भाकृअनुप
ICAR

Vision 2050

प्या ल अनु नि
DOGR

Directorate of Onion and Garlic Research

Rajgurunagar, Pune – 410 505, Maharashtra, India

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MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

MESSAGE

The scientific and technological inputs have been major drivers of growth and development in agriculture and allied sectors that have enabled us to achieve self reliant food security with a reasonable degree of resilience even in times of natural calamities, in recent years. In the present times, agricultural development is faced with several challenges relating to state of natural resources, climate change, fragmentation and diversion of agricultural land to non-agricultural uses, factor productivity, global trade and IPR regime. Some of these developments are taking place at much faster pace than ever before. In order to address these changes impacting agriculture and to remain globally competent, it is essential that our R&D institutions are able to foresee the challenges and formulate prioritised research programmes so that our agriculture is not constrained for want of technological interventions.

It is a pleasure to see that Directorate of Onion & Garlic Research (DOGR), Pune, a constituent institution of the Indian Council of Agricultural Research (ICAR) has prepared Vision-2050 document. The document embodies a pragmatic assessment of the agricultural production and food demand scenario by the year 2050. Taking due cognizance of the rapidly evolving national and international agriculture, the institute, has drawn up its Strategic Framework, clearly identifying Goals and Approach.

I wish DOGR all success in realisation of the Vision-2050.

(SHARAD PAWAR)

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FOREWORD

The Indian Council of Agricultural Research, since inception in the year 1929, is spearheading science and technology led development in agriculture in the country. This is being accomplished through agricultural research, higher education and frontline extension undertaken by a network of research institutes, agricultural universities and Krishi Vigyan Kendras. Besides developing and disseminating new technologies, ICAR has also been developing competent human resources to address the present and future requirements of agriculture in the country. Committed and dedicated efforts of ICAR have led to appreciable enhancement in productivity and production of different crops and commodities, which has enabled the country to raise food production at a faster rate than the growth in demand. This has enabled the country to become self-sufficient in food and emerge as a net food exporter. However, agriculture is now facing several challenges that are expected to become even more diverse and stiffer. Natural resources (both physical and biological) are deteriorating and getting depleted; risks associated with climate change are rising, new forms of biotic and abiotic stress are emerging, production is becoming more energy intensive, and biosafety concerns are growing. Intellectual property rights and trade regulations impacting technology acquisition and transfer, declining preference for farm work, shrinking farm size and changes in dietary preferences are formidable challenges.

These challenges call for a paradigm shift in our research approach to harness the potential of modern science, innovations in technology generation and delivery, and enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy efficiency, agri-incubators and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive.

It is an opportune time that the formulation of Vision-2050' by ICAR institutions coincides with the launch of the national 12th Five Year Plan. In this Plan period, the ICAR has proposed to take several new initiatives in research, education and frontline extension. These include creation of consortia research platforms in key areas, wherein besides the ICAR institutions, other science and development organizations would be participating; short term and focused research project through scheme of extramural grants; Agri-Innovation fund; Agri-incubation fund and Agri-tech Foresight Centres (ATFC) for research and technology generation. The innovative programme of the Council, 'Farmer FIRST' (Farmer's farm, Innovations, Resources, Science and Technology) will focus on enriching knowledge and integrating technologies in the farmer's conditions through enhanced farmer-scientist interface. The 'Student READY' (Rural Entrepreneurship and Awareness Development Yojana) and 'ARYA' (Attracting and Retaining Youth in Agriculture) are aimed to make agricultural education comprehensive for enhanced entrepreneurial skills of the agricultural graduates.

I am happy to note that the Vision-2050 document of **Directorate of Onion & Garlic Research, Pune** has been prepared, based on the assessment of present situation, trends in various factors and changes in operating environment around agriculture to visualize the agricultural scenario about 40 years hence and chalk out a demand-driven research agenda for science-led development of agriculture for food, nutrition, livelihood and environmental security, with a human touch.

I am sure that the **'Vision-2050'** would be valuable in guiding our efforts in agricultural R&D to provide food and nutritional security to the billion plus population of the country for all times to come.

Dated the 27th June, 2013
New Delhi

(S. Ayyappan)

PREFACE

Agriculture, which provides a livelihood to an estimated 2.5 bn people, is lagging behind population growth. Come 2050, the UN predicts earth will be home to another 2 bn people. The population of India is likely to cross 1.7 bn in 2050. In order to feed us all, production needs to increase by an estimated 70%. That is a big task, not least since the land that humans have so long been tilling for agriculture is being diverted to other uses including industries, roads, buildings, and other infrastructures. So any increase in production has to come from an increase in productivity per unit area per unