfall damages the standing crop by inducing the outbreak of various diseases like Purple blotch, Stemphyllium blight, Colletotrichum blight and Basal rot; ultimately affecting the crop and leads into poor bulb formation and development. The high night temperature during bulb initiation stage resultsFig 1. Structure of onion value chains a poor bulb development whereas, temperature more than 42^{0}C at the time of bulb maturity in April- May leads to reduction in bulb size along with poor keeping quality. High temperature affects the crop fertilizer use efficiency and forces the plant to complete its life cycle ultimately causing early maturity without proper development of the bulb. Likewise, low temperature (<10 degree C) for more than one week from January-February during bulb development initiates bolting in onion that possesses considerable impact on production and affect its value in domestic and international market. These biotic and abiotic stresses are masking the true yield potential.
- **Inadequate storage facilities**
  In India, onion crop shows an asymmetry in production and storage throughout the year. Though Onion is cultivated in three seasons (kharif, late kharif and rabi), 60% of onion production is harvested in rabi season (arrival at April - May) which create a glut in the market. The onion cultivated during rabi season is suitable for storage for next six months to meet domestic as well as export demand till the arrival of the kharif onion crop (arrival at October-November). The prices shoot-up when the stored rabi onion stocks are almost finished and kharif onion is yet to reach the markets. Lack of storage facility is one of the prime reasons behind high volatility in onion prices. The available open ventilated storage structures are suitable only in the areas where climatic conditions meet the physiological needs of storage. In areas of high temperature, humidity and rainfall, these structures are not suitable.
- **Price volatility**
  Prices of onion are highly volatile due to production uncertainties and perishability. The trend of

wholesale, retail prices and market arrival of onion in Maharashtra during 2016 to 2018 revealed that average wholesale market price was Rs. 1172.6 /q and average retail price was Rs. 1775.8/q. The wholesale prices of onion were found above the average during August to February except September and below the average during March to July. Highest average drop in wholesale price (62.60%) was found in the month of May and highest average increase in price (29.70%) was found in the month of November. Similarly, the retail prices of onion were found above the average during August to February and below the average during March to July. Highest average drop in retail price (51.64 %) was found in the month of May and highest average increase in price (30.94%) was found in the month of November. Successful storage of *rabi* (April-May) harvested onion with minimum losses till the kharif crop arises in the market (October-November) will be helpful in getting more price to the onion.

Fig 2. Monthly market arrival and wholesale as well as retail Prices fluctuation in major onion markets of Maharashtra

- **Regional concentration in production**
  In India, onion production is concentrated to a few states while consumption requirement and demand is countrywide. Five states, Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Rajasthan account for about 77 per cent of onion production with Maharashtra alone accounting for more than 39 per cent. Therefore majority of the onion production originates only in seven states and supplied to other states.
- **Low level of processing**
  Onion processing facilities are meager despite Nashik district being a major production centre. Though Nashik is considered as onion capital, Bhavnagar district of Gujarat has emerged as a hub for onion processing in India. Only 3-4% of the onion production is processed in India. Indian dehydrated onion has very limited domestic market, but has well demand in the USA, Europe and some parts of South America. There is vast scope to set up onion processing industries that also can spur the contract farming in the region.
- **Export irregularities**
  Due to fluctuations in domestic price, to overcome the shortage at domestic markets, government imposes curbs on onion exports. Minimum export prices (MEP) have been imposed on onions several times to restrict the import. These measures adversely affect the export market and Indian traders have

to lose the credibility in global export markets.

- **Unorganized and fragmented supply chain**
  Supply chain of onion in India is a fragmented and unorganized sector involving a diverse range of distinct stakeholders such as inputs supplier, farmers, traders, commission agents, processors and distributors. The supply chain suffers from inefficiency at every stage such as lack of proper infrastructure for procurement at farm gate to the consumer which led to huge losses in transit. The onion growers hardly benefit from any price rise while traders enjoy high margins. Many times farmers are forced to sell their produce at throwaway prices in times of bumper crops, but prices at retail remain high.The quanta of marginal farmers is high. It makes the production distributed in small farms. These farmers with various reasons remain unorganised and devoid of benefits of the scale being organized. The poor data available with the production and storage scenario; the seasonal planning and regarding decisions are hampered. The percolation of financial inclusion is lower at farming section keeping them away from the financial linkages with institutional credit. The cryptic and lengthy procedures are amongst the some of the reasons. Also the marginal sizes of the farm lands and seasonal vagaries produces farming as highly risky and less valued mortgage. Huge makeup of the seed input in market being farmer sourced, the seed demand from a regulated section is much lower. With unstable export policies, the stakeholders are uncertain about the supply guarantee. It is highly focused on the regional export partners with real time demand which they assured the supply time.

Scope for farmer participatory onion value chain

In India almost 86.1 % farmers are falling under the category of small and marginal landholding. In fact, the average size of landholdings in India is 1.08 ha (DoAC&FW, 2020).In India, 70.4% onion farmers are in the small and marginal category (Gulati, 2022).Today India is self-sufficient in Food Grains and horticultural crops with the production from small and marginal farmers. Hence, small and marginal farmers have an important stake in agricultural development in India. Inclusionofsuchsmall and marginal farmers in various stages of horticulture and onion value chains can only sustain the interest of the farmers and enhance the income.

The cooperative movement has succeeded to raise farmer inclusiveness in value chains in Gujarat (milk) and Maharashtra (sugar), however their performance in most states is found weak due to regional politics and excessive state interfere. Collective approach has proved to be an effective tool in boosting up bargaining power and reap numerous benefits compared to the individual approach. Concept of Farmer Producer Companies (FPCs) has emerged as an alternative to state-sponsored or state-led cooperatives since 2003 with the recommendations of the Alagh Committee (1999), to frame a legislation that would 'accommodate the spirit of a cooperative with the operational flexibility of a private company,' The main aim of FPCs is to ensure better income for the producers through an organization owned by themselves. Small holder farmers do not have the volume individually including both inputs and farm produce to get the benefit of economies of scale. Besides, in agricultural marketing, there is a long chain of intermediaries where the share of the farmer producer in consumer rupee is very low. Through aggregation, the primary producers can avail the benefit of economies of scale and better bargaining power vis-à-vis the bulk buyers of inputs and bulk suppliers of Produce.

Government of India is also focusing on promoting the Farmer Producer Organizations to integrate the farmers in farm value chain. Government has launched a scheme for Formation and Promotion of 10,000 Farmer Producer Organizations (FPOs**)** in a production cluster area approach with a comprehensive and wide-ranging ecosystem of support in order to promote the growth of thriving, sustainable income-oriented farming and the general socio-economic progress. The concept of farmer producer company emerged to provide the institutional support to safeguard interests of farmers by integrating them with the agricultural value chains. In order to scale up for growth and survival in a competitive environment, the FPOs can federate at the district and state levels based on their needs for onion processing, branding, and marketing. The implementing Agencies- SFAC, NCDC, and NABARD, shall be in charge of forming and promoting FPOs in order to meet the goal of forming 10,000 new FPOs in 5 years and to ensure that the FPOs are economically sustainable.

Primary Producers Organizations are the only institutions which can protect small farmers from globalization by helping farmers buy or sell better due to scale benefits, lower transaction costs, technical help in production and creating social capital. Producers Organizations can also help appropriate a part of the value created in the chain by private sector, for their members. Some of the major benefits of organizing farmers into collectives are as under:

a. Cost of production can be reduced by procuring all necessary inputs in bulk at wholesale rates.
b. Aggregation of produce and its bulk transport reduces marketing cost; enhance the net income of the producer.
c. Building the scale through produce aggregation enables to take advantage of economies of scale and attracts traders to collect produce at farm gate.
d. Access to modern technologies, facilitation of capacity building and extension trainings on production technologies and ensuring traceability of agriculture produce.
e. Post-Harvest losses can be minimized through increasing management efficiency or by the value addition.
f. Supply regularity and quality control is possible through proper planning and management.
g. Ease in communication/dissemination of information about price, volume and other farming related advisories.
h. Easy access to financial support and other schemes or services by government, donors, service providers.
i. Improved bargaining power and social capital building.
j. Price fluctuation can be managed, by implying contract farming, agreements etc (National Paper, 2020).

MAHA-Farmers Producer Company (MAHAFPC): Case study of FPOs based Onion Value Chain in Maharashtra

MAHAFPC as a State Level Producer Company is to promote and facilitate the member FPOs in the state of Maharashtra through business facilitation for backward as well as forward linkages. MAHAFPC has focused on cluster of commodities specific and value chain centric farmer producers' organizations. MAHAFPC has strong reach across the 28 districts of Maharashtra through 541 share-holder farmer producer organizations under the Company Act having registered shareholder base of more than 2.0 Lakh small and marginal farmers. MAHAONION is joint venture between the National Agricultural Marketing Federation of India (NAFED) and MahaFPC. Since there is lack of adequate infrastructure for onion storage, Maha-Onion, has created warehousing facilities of 1,000 tons of onion and marketing facilities like weighing bridge, grading shed etc. at each of the 25 FPC locations for onion storage and marketing through the public-private-partnership (PPP) model. This will benefit farmers by giving them access to centralized infrastructure to help reduce post-harvest losses as well as assured market linkages.

This project has direct ownership of 2500 farmers and will benefit about 25000 onion producers through interstate trade, linkages with corporate buyers, retail chains etc. These facilities will act as alternative marketing channel for the farmers wherein artificial intelligence will be used for backward linkages and electronic platform for marketing etc.

Weighing Bridge | Grading Shade | Onion Storage Boxes

Fig 3. Naathji Farmer Producer Company, Vaijapur (Aurangabad)

Strengthening Agricultural Value Chain:

To develop a sustainable supply chain of agricultural commodities, there is need to strengthen the backward and forward linkage and integrate it with proper stakeholders' engagement. The efforts of the MAHAFPC to strengthen the supply chain are given in figure. (Kale et al, 2021)

Backward Linkage ← **FPO** → **Forward Linkage**

Backward Linkage:

- Creation of infrastructure for storage and market at village level
- FARM ERP for farmers database
- Capacity building of the farmers
- IFFCO dealership
- Tie-up with private agro-industries for quality input and developing SOPs
- Linkages with govt. agencies for various schemes
- Grassroot level reach

Forward Linkage:

- Decentralized government procurement
- Interstate trade
- e-Krishi Mandi
- Linkages with processor, retailers, private players
- Processing and retailing
- Producer to government, Producer to processor/ retailer, Producer to consumer models
- Farm to Fork model

Fig 2. Forward and backward linkages

Efforts for price stabilization of onion through procurement:

Prices of onion are highly volatile. After *rabi* season harvest, a steep fall in the prices is normally observed. Withthe limited stored stocks, adverse climatic condition during *kharif* season the prices tend to increase after September to December. Price volatility affects consumers as well as farmers in a big way. Therefore, to stabilize the prices, a corpus – "Price Stabilization Fund" is created by Government of India for providing working capital and other incidental expenses for procurement and distribution of Agri-horticultural commodities.

MAHAFPC has partnered with NAFED for handling the procurement operations. To promote direct purchase from farmers through FPCs at farm gate level; MAHAFPC has engaged 40FPCs in the procurement channel. Due to constraint of centralized storage system, MAHAFPC explored decentralized storage structure at farmer owned Open Ventilated Storage Structures. Large scale storage infrastructures are also being created under PPP mode.

Presently 50 FPCs from 7 onion producing districts of Maharashtra are working with MAHAFPC. MAHAFPC has built capacity of its member organizations through hands on training of supply chain development activities by business opportunities. MAHAFPC has taken procurement of onion first time out of APMC to village level and stored the onion at farmer's storage points. MAHAFPC facilitated the disposal of onion across the country. Based on the value chain handling experiences of onion commodity under PSF; FPCs successfully entered the interstate trade on onion in southern part of the country in the markets like Chennai, Kerala and Bangalore etc.

Table1. Procurement and trade of onion by MAHAFPC

Year	PSF Onion		Interstate/Retail Trade		Total	
	Quantity (MT)	Value (₹in Cr.)	Quantity (000 MT)	Value (₹in Cr.)	Quantity y	Value (₹in Cr.)
2020-21	37448	41.98	0.007	0.26	37448	42.24
2019-20	24773	29.55	0.015	0.3	24773	29.85
2018-19	5261	6.81	2405	1.93	7666	8.75

Opportunities for FPOs In onion Value Chain Development:

The Onion Seed Chains:

Seed is the prime input in successful crop production. In India, a major quantum of onion seed comes from the farmer sources. As Onion being highly cross-pollinated crop, the purity concerns highly affect the seed purchase and the cost of seeds too. It pertains the reach of improved varieties to a limitation as the quantity produced of such varieties is much low. This thrives great chance for a business model in the Onion seed production. Directorate of onion and garlic research has been developing need-based varieties in onion crop and has developed 10 improved varieties with higher yield potential. It has provided seed production licenses to 25 FPO and 60 private seed production companies and the technical skilling too. As a FPO, consisting farmers from a same village or proximity, it is helpful for creating common decision on varietal selection for seed production and also avoids the contaminations. It helps in generation of enough quantity to ease the merchandise. For a FPO it is easy to skilling its members for scientific seed production and market development.

Export and interstate trade:

Onion production of India is centralized to a few states. The Maharashtra alone contributes more than 39% of the nation total followed by Madhya Pradesh, Gujarat, Karnataka and Rajasthan. Thus, the major metropolitans and other states face volume deficit and big price gap throughout the year. It generates a great movement of onion from the production centers towards deficit markets nationwide. The interstate trade involves a huge chain of intermediaries from procurement to sale; it broadens the price gaps between what farmers and the end consumers are getting. As a FPO linking the producers at production and at its marketing too, can reduce the number of intermediaries and can catch the profit gaps wisely. This needs creation of facilities such as grading, handling, storage, resourcing, transport, market intelligence and the technological supports as a single entity by an FPO. The government initiatives here come true for the support. The integration of more than 1000 mandis over the E-NAM platform has a network of traders and farmers across the nation serving the real-time market intelligence facilitating the market selection. The transport access to the railways through the initiatives like Kisan rath and Kisan special railways throughout the major markets along with loading, handling facilities for the farmers is availing alternatives for the transport of their farm produce along with subsidies for the freight costs. Aimed at quickly transport of agri produce from surplus regions to consuming while ensuring minimal transit damage Kisan Rail is a promising operating system that makes it possible for farmers to trade better and get better returns for their produce. Apart from availing the extensive network of Indian railways this scheme also offers 50 % subsidy in freight for transportation of fruits and vegetables. It has no minimum quantity requirement, and allows small farmers to access more expansive and far-flung marketplaces.

The scale of economy in storage of onion is positively acts for the FPOs by lowering the cost involved in handling, grading and construction of storage structures. The government support through the operation green and the price stabilization policies highly emphasize on generation of storage capacities. This safeguards the farmers from the low prices at peak periods and also ensures the availability of onion to the consumers in lean season at affordable prices. Here FPO can role as facilitator for procurement, storage, transport or for all.

The onion processing and value addition:

The global form of consumption is tending towards processed and value-added forms of different agricultural commodities and has also raised the scope for value addition and processing in onion. The onions are being processed for dehydrated powders, flakes, pickles, rings, sauces, beverages and medicinal preparations. Also, these processed forms are used in other value-added products. The processing in onion in India is concentrated at Mahua and Jalgaon districts. The major technical and risk support policies have seen to govern the success of these industries. FPOs willing to work simultaneously in market creation with the processing can explore this scope. ‘Operation Greens’ under Ministry of Food Processing Industries with a budgetary allocation of INR 500 crores is a new Central Sponsored Scheme (CSS) for integrated development of the tomato, onion, and potato (TOP) value chains. It is Aimed at encouraging the capacity building of FPOs by fostering their professional growth, reducing post-harvest losses, developing infrastructure for preservation and processing, offering agri-logistics for the supply chain, stabilizing prices for both consumers and producers, and preventing TOP farmers from making distressed sales. Implementing the scheme with two head strategies *viz*. Price stabilization measures (short term measures) and integrated value chain development projects (long term measures). It assists the entities involved either for transportation or for the storage in hired or creation form.

Another scheme PM Formalisation of Micro food processing Enterprises (PMFME), is also an initiative by the Ministry of Food Processing Industries (MoFPI) which is a project under the Aatma Nirbhar Bharat Abhiyan, with a budget of 10,000 Crore for a 5-year period from 2020–2021 to 2024–2025 specially focus on Farmer Producer Organizations (FPOs) and Self-Help Groups (SHGs) engaged in the agri-food processing sector, the Scheme aims to augment the existing individual micro-enterprises in the unorganized segment of the food processing industry and formalize two lakh micro food processing enterprises by providing Seed capital, Credit linked capital subsidy or a grant @35% of project cost for generation of facilities including common processing facility, lab, warehouse, cold storage, packaging and incubation centers. It also supports to FPOs for marketing & branding to micro units following the ODOP approach. It enhances a common packaging & branding with provision for quality control, standardization and adhering to food safety parameters for consumer retail sale. This ODOP approach involves up to a maximum 50 % of the overall budget support for branding and marketing and also imparts trainings and capacity building activities.

References:

1. FAO. 2005. Addressing marketing and processing constraints that inhibit agrifood exports. A guide for policy analysts and planners, FAO Agricultural Services Bulletin 60, Rome.
2. Wong, L. Agrofood Value Chains Management for Agricultural and Rural Development, Food Security, and Regional/Global Integration. Presentation at Enabling Agro Food Value Chains: A Capacity Building Workshop. Tokyo: Asian Development Bank Institute. (2016) www.exportgenius.in
3. **Kale R.B.,** Gadge S.S. and Singh M. 2021. Strengthening Farmer Participatory Agricultural Supply Chain: A Case Study of Maharashtra State-Level Farmer Producers Company (MAHA-FPC) in 'Catalyzing Sustainable Development through Producers Collectives: Case Studies from India's Hinterland' Published by VAMNICOM Pune.
4. DoAC&FW (2020) Agricultural census 2015–16. Department of Agriculture Cooperation and Farmer's Welfare, Ministry of Agriculture, Government of India, New Delhi. Retrieved from http://agcensus.dacnet.nic.in/

Chapter 16

NATIONAL POLICY FOR FARMER PRODUCERS' ORGANIZATIONS (FPOS)

Sagar Kisan Wadkar[1] and R. B. Kale[2]
[1]Adviser – Research and Study, National Cooperative Union of India (NCUI), New Delhi
[2]ICAR-Directorate of Onion and Garlic Research, Pune, Maharashtra-410505
*Email: sagarkwadkar@gmail.com

The producers' collectives[1] model has been identified as a best-fit model for addressing the key concerns at the front and back end of agricultural value chain. The present chapter presents the rationale for renewed thrust on the producers' collectives model in the form Farmer Producers Organizations (FPOs) by giving an overview of Indian agriculture, paradigm shift and its key drivers leading to the development of agribusiness in India. During this transformation, the key vulnerable factors have been discussed along with the Government of India's multi-pronged approach adopted during the last 74 years to address farmers' distress. At the end, the chapter presents the provisions of central sector scheme for the formation and promotion of new 10,000 FPOs with its present status and way ahead for making FPOs movement sustainable.

Background

Small holders are the core of Indian Agriculture, comprised of 85% and having less than 2 ha of land size. However, they are vulnerable to risk in agricultural production like the Lower scale of operation, Lack of access to credit and insurance services, Lack of capital and education coupled with poor access to adequate information, Exploitation by intermediaries in procurement and marketing, Vagaries of the climate, etc. Despite these constraints, between 1951 and 2018-19, with the cumulative support from all the stakeholders, the Indian farmers could achieve the production targets, like Foodgrain production from 51 to 281.37 mt, Pulses production from 8.41 mt to 24.51 mt, Horticultural production from 40 to 314.7 mt, Milk production 17 to 176.35 mt, Fish production 0.75 to 12.6 mt, Meat production 7.7 mt, Egg production 95.2 billion, etc. With this massive increase in production, India became a food-Secured country and able to provide a "Right to Food" to its citizens. This can be viewed as the "Brighter-side" of Indian Agriculture.

The ICAR - Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana estimated that the post-harvest loss is to be more than Rs. 92,651 crores across different commodities like Fruits and Vegetables (40,811 cr), Cereals (20,698 cr), Oilseeds (8,278 cr), Pulses (3,877 cr), Marine Fish (4, 315 cr), Inland Fish (3,766 cr), Poultry Meat (3,942 cr), Egg (1,320 cr), Meat (1,235 cr) and Milk (4,409 cr). This can be viewed as the "Darker-side" of Indian Agriculture. This implies

[1] Producers Collectives are any form of groups formed by primary producers, voluntarily coming together to enhance and expand their livelihood opportunities. This may include Community Based Organizations (CBOs), Producers Groups (PGs), Farmers Interest Groups (FIGs), Commodity Interest Groups (CIGs), Farmers Clubs (FCs), Water Users Associations (WUAs), Self-Help Groups (SHGs), SHGs Federations, Cooperatives, Farmer Producers Organizations (FPOs), Farmer Producers Companies (FPCs), etc. (Tripathy, et al., 2021).

that there is a lack of an appropriate ecosystem at the front end of the agri value chain. The percentage of loss to the total is minimal in the case of milk i.e. 0.92% to the total post-harvest loss. The reasons could be the end-to-end value chain established through dairy cooperatives and private dairy business houses. This indicates that there is a need to develop commodity specific end-to-end value chain in order to minimize the losses at both ends of agri value chain and thereby to reduce the total cost of production & increase productivity on the "backward linkages" side whereas increasing the farmers During the last 74 years, Indian Agriculture has witnessed distinct transitions from subsistence farming to intensive farming, commercial farming, high-value farming, and now in the 21st century the focus is on "*high-tech farming*" in order to improve the efficacy of agriculture ecosystem. It can be mapped as "*Production Only*" from the 1940s to the 1980s. From the 1990s onwards the focus was on "*Production and its efficient Marketing*" and now 2010s onwards the focus has been on "*Marketing and Value Addition*" besides maintaining the production targets to feed the growing population. Thus, we can see the paradigm shift in Indian agriculture i.e. from "*agriculture to agribusiness*".

Major Drivers for the Paradigm Shift from Agriculture to Agribusiness

The following are the key factors that are contributing to the growth and development of agribusiness in India.

1. Declining landholding and the need for improving the productivity
2. Reorganizing the production and marketing system by changing the scale of operation
3. Growing Markets, Urbanization and Increasing Commercialization of Agriculture
4. Improving policy reforms and liberalization of agricultural marketing systems
5. Changing food consumption pattern and demand for quality and convenience
6. Growing agri-Infrastructure and rural-urban migration
7. Usage of information and communication technology across value chains

Farmer Producers Organizations (FPOs)

FPOs is an aggregation of primary producers for addressing the key concerns at the back and front end of the agri value chains. There are many legal entities where primary producers and/or Farmer Producers' Organizations (FPOs) can organize themselves. Any FPO can register itself as either a "for-profit" or "not-for-profit" entity. As far as "for-profit" entities are concerned, they can get registered as a legal entity under the following provisions:

1. Producer Company under Section 581(C) of the Indian Companies Act, 1956, as amended in 2002 and 2013, where the Registrar of Companies (RoC), Ministry of Corporate Affairs, Govt. of India regulates the companies.
2. Cooperative Society Act 1912 and respective State government's Cooperative Societies Act; and/or Mutually Aided Co-operative Societies (MACS) Act 1995, where the Registrar of Cooperative Societies (RCS) of respective State Department of Cooperation regulates their respective state's societies.
3. Multi-State Cooperative Society Act, 2002 comes under the Central Registrar, Department of Cooperation, Newly formed Ministry of Cooperation, Govt. of India.

Further, with regard to "not-for-profit" entities, there are the following legal provisions, where the FPOs can be registered as -

4. Section 8 Company under Indian Companies Act 1956, as amended in 2013
5. Society under Societies Registration Act, 1860
6. Trust under Indian Trusts Act, 1882

At a fundamental level, "cooperatives", "SHGs" and "FPCs" are various forms of producers' collectives. In the agribusiness context, they may be termed as FPOs. These are member-driven organizations' also called as "*Social Enterprises*". Tripathy and Wadkar (2021) explained the concept of social enterprises in agriculture and highlighted the key issues constraining their growth and development. These member-driven organizations can be created at the cluster, block, district or State level depending upon the needs of the producers considering the "*demand potential to adopt value chain approach"* to enhance farmers'/ producers' economic and social benefits.

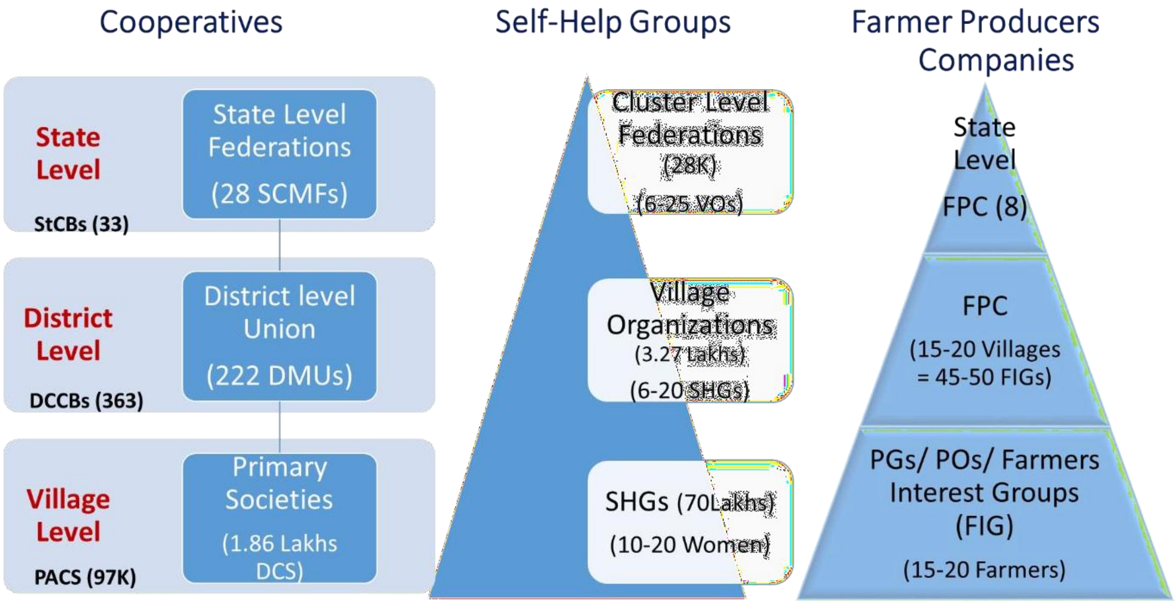


Fig. 1: Social Enterprises in Agriculture (Source: Tripathy and Wadkar, 2021)

Tripathy et al., (2020) have discussed in detail the emergence, endurance and issues & challenges in making these three forms of organizations competitive ad sustainable. *The very fundamental objective is to provide collective bargaining power for smallholders and ensure access to quality inputs, technology, & market, etc.*

Principles of FPOs

In the 21st century, the renewed thrust has been put on the concept of the FPOs, where the key focus is on the "business model" rather than "Social Benefits". These member driven collectives are based on the principles of cooperatives and corporates as follows –

1. Voluntary and Open Membership
2. Democratic Member Control
3. Member Economic Participation
4. Autonomy and Independence
5. Education, Training and Information
6. Cooperation among Cooperatives/FPOs
7. Concern for the Community
8. Professionalization in Approach

9. Digitalization of Operations
10. Focus is on Revenue Model

Present Status of FPOs (2002 to 2020)

The concept of FPOs as a producers company came in 2002, but the actual promotion of FPOs started 2011-12 onwards under two schemes of "*Rashtriya Krishi Vikas Yojana* (RKVY) viz. '*National Vegetable Initiatives for Urban Clusters' and 'Programmes for Pulses Development for 60,000 Rainfed Villages'*. The Government of India has entrusted the Small Farmers Agribusiness Consortium (SFAC) and National Agricultural Bank for Agriculture and Rural Development (NABARD) to promote and support FPOs.

Table 1: Number of FPOs registered during 2000 to 2020

Supporting/ Implementing Agencies	**As Cooperatives, FPC, Sector 8, Society, Trust**
SFAC	910
NABARD	4251
DAY-NRLM	177
Self-Promoted	63
Sub-Total	**5401**
State & its development agencies	3500+
Total	**8901+**
Source: Retrieved from SFAC and NABARD Website	

These FPOs have played a pivotal role in the socio-economic development of farmers. There are many success stories documented by academic and development agencies (Tripathy, et al., 2021; NICR, 2020; Tripathy & Sneha, 2020; SFAC, 2014; DSC, 2007 and many more). During the COVID-19 pandemic as well the cooperatives, FPCs and SHGs Federations have played a very important role in extending essential services to consumers (ECWG, 2020; FICCI, 2020; ICAR, 2020; NABARD, 2020; SFAC, 2020; Wadkar, 2020; World Bank, 2020 and many more).

Central Sector Scheme for the Formation and Promotion of New 10,000 FPOs

On 9th Feb. 2021, Hon'ble Prime Minister Shri. Narendra Modi launched the Central Sector Scheme for the Formation and Promotion of New 10,000 FPOs as a clear strategy towards the transformation of agriculture into a sustainable enterprise and to achieve global outreach for making "*Atmanirbharata in Krishi*".

Promotion and Formation

Formation and promotion of FPO is based on "*Produce Cluster Area*", which is broadly defined as: "*a geographical area wherein agricultural and allied produce such as horticulture produce of similar or of almost similar nature is grown/ cultivated; therefore, an FPO can be formed for leveraging economies of scale in production and marketing*" (FPOs Operational Guidelines, 2020). In addition, the FPOs will also focus on the "*One District One Product*" (ODOP) approach for developing a commodity/ product-specific value chain in a district.

A total of nine Implementing Agencies (IAs) have been identified for supporting this national agenda such as SFAC, NABARD, National Cooperative Development Corporation (NCDC), National Agricultural Cooperative Marketing Federation (NAFED), North Eastern Regional Agricultural Marketing Cooperation Limited (NERAMAC), SFAC-Tamil Nadu, SFAC-Haryana, Karnataka Watershed Development Department, and Foundation for Development of Rural Value Chain (FDRVC). The NAFED would provide market and value chain linkages to all FPOs. These IAs have empanelled the FPOs promoting institutions, known as "Cluster Based Business Organizations (CBBOs). The CBBOs would promote and register FPOs under both cooperatives and FPC Act and nurture FPOs for five years. The focus is on the Aspirational Districts and Notified Tribal Areas. The FPOs should have a minimum of 300 members in plain areas and 100 members in the North Eastern Region & Hilly areas.

The CBBOs would get a maximum of Rs. 25 lakhs per FPO for five years from the year of formation. It includes cost towards undertaking baseline survey, mobilization of farmers, organizing awareness programmes and conducting exposure visits, professional hand holdings, incubation, cost of engaging CBBOs and other overheads, etc. There is also a provision for cost of NPMA towards manpower, establishment, travel and advisory and maintaining MIS portal. This also includes a provision towards the cost for the development of an appropriate overall ICT-based MIS web portal for the Scheme.

Roles and Responsibilities of CBBOs

The primary responsibility of CBBOs is to understand that the FPOs reach a sustainable level of business and the staff of the FPO acquires technical and managerial capability to run the business successfully when it withdraws its support. The CBBOs would follow the following steps for promotion and formation such as Cluster Identification; Diagnostic and Feasibility Studies; Baseline Assessment; Business Planning; Mobilization – Organizing – Formalizing; Resource Mobilization; Development of Management Systems and Procedures; Business Operations; and Assessment and Audit.

Implementation and Monitoring Mechanism

Considering the significance of effective implementation and better monitoring mechanism for the success of a scheme, there is a well-structured, institutionalized three tired structure at the National level, State level and District level for effective implementation and monitoring of formation and promotion of FPOs.

At the National level, Ernest and Young Global Limited (E&Y) Company was identified as a National Programme Management Agency (NPMA) for overall guidance, data management and monitoring. The NPMA would be equipped with a technical team having expertise in areas like agriculture/ horticulture, marketing and processing, incubation service provider, IT/MIS and law & accounting to provide overall guidance at all India levels.

At the State level – Consultative Committee (SLCC) would work in close coordination with NPMA for necessary support at State level. The Addl. Chief Secy/ Secy. Or I/c Agriculture/ Agriculture Marketing would be the Chairperson of SLCC and Representative of NABARD would be the member secretary. The State government's role is crucial in supporting these FPOs. It is expected that the State should extend support – (a) By making provisions for easy issue of licenses to FPOs to trade; (b) By using FPOs as producers of certified seed, saplings and other planting material; (c) To allow the direct sale of farm produce by FPOs at the farm gate; (d) By using FPOs as implementing agencies for various agricultural development programme; (e) By linking FPOs to financial institutions like cooperative banks, etc. for working capital or term loan; (f) By promulgating state-level policies to support and strengthen FPOs.

At the District Level – Monitoring Committee (D-MC) would monitor the scheme at the District / Cluster Level to ensure effective coordination among the stakeholders and benefit to the farmer members. District Collector would steer the D-MC and District Development Manager (DDM), NABARD would act as a member secretary.

In addition to three-tiered afore-stated structured mechanism for monitoring of the scheme, there would be continuous in-house monitoring by DAC&FW as well as by the Implementing Agencies also. The DAC&FW may utilize the services of the Directorate of Marketing & Inspection (DMI), which has existed through its Regional & Sub-Offices across the country. For effective monitoring, DAC&FW may engage consultants also and the cost for the same would be borne from the budget of the scheme itself.

Management and Credit Support

The scheme extends the financial support to FPOs up to a maximum of Rs. 18 lakhs per FPO or actual, whichever is lesser would be provided during three years from the year of formation. It was learned that FPOs need such kind of seed fund at least for three years for making them sustainable and economically viable. Further, it is expected that the FPO should manage their management & other expenditure from their own business activities. The indicative financial support broadly covers – (a) Registration expenditure Rs. 40K (one time); (b) CEO/ manager salary Rs. 25K per month; (c) Accountant Rs. 10K per month; (d) Office rent max. up to Rs. 48K per year; (e) Utility charges max up to Rs. Rs. 12K per year; (f) Furniture & Fixtures max. Rs.20K (one time); (g) Travel and meeting Rs. 18K per year; (h) Miscellaneous Rs. 12K per year.

Equity Grant Scheme (EGS)

The EGS started in 2014 with the objective to enhance the creditworthiness & viability of FPOs in order to make them sustainable and to enhance the shareholding of members to increase their ownership and participation in FPOs. The Equity Grant would be in the form of a matching grant up to Rs. 2,000 per farmer member of FPO subject to a maximum limit of Rs. 15 lakhs per FPO. From 2014 to 2021 a total of 735 FPCs with a 6.29 Lakhs member Farmers received around 4822 Lakhs as matching equity grants.

The FPO can make online application[2] for the same with proofs in fulfillment of eligibility criteria like Minimum shareholders more than 50 and Paid-up capital less than Rs. 30 lakhs; Minimum 33% of its shareholders are smallholders (50% for coops); Maximum shareholding by any one member should not be more than 5% of the total equity of the FPC (10% in case Coops); Minimum of five BoDs farmers and minimum one woman member; Should have Management Committee responsible for the

[2] Online Application for getting equity grant on http://sfacindia.com/EGFAppliactionForm.aspx

business; and Viable Business plan and budget for next 18 months.

Credit Guarantee Fund

In order to ensure access of FPOs to credit from mainstream banks and financial institutions, a dedicated fund was created in 2014. The objective is to provide suitable credit guarantee cover to accelerate flow of institutional credit to FPOs by minimizing the risk of financial institutions for granting the (collateral free) loans to FPOs so as to improve their financial ability to execute better business plans leading to increased profits.

The CGF would provide protection to eligible lending institutions by extending credit guarantee and covering their lending risks up to Rs. 1 Crore (85% CG cover) and between Rs 1 – 2 Cr (75% CG Cover) so as to enable FPO to get collateral-free loan. The FPOs can make an online application with the proof of fulfillment of eligibility criteria as like EGS and the number of its individual shareholders should not be lower than 300. As of July 2021, a total of 31 Financial Institutions have MoU with SFAC to avail this facility and from 2014 to 2021, around 183 FPCs could get a guarantee cover of Rs. 6346 Lakhs. Thus, there is a need for sensitization and orientation of financial institutions towards the concept of FPOs, their business models, credit requirements and governments financial & non-financial provisions, etc.

Venture Capital Assistance (VCA) Scheme

VCA scheme started in the year 2002 as financial support in the form of an interest-free loan to qualifying agribusiness projects to meet the shortfall in the capital requirement for the implementation of the project. It is being implemented by SFAC. The promoter's/ entrepreneur needs to have a 26% stake out of total project cost and in the case of FPOs, it is 40% to the total project cost. From 2002 to 2021, around 41 Banks have had MoU with SFAC and sanctioned & disbursed Rs. 900.43 Cr to 3164 agri-business projects, having a total project value of Rs. 10,564 Cr, benefitting approximately 2.07 lakh farmers and generating employment of 1.12 Lakhs persons. In addition, the SFAC has mapped 560 FPOs[3] with these 3164 sanctioned projects for getting agri-infrastructure and technical support.

Tax Exemption for FPOs

The FPOs are tax exempted subjected to an annual turnover of less than 100 Cr from farm activities for five years (up to 2023-24) with a view to reduce hardships and to extend support at the FPOs' formative years (Government of India, 2018). The objective is to promote value addition and encourage professionalism in the operations of FPOs. It is expected that the FPOs should invest profit so earned into their business activities and particularly to enhance productivity through efficient, cost-effective and sustainable resource utilization. However, the FPCs need to pay the Minimum Alternate Tax (MAT) @15 percent of their book profit. The FPOs are seeking MAT exemption too, to realize full benefits from IT relief.

[3] List of such FPOs available online on http://sfacindia.com/UploadFile/Statistics/VCA%20PPT%2031.03.2021.pdf

Training and Capacity Building for FPOs

It was observed that out of around 8000+ FPOs registered from 2002 to 2020, around 12 to 15 percent FPOs are functional and most of them are struggling to kick start their business activities. One of the reasons could be the lack of training and capacity-building support. Therefore, in this scheme, the FPOs would get frequent skill-based training to build their capacity to manage FPOs functioning's and business operations. The focus is on governance, management, vertical and horizontal aspects of the agricultural value chain, value addition & processing, and marketing. In addition, the subject matter of training would also cover topics ranging from organisational management/ behaviour, crop husbandry, trading, export, supply chain, grading, labelling, packaging, branding, accounting, auditing, compliance requirements, use of MIS/ ERP, etc.

To do so, the Govt. of India has adopted a consortium approach to provide need-based trainings in local/ regional languages. The Bankers Institute of Rural Development (BIRD), Lucknow promoted by NABARD is designated as Nodal Training Institution (NTI) at the central level for FPOs registered in FPC Act, whereas the Laxmanrao Inamdar National Academy for Co-operative Research & Development (LINAC), Gurugram promoted by NCDC is designated as Nodal Training Institution at central level for FPOs registered under Cooperative Societies Act. These two NTIs would work in partnership with other reputed academic cum training organisations like NIRD&PR, Hyderabad; MANAGE, Hyderabad; NIAM, Jaipur; NIFTEM, Haryana; VAMNICOM, Pune and such other national and regional institutions such as IRMA, Anand and ASCI, Hyderabad, State and Central Government Agriculture Universities, National Level Skill Development Universities, Krishi Vigyan Kendra's (KVKs) and other National Level Management and Skill Development Institutions, etc.

Conclusion and Way Forward

Agriculture is in the transformation phase. During the last 74 years, agriculture has witnessed a paradigm shift in the quest for achieving the food security targets to now attaining nutritional security. Earlier it was more of on "Production" orientation, which is now "Production & its effective Marketing". To cope up with this change and in order to address farmers' distress, India has had a century-old cooperative model, used as an instrument for socio-economic development during the pre and post-Independence era. However, the cooperative model got diluted over the period of time and it was felt necessary to give autonomy & independence back to these organizations with a focus on business aspects rather than vehicles for extending welfare services, particularly after structural reforms in 1991. A number of attempts were made to revamp the cooperative organizations, but it could not happen to that extent because of the nexus of political parties and bureaucracy. Thus, in the 21st century, the renewed focus has been given to the concept of member-driven and member-controlled organizations to act as a business organization and to address the emerging challenges, which is conceptually now being called "FPOs".

The emphasis is on developing a comprehensive and holistic ecosystem to form and promote farmers' organizations in order to facilitate the development of a vibrant and sustainable income-oriented farming system and for the overall socio-economic development and wellbeing of agrarian communities. The objective is to enhance productivity through efficient, cost-effective and sustainable resource use and realize higher returns through market linkages and technology usage in value addition & processing of their products and become sustainable through collective action.

Thus, FPOs viewed as an economic enterprise for enhancing and expanding livelihoods opportunities. However, to reap the benefits of liberalized markets and making FPOs movement competitive and sustainable in the long run, FPOs needs to develop and follow 4 S's i.e. *Standard Operating Procedures*, *Scaling-up* of business operations, *Skilling* to perform across value chains, and *Sustenance* in managing governance and management practices. It demands 3 C's approach i.e. Collaboration, Convergence and Collective action by all the key stakeholders, who matter the development of "Farmers".

References

DSC. 2007. Development Support Centres's Experience. Dhari Krushak Vikas Producer Company Ltd. PRADAN'S Workshop on Producer Companies.

ECWG. 2020. Women's groups and COVID-19: Challenges, engagement, and opportunities. Evidence Consortium on Women's Groups, Bill & Melinda Gates Foundation. Available on https://womensgroupevidence.org/sites/default/files/2020-06/June%201%20COVID%20ECWG%20Final.pdf

FICCI 2020. Empowering FPOs. Federation of Indian Chambers of Commerce & Industry. Available online on https://ficci.in/spdocument/23272/FICCI-Empowering-FPOs-Paper.pdf

FPOs Operational Guidelines 2020. Formation and promotion of 10,000 farmer producer organizations (FPOs): Operational Guidelines. Ministry of Agriculture & Farmers' Welfare, Government of India.

Government of India 2018. The report of Union Budget 2018-19, Ministry of Finance, Govt. of India.

ICAR 2020. Innovative agri-solutions during COVID-19. Available online on https://icar.org.in/sites/default/files/Innovative_Agri-Solutions_COVID-19-2020-1106.pdf

NABARD 2020. Impact Assessment of COVID-19 on Indian Agriculture & Rural Economy. Department of Economic Analysis & Research, NABARD. Available online on https://www.nabard.org/auth/writereaddata/tender/1211203145Impact%20Assessment%20of%20COVID.pdf

NICR. 2020. Success stories of FPOs. Available online on https://ncdex.com/downloads/fpo/casestudy/Success%20Stories%20of%20FPOs_Aug%202020_compressed.pdf

SFAC. 2014. Krishi Sutra 2: Success stories of Farmer Producer Organizations. Available online on http://sfacindia.com/PDFs/Krishi-Sutra(Version2).pdf

SFAC. 2020. FPO activities during lockdown period. Available online on http://sfacindia.com/PDFs/covid-19/FPO%20activities%20during%20lockdown%20period.pdf

Tripathy, K. K. and Sneha Kumari 2020. *Cooperative – Cases and Success Stories.* A. K. Publication, New Delhi.

Tripathy, K. K. and Wadkar, S. K. 2021. Social Enterprises: An Instrument for Sustainable Development. Agricultural Extension in South Asia (AESA) Blog 157 - August 2021.

Available online on https://www.aesanetwork.org/wp-content/uploads/2021/08/AESA-BLOG-157.pdf

Tripathy, K. K., Deshpande, D. V., Wadkar, S. K., and Lokhande, J. 2020. Catalyzing Development through Collectives: Status and Issues of Cooperatives, SHGs and Farmer Producers Organizations in India. VAMNICOM Working Paper Number 3, 2 (1): 1 - 42.

Tripathy, K. K., Wadkar, S. K. and Singh, A. 2021. Catalyzing sustainable development through producers' collectives: 11 cases studies from India's hinterlands. Ed. Book. VAMANICOM and Notion Press Publisher (Forthcoming).

Wadkar, S. K. 2020. Collective Action in Maharashtra to deal with COVID-19: Impact on Agriculture. Agricultural Extension in South Asia (AESA) Blog 111 - April 2020. Available online on https://www.aesanetwork.org/wp-content/uploads/2020/04/AESA-BLOG-111.pdf

World Bank 2020. In India, women's self-help groups combat the COVID-19 pandemic. Available online on https://www.worldbank.org/en/news/feature/2020/04/11/women-self-help-groups-combat-covid19-coronavirus-pandemic-india.

Chapter 17

IMPACT OF IMPROVED ONION TECHNOLOGIES AT FARMERS' FIELD

Dr. S. S. Gadge*, R. B. Kale, A. J. Gupta and A. Thangasamy, V. Mahajan and Major Singh
ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune
*Email: shailendragadge@gmail.com

Agricultural extension is the application of scientific research and new knowledge to agricultural practices through farmers' education. Extension activities help to disseminate the technology and evaluate its impact for further refinement. Improving knowledge and skill of the farmers with onion production through dissemination of improved onion technologies developed by the Directorate and conduction of various training programmes is required to enhance socio-economic status of the farmers. All the technologies need to reach out to the actual farmers in the fields. ICAR-DOGR has always considered it as its top priority to reach out to them through demonstrations, trainings, exhibitions, media and technical bulletins through research project, TSP, TSP-NEH, SCSP, NEH Plan, AINRPOG and MGMG schemes. Monthly advisories are published in three languages (Marathi in Agrowon, English and Hindi on ICAR-DOGR website) for farmers' benefit. Countless farmers are already reaping the benefits of higher yield and better storage facilities.

Conduction of frontline demonstrations

Frontline demonstrations were carried out in mainly three states *viz.*, Maharashtra (1525), Uttar Pradesh (300) and NEH region (1370) during *kharif*, late *kharif* and *rabi* seasons through research project and TSP, TSP-NEH, SCSP, NEH Plan, AINRPOG and MGMG schemes to demonstrate crop production and protection technologies and its management practices in the farmers' field under different agro-climatic regions and farming situations. The seed of ICAR-DOGR onion varieties were provided to the selected progressive farmers of these states. The onion seed of local varieties were arranged by the farmers.

Demonstrations in Maharashtra

Onion varieties, Bhima Red, Bhima Dark Red, Bhima Super, Bhima Raj, Bhima Safed and Bhima Shweta were selected for *kharif*, Bhima Super, Bhima Red, Bhima Raj, Bhima Shakti and Bhima Shubhra for late *kharif* and Bhima Shakti and Bhima Kiran for *rabi* demonstrations in Pune, Ahmednagar, Nashik, Aurangabad, Parbhani, Jalna, Jalgaon, Latur, Sangli, Satara, Solapur, Nandurbar, Dhule, Wardha, Akola, Amravati, Washim, Buldhana districts of Maharashtra.

Demonstrations in Uttar Pradesh

Onion varieties, Bhima Dark Red (Sets) selected for early *kharif*, Bhima Super and Bhima Dark Red were selected for *kharif* and Bhima Shakti and Bhima Kiran for *rabi* demonstrations in Mirzapur and Hamirpur districts of Uttar Pradesh.

Demonstrations in NEH region

Onion varieties, Bhima Super and Bhima Dark Red were selected for *kharif*, Bhima Kiran, Bhima Shakti was selected for *rabi* demonstrations in Mirzapur district of Uttar Pradesh. Ten progressive farmers were selected from villages – Jalalpur Mafi, Bagahi, Keshavpur, Bhavanipur, Gangpur, Pratappur, Ramnagar, Purushottampur, Bhopti and Govindpur. For demonstration purpose, 4 kg onion seed was provided by the Directorate to each farmer.

Demonstrations in other states

Demonstrations were also conducted in Morena (*kharif*, 10 demos of Bhima Super) and Shajapur (*rabi*, 13 demos of Bhima Shubhra) district of Madhya Pradesh, Gadakh (late *kharif*, 16 demos of Bhima Shubhra and Bhima Shweta) district of Karnataka, Morbi (*rabi*, 5 demos of Bhima Shweta), Dahod (late *kharif*, 2 demos of Bhima Raj, Bhima Shakti, Bhima Super, Bhima Red and Bhima Shubhra) and Bhavnagar (late *kharif*, 4 demos of Bhima Shubhra and Bhima Shweta) districts of Gujarat, Jalore (*rabi*, 2 demos of Bhima Shakti) district of Rajasthan and Kurnool (*rabi*, 3 demos of Bhima Shubhra, Bhima Shweta and Bhima Safed) district of Andhra Pradesh.

Recommendations made by the Directorate were followed in all trials.

Performance of frontline demonstrations in Maharashtra

The performance of frontline demonstration trials in Maharashtra is given in Table 10.1

Table 1: Performance of frontline demonstration trials in Maharashtra

Season	Variety	Germination Percentage	Average weight of one fresh bulb (g)	Marketable yield (q/ha)
Kharif	Bhima Super	96	76.00	245
	Bhima Shweta	95	78.00	220
	Bhima Safed	96	76.00	225
	Bhima Raj	94	75.00	235
	Bhima Red	92	76.00	230
	Bhima Dark Red	**98**	**80.00**	**265**
	Local	80	65.00	175
Late *Kharif*	**Bhima Shakti**	93	**90.00**	**450**
	Bhima Super	94	82.00	375
	Bhima Raj	**95**	75.00	415
	Bhima Red	90	83.50	425
	Bhima Shubhra	94	85.00	410
	Local	75	70.25	320
Rabi	**Bhima Shakti**	**96**	**80.00**	**420**
	Bhima Kiran	93	75.00	415
	Local	75	72.00	270

The demonstrations in Maharashtra in *kharif* season revealed that the germination percentage (98), average bulb weight (80g) and yield (265 q/ha) of Bhima Dark Red was the highest. Bhima Super (245 q/ha), Bhima Raj (235 q/ha), Bhima Red (230 q/ha), Bhima Safed (225 q/ha), Bhima Shweta (220 q/ha) also yielded more than local variety (175 q/ha).

The germination percentage (95) of Bhima Raj, average bulb weight (90 g) and the yield (450 q/ha) of Bhima Shakti were the highest in late *kharif* demonstrations in Maharashtra. Bhima Red (425 q/ha), Bhima Raj (415 q/ha), Bhima Shubhra (410 q/ha) and Bhima Super (375 q/ha) also yielded more than local variety in late *kharif* demonstrations.

Demonstrations conducted in *rabi* in Maharashtra revealed that the germination percentage (96) of Bhima Shakti was the highest followed by Bhima Kiran (93). Average bulb weight (80 g) and marketable yield (420 q/ha) of Bhima Shakti were the highest. The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations.

Transforming livelihood of tribal farmers of Nandurbar in Maharashtra through onion and garlic cultivation

The tribal belt of Nandurbar in Maharashtra has congenial climatic conditions for production of onion and garlic at commercial level. But cultivation of these crops was limited to the kitchen garden before the initiation of Tribal Sub-Plan (TSP) in this area by ICAR- DOGR with KVK, Nandurbar. About 1030 tribal farmers were selected in the form of 103 groups under this scheme. Each group comprised 10 selected farmers with one acre of land for conduction of field demonstrations, trainings and input distribution. Thirty-two tribal villages have been selected from three Talukas *viz.;* Navapur, Akkalkua and Dhadgoan of Nandurbar for implementation of TSP on onion and garlic. Onion seed and garlic bulbs of improved varieties along with kits containing fertilizers, fungicides, insecticides, weedicides, etc., distributed to the groups of tribal farmers. A total of five trainings and 143 field demonstrations (58 during *kharif* and 85 during *rabi*) under TSP during 2021-22 were conducted for livelihood development of tribal farmers.

Impact of technological intervention in Nandurbar area

- More than 5000 tribal farmers have been trained by organizing 518 field days/trainings by ICAR-DOGR.
- Most of the farmers from selected areas are now cultivating onion and garlic on commercial scale.
- Onion and garlic are giving more profit than traditionally grown crops in these areas and even got the highest price of onion produced in Indore market.
- The production and productivity of onion in Nandurbar has been increased 91% and 38%, respectively after initiation of TSP.
- Initially cultivation of garlic in Nandurbar was negligible whereas at present cultivation of garlic initiated at commercial level (250 ha area and 2250 t production) with the 9.0 t/ha productivity.
- Buy back of onion seed were taken by ICAR-DOGR to insure net income from onion seed production to the selected tribal farmers.
- After increase in income level due to ICAR-DOGR initiatives, the tribal farmers established *NESU Parisar Farmers Producer Company* at Nimboni, Nandurbar with the support of ICAR-DOGR through TSP.

After successful intervention of technologies in Nandurbar district, TSP programme started for tribal farmers in Bhima Shankar area of Pune district.

Fig. 1. Trainings and demonstrations under TSP

***Kharif* onion production technology: for improving livelihood of onion farmers**

Onion is grown in three main seasons namely *kharif* (monsoon), late *kharif* and *rabi* (winter) contribute 20%, 20% and 60%, respectively, to the total onion production in India. Onion bulb produced during *rabi* season could be stored up to October and meets the demand of consumers. *Kharif* onion will come to market during October-November months. *Kharif* onion plays an important role in filling the gap of onion supply from October-December which helps in stabilization of market prices. Excessive rains, humidity, temperature, pests and disease are critical factors affect *kharif* onion cultivation. Such adverse conditions prevailed are common during *kharif* season which causes reduction in marketable bulb yield. The average marketable bulb yield during *kharif* season was about 4 t/ha. The cumulative rainfall received during 1998 and 2005, was 734 and 728 mm, respectively. This rainfall received was higher by about 28-29% as against long-term average annual rainfall of 567 mm. The rainfall received from July to October in 1998 and 2005 was excess by 55.95 and 27.44%, respectively, compared to long-term average, which signifies that the damage due to excess rainfall was significantly higher (50-80%) in 1998 compared to 2005 (10- 15%) leading to “classical situation of price hike”.

To minimize such weather induced damages and stabilize onion yields, *kharif* production technology has been developed by ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune.

Kharif onion production technology involves;

- Selection of varieties recommended for *kharif* season (Bhima Super, Bhima Darkred, Bhima Red, Bhima Raj, Agrifound Darkred, Arka Kalyan, Baswant 780, Phule Samarth *etc*.)
- Raising nursery during second fortnight of June on broad bed furrow with drip or sprinkler irrigation under shade nets and keeping the seedlings ready for transplanting in the first fortnight of August.
- Raising seedling under shade net

- Transplanting of seedlings on broad bed furrow with drip irrigation. The raised bed in broad bed furrow facilitates quick and efficient drainage of rainwater, which minimizes the incidence of soil borne and foliar diseases.
- Combined application of 75:40:40:20 kg NPKS/ha, organic manure equivalent to 75kg N/ha is recommended for *kharif and* Azospirillum and phosphorus solubilising bacteria at 5kg each per ha is recommended.
- Application of FYM or Vermicompost pre-mixed with *Trichoderma viride* before bed preparation, It helps in reducing the incidence of soil borne diseases.
- Fertigation through drip avoids leaching losses of nutrients, which is common in high rainfall conditions: 2/3 of top-dressing N needs to be applied in seven splits at weekly interval from transplanting to 60 DAT.
- Application of pre-emergence herbicide pendimethalin @0.2%.
- Developed Spray schedule for effective management of pest and diseases
  1. Mancozeb @ 0.25% with Methomyl @ 0.08 g/l at 30 days after transplanting (DAT),
  2. Tricyclazole @ 0.1% with Carbosulphan @ 0.2% at 45 DAT,
  3. Hexaconazole @ 0.1% with profenofos @ 0.1% at 60 DAT.
  4. Propiconazole @ 0.1% with fipronil @0.1% at 75 DAT if required

This technology ensures 20-25 tons of yield per hectare without compromise in quality of bulbs.

Demonstration and adoption

This technology has been demonstrated to the farmers of different states and non-traditional areas such as Vidharba regions and Nandurbar districts of Maharashtra and across the country.

About 150 demonstrations were carried out in districts viz., Akola, Wardha, Washim, Buldhana and Amravati districts of Vidarbha region of Maharashtra. Shri Namdeorao Adhau, from Patur, Akola (Maharashtra), purchased seeds of 'Bhima Shubhra' and Bhima Kiran from DOGR and raised onion on raised bed following kharif production technology of ICAR-DOGR. He obtained a record marketable yield of 21 tonnes/acre of Bhima Shubhra (white onion) and 10 t/acre of Bhima Super (red onion). He earned a net profit of ₹6.0 lakhs during *kharif* season. Shri Adhau formed a group of about 300 farmers from twelve villages of the region. He is promoting *kharif* production technology in Vidharba region. Area under *kharif* onion production in 2014-15 has increased by 100-150% in Vidarbha region compared to 2011-12.

Kharif onion production was also demonstrated in Navapur Taluka of Nandurbar in 2013. With this demonstration, area under kharif onion production has increased to about 3000 ha in Nandurbar district with the production of 0.5 lakh tones. The *kharif* production technology has also been successfully demonstrated to the farmers of Karnataka, Madhya Pradesh, Uttar Pradesh, Rajasthan, Andhra Pradesh, Bihar, Gujarat and West Bengal with help of All India Network Project on Onion and Garlic and local Krishi Vigyan Kendra's. The area under *kharif* production has been increased considerably in these states as well. Government of West Bengal has approved a pilot project for increasing area under *kharif* onion production through field demonstration.


Fig. 2: Shri Adhau adopted *kharif* onion production technology and gain profit from both red and white onion

The highest adopted variety by the farmers of Vidarbha was Bhima Shubhra (56%), followed by Bhima Super (21%) and Akola Safed (6.5%). ICAR-DOGR developed varieties, package of practices, broad bed furrow with micro irrigation and modified storage structures were adopted by 77%, 74%, 60.5% and 45% farmers, respectively. Adoption of technologies had positive effect on socio-economic condition of the farmers in terms of increase in annual income, loan repayment capacity, improvement in farm and home condition, increase in domestic spending and participation in social events.

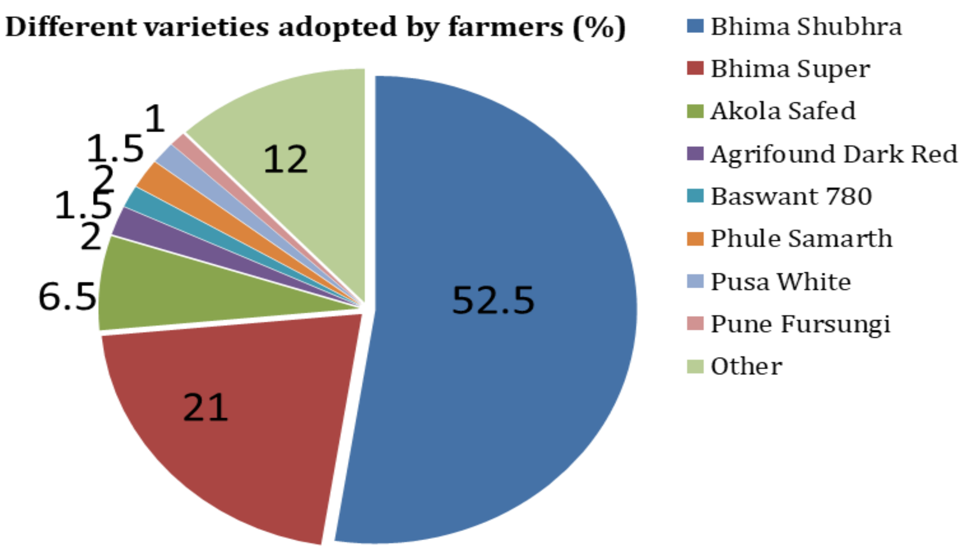


Fig 3: Varietal distribution of onion

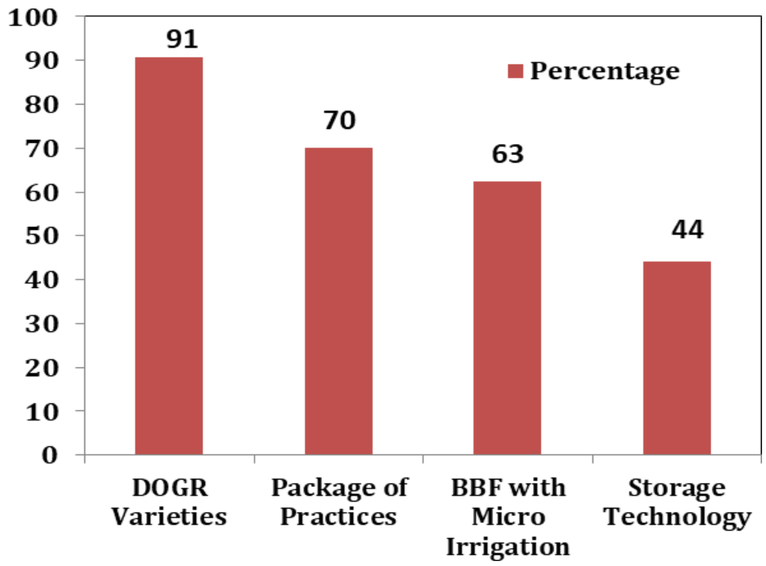


Fig. 4: Adoption of ICAR-DOGR technologies

Socio-economic benefits

With *kharif* onion production technology of ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune, the farmers are continued to grow onion with higher productivity with increased profit. The farmers are producing higher (20-25 t/ha) bulb yield and profit. Overall *kharif* onion growing areas in Maharashtra during 2014-15 has increased by 1.4 times (1.54 lakh ha area) compared to 2004-05 with production of about 23.5 lakh tones of onion with economic benefit of about ₹1156.0 Crores. With this intervention, the livelihood of onion farmers is improved.

Intervention of *kharif* onion technology in eastern parts of Uttar Pradesh

Onion is an important commercial crop which can improve livelihood of poor farmers. It also plays a crucial role in food and nutritional security of human beings. Though, the south eastern part of Uttar Pradesh especially Mirzapur has congenial climatic conditions for onion production at commercial level, the cultivation of onion was limited to only *rabi*season at small level, mostly for kitchen gardens. There is tremendous scope to cultivate onion during *kharif* at commercial level to achieve more profit than *rabi* season and other traditionally growing vegetables. The farmers of Mirzapur district generally cultivates local varieties of onion which yields only 10-15 t/ha. As the quality of onion bulbs of these varieties is also poor, they get less profit. Therefore, it was decided to promote onion varieties and other production technology of ICAR-DOGR in Mirzapur district of Uttar Pradesh.

The systematic efforts were taken to improve the area and production of onion in *kharif* as well as *rabi* with careful application of improved varieties and recommended production technologies. The focus was given on conduction of field demonstrations of improved technologies at farmers' fields through improved varieties, knowledge dissemination, capacity building and entrepreneurship development. Initially, few interaction meetings were conducted with progressive farmers in collaboration with Seva International, Kashi and GK Research Development Foundation, Varanasi.Onion Awareness Camp was organized on 12 December, 2017 under the chairmanship of Dr. Major Singh, Director, ICAR-DOGR to create awareness and enhance the knowledge level of farmers to adopt new technologies of onion production in Mirzapur, Varanasi, Ghazipur and other adjoining areas.

Trainings organized

Onion cultivation is not yet commercialized in large areas of Mirzapur, Varanasi and Ghazipurdue to lack of awareness among the farmers about its high yielding varieties, improved production and post-harvest technologies. Hence, total five trainings on different topics such as onion awareness camp, onion nursery management, improved cultivation of onion, *kharif* onion production technology and raising of early *kharif* onion through sets technology were conducted to create awareness about improved onion cultivation practices among the farmers of this area. These trainings were attended by about 260 farmers from twelve villages including Gangpur, Bagahi, Jalalpur, Sahaspura and Govindpur of Chunar taluka, Mirzapur (UP).

Table 2: Trainings organized in Mirzapur district

Date	Topic of training	Beneficiaries
12 December, 2017	Onion Awareness Camp	50
2 June, 2018	*Kharif* onion production technology	50
10 March, 2019	*Kharif* onion production technology	40
10 June, 2019	Raising of early *kharif* onion through sets technology	60
23 November, 2019	Improved cultivation of onion	60

Field Demonstrations

Field demonstrations are the effective means to facilitate dissemination and adaptation of farm innovations and other practical information among the farmers. These are based on the principle of '*Seeing is Believing*'. Thus, the recommended package of practices along with improved varieties was demonstrated especially on onion cultivation in selected belts of Mirzapur.

Table 3: Demonstrations conducted in Mirzapur district

Demonstrations	Onion varieties	No. of Demos	Onion seeds distributed (kg)	Beneficiaries of demonstrations
Cultivation of onion during *kharif* 2018-19	Bhima Super and Bhima Dark Red	20	40 (20 kg of each variety)	20
Cultivation of onion during *rabi* 2018-19	Bhima Shakti	20	40	20
Cultivation of onion during *kharif* 2019-20	Bhima Super and Bhima Dark Red	50	100 (50 kg of each variety)	50
Raising early *kharif* onion through sets during *kharif* 2019-20	Bhima Dark Red	20	250	20
Cultivation of onion during *rabi* 2019-20	Bhima Kiran	30	60	30

Table 4: Performance of frontline demonstration trials in Uttar Pradesh

Season	Variety	Germination Percentage	Average weight of one fresh bulbs (g)	Marketable bulb yield (q/ha)
Kharif	Bhima Super	92	73.00	150
	Bhima Dark Red	**98**	**80.00**	**175**
	Local	80	62.00	130
Early *Kharif*	**Bhima Dark Red (Sets)**	**-**	**85.00**	**225**
Rabi	**Bhima Shakti**	**94**	**80.00**	**340**
	Bhima Kiran	90	75.00	320
	Local	75	72.00	270

Performance of frontline demonstrations in Uttar Pradesh

Demonstrations conducted in Uttar Pradesh in *kharif* revealed that the germination percentage (98), average bulb weight (80g) and yield (175 q/ha) of Bhima Dark Red was the highest. Bhima Super (150 q/ha) also yielded more than local variety (130 q/ha). Demonstrations on raising early *kharif* onion through sets also perform well and farmers received 225 q/ha yield through onion sets. The germination percentage (94), average bulb weight (80g) and yield (340 q/ha) of Bhima Shakti was the highest in *rabi* demonstrations. The onion varieties of ICAR-DOGR performed well even after receiving very high rainfall which created flood situation at the time of harvesting of *kharif* onion and nursery preparation of *rabi* onion. The demonstrations led to conclusion that the eastern part of Uttar Pradesh is suitable for *kharif* onion production.

Impact of *kharif* onion cultivation in Mirzapur district

About 50 progressive farmers were selected from twelve villages including Gangpur, Bagahi, Jalalpur, Sahaspura and Govindpur of Chunar taluka, Mirzapur (UP). A total of 90 demonstrations on newly improved onion varieties and improved production technologies were carried out during *kharif* 2018 and 2019.

For the first time, *kharif* onion production was initiated at commercial level in Chunar taluka of Mirzapur. Farmers have earned a net income of Rs. 0.70-0.80 lakh per acre through production of onion bulbs about 80-100 q from Bhima Super variety during *kharif* 2018-19 whereas during *kharif* 2019, farmers got a net income of Rs. 2.0-2.5 lakh per acre by producing about 70-80 q onion bulbs of varieties *viz.*, Bhima Super and Bhima Dark Red.

Most of the farmers from selected villages are now ready to cultivate onion crop on commercial scale as they have seen the profit gained by farmers through demonstration areas. They are also ready to replace their traditional crop groundnut for *kharif* onion. Previously, these farmers were producing groundnut yield of 8-9 q/acre and selling it at Rs. 32-35 per kg. In this way, they were getting maximum profit of Rs. 21000 per acre. As per farmers' opinion, *kharif* onion is 3-4 times more profitable than traditionally grown groundnut. The onion farmers are also enjoying unexpected income through *kharif* onion cultivation due to hike of onion price in the market as well as drastic decrease in onion production due to erratic rainfall causing water stagnation in the fields during current *kharif* season. The farmers sold their onion at Rs. 40-60 per kg and got the income up to 4.80 lakh per acre.

Mr. Virendra Kumar from Jalalpur Mafi, Chunar, Mirzapur (UP) raised onion bulb crop as per ICAR-DOGR recommended technology and produced 87 q per acre marketable bulb yield. He earned net income of Rs. 4.80 lakh per acre as his onion bulbs were sold at the rate of Rs. 57 per kg in the market whereas one lady farmer Mrs. Geeta Devi from Bagahi, Chunar, Mirzapur (UP) produced 59 q per acre onion bulbs by following ICAR-DOGR recommendations and earned Rs. 3.27 lakh net income. Her onion bulbs were sold at the rate of Rs. 58 per kg during *kharif* 2019.

Table 5: Performance of onion production by selected farmers during *kharif* 2019

Name of farmer	Onion varieties	Yield/ Acre (q)	Rate of sold onion bulbs (Rs. /kg)	Benefit gain (Rs. /Acre)
Mr. Santosh Kumar Singh Village- Jalalpur Mafi, Chunar, Mirzapur (UP)	Bhima Dark Red	48.57	56.7	2,55,238/-
Mr. Manoj Kumar Singh Village- Jalalpur Mafi, Chunar, Mirzapur (UP)	Bhima Dark Red	50.79	44.0	2,03,587/-
Mr. Virendra Kumar Village- Jalalpur Mafi, Chunar, Mirzapur (UP)	Bhima Dark Red	87.30	57.3	4,80,325/-
Mr. Dilip Kumar Singh Village- Jalalpur Mafi, Chunar, Mirzapur (UP)	Bhima Dark Red	93.6	36.0	3,07,270/-
Mrs. Geeta Devi Village- Bagahi, Chunar, Mirzapur (UP)	Bhima Super	59.37	58.5	3,27,111/-

Demonstrations on onion production have been conducted successfully by ICAR-DOGR in 300 acres in selected areas of Mirzapur which can be extended in Rajgadh and Shikhar block of Mirzapur as well as adjoining districts of Sonbhadra, Varanasi and Chandauli. The production and productivity of onion in Mirzapur has been increased by 93% and 32%, respectively after intervention of ICAR-DOGR in collaboration with Agrimitra FPO and GKRDF. The area under onion cultivation in Mirzapur district increased from 352 ha (2016-17) to 515 ha (2018-19) whereas production of onion increased from 4887 t (2016-17) to 9414 t (2018-19). Productivity of onion has been increased from 13.8 t/ha (2016-17) to 18.3 t/ha (2018-19*) (Source: Dept. of Agri., Govt. of UP).* The most of the area expansion was in *kharif* season due to high profitability.

The demonstrations led to conclusion that the eastern part of Uttar Pradesh is suitable for *kharif* onion production. It requires to extend onion production technology in these pockets of the country to solve the issue of onion price fluctuation during the months of October to November.

Onion awareness camp on 12 December, 2017

Training on *kharif* onion production technology on 2 June, 2018

Training on *kharif* onion production on 10th March, 2019

Training on improved cultivation of onion on 23rd November, 2019

Popularization of improved onion cultivation NEH region

The North-Eastern region is characterized by hills and mountains with folded topography, plateaus and hills with near tropical and alpine climatic conditions.

Fig. 5: Performance of *kharif* onion crop at farmers' fields in the year 2019

Only 18.91 per cent of total cropped area comes under horticultural crops in North–Eastern region. The people of NEH region have to depend on other parts of the country for onion as onion cultivation is not popular in this region. Keeping these in view, the various activities were carried out by ICAR-DOGR from the year 2018 for the benefit of the tribal people for the promotion of onion cultivation in NEH region.

The six states *viz.*, Arunachal Pradesh, Nagaland, Manipur Meghalaya,Tripura and Sikkim were selected for popularization of onion cultivation in NEH region. The districts *viz.*, East Siang from Arunachal Pradesh; Dimapur and Mokokchung from Nagaland; Ukhrul, Chandel, Churachandpur and Tamenglong from Manipur and Ri-Bhoi from Meghalaya were selected for promotion of onion cultivation.

Demonstrations and Trainings:

- In total, 1370 field demonstrations were conducted in 310 ha area from which 1550 farmers directly benefitted in six NEH states *viz.*, Meghalaya, Nagaland, Manipur, Arunachal Pradesh, Tripura and Sikkim. The onion seed of Bhima Super and Bhima Dark Red in *kharif* season and Bhima Shakti and Bhima Kiran in *rabi* season were provided by ICAR-DOGR to these farmers. Demonstration kits consisting organic inputs were also distributed among these farmers.
- Total 80 trainings and 32 field day programmes were conducted in these states to provide knowhow about *kharif* and *rabi* onion cultivation technology developed by ICAR-DOGR in which total 3921 farmers were participated.

Fig. 6. Trainings and demonstrations conducted in NEH region

Performance of frontline demonstration trials in Arunachal Pradesh

- Demonstrations conducted in North Eastern Hill Region also revealed that Bhima Super and Bhima Dark Red varieties of ICAR-DOGR were superior over the local varieties of that region.
- Arunachal Pradesh in *kharif* revealed that the germination percentage (98), average bulb weight (85g) and yield (282.5 q/ha) of Bhima Super was the highest. Bhima Dark Red (257.5 q/ha) also yielded more than local variety (165 q/ha). The germination percentage (94), average bulb weight (80 g) and marketable yield (285 q/ha) of Bhima Kiran were the highest in *rabi* demonstrations.
- Green onion yield of Bhima Dark Red was 428.33 q/ha followed by Bhima Super (398.75 q/ha) in *kharif* while green onion yield of Bhima Kiran was (352 q/ha) in *rabi* season.

Table 6: Performance of frontline demonstration trials in Arunachal Pradesh

Season	**Variety**	**Germination Percentage**	**Average weight of one fresh bulb (g)**	**Marketable bulb yield (q/ha)**
Kharif	**Bhima Super**	**98**	**85.00**	**282.50**
	Bhima Dark Red	92	80.00	257.50
	Local	75	60.00	165.00
Green onion	Bhima Super	-	-	398.75
	Bhima Dark Red	-	-	**428.33**
	Local	-	-	250.25
Rabi	**Bhima Kiran**	**94**	**80.00**	**285.00**
	Local	75	75.00	260.00
Green onion	**Bhima Kiran**	-	-	**352.00**
	Local	-	-	225.00

Fig. 8. Hema Takit of village Runne, District East Siang (Arunachal Pradesh) received bumper yield of onion

Table 7: Performance of frontline demonstration trials in Meghalaya

Season	**Variety**	**Germination Percentage**	**Average weight of one fresh bulb (g)**	**Marketable bulb yield (q/ha)**
Kharif	**Bhima Super**	**95**	**80.00**	**220**
	Bhima Dark Red	90	75.00	215
	Local	74	62.00	160
Green onion	Bhima Super	-	-	350
	Bhima Dark Red	-	-	**400**
	Local	-	-	245

Fig. 9. Green onion sale (Arunachal Pradesh)

Table 8: Performance of frontline demonstration trials in Nagaland

Season	Variety	Germination Percentage	Average weight of one fresh bulb (g)	Marketable bulb yield (q/ha)
Kharif	**Bhima Super**	**94**	**80.00**	**225**
	Bhima Dark Red	92	75.00	220
	Local	70	58.00	180
Green onion	Bhima Super	-	-	390
	Bhima Dark Red	-	-	**420**
	Local	-	-	250
Rabi	**Bhima Kiran**	**95**	**82.00**	**275**
	Local	75	75.00	240
Green onion	**Bhima Kiran**	-	-	**350**
	Local	-	-	220

Demonstrations conducted in Meghalaya in *kharif* revealed that the germination percentage (95), average bulb weight (80g) and yield (220 q/ha) of Bhima Super was the highest. Bhima Dark Red (215q/ha) also yielded more than local variety (160 q/ha). Regarding green onion, Bhima Dark Red (400 q/ha) was yielded the highest.

Demonstrations conducted in Nagaland in *kharif* revealed that the germination percentage (94), average bulb weight (80g) and yield (225 q/ha) of Bhima Super was the highest. Bhima Dark Red (220 q/ha) also yielded more than local variety (180 q/ha). Regarding green onion in *kharif* season, Bhima Dark Red (420 q/ha) was the highest yielding variety. Demonstrations conducted in *rabi* season revealed that the germination percentage (95) and yield of Bhima Kiran (275 q/ha) was the highest in *rabi* demonstrations. Regarding green onion, Bhima Kiran (350 q/ha) was the highest yielded variety. Demonstrations conducted in Manipur in *kharif* revealed that the germination percentage (92), average bulb weight (80g) and yield (224 q/ha) of Bhima Super was the highest. Bhima Dark Red (218 q/ha) also yielded more than local variety (180 q/ha). Regarding green onion, Bhima Dark Red (360 q/ha) yielded the highest. The germination percentage (94), average bulb weight (82g) and yield (275 q/ha) of Bhima Kiran was the highest followed by Bhima Shakti (90), average bulb weight (80g) and yield (268 q/ha) in *rabi* demonstrations. Regarding green onion, Bhima Shakti (395 q/ha) yielded the highest. It was followed by Bhima Kiran (380 q/ha) yielded more than local variety (255 q/ha).

Fig. 10.Green onion in Nagaland

Table 9: Performance of frontline demonstration trials in Manipur

Season	**Variety**	**Germination Percentage**	**Average weight of one fresh bulb (g)**	**Marketable bulb yield (q/ha)**
Kharif	**Bhima Super**	**92**	**80.00**	**224**
	Bhima Dark Red	90	75.00	218
	Local	75	62.00	180
Green onion	Bhima Super	-	-	340
	Bhima Dark Red	-	-	**360**
	Local	-	-	240
Rabi	**Bhima Kiran**	**94**	**82.00**	**275**
	Bhima Shakti	90	80.00	268
	Local	78	74.00	225
Green onion	Bhima Kiran	-	-	380
	Bhima Shakti	-	-	**395**
	Local	-	-	255

The varieties developed by ICAR-DOGR were found superior over the local cultivars in all the demonstrations.

Impact of activities carried out in NEH region

- The farmers of NEH region received 20-22 t/ha yield of ICAR-DOGR onion varieties. *Rabi* onion bulbs can be successfully grown in NEH states like Arunachal Pradesh, Manipur, Meghalaya, Nagaland, Tripura and Sikkim.

- The onion crop from sets matured about one month earlier than the other onion crops and yield received from sets of Bhima Dark Red was 225 q/ha in *kharif* season.

- The yield of green onion of Bhima Shakti and Bhima Kiran was recorded 35-40 t/ha in these states. As the rate of green onion in market is Rs. 20-30 per kg, it was recommended to harvest green onion for sale. The farmers get Rs. 10-12 lakh from green onion. Therefore, green onions can be successfully grown in NEH states.

Lessons Learnt –

- There is good scope for cultivation of kharif and rabi onion in NEH region. The demonstration led to conclusion than NEH region is suitable for kharif and rabi onion production.
- To extend the area under onion production technology in the states like Meghalaya, Arunachal Pradesh, Nagaland, Tripura, and Sikkim requires continuous efforts
- The support of local extension functionaries required to popularize improved onion production technologies.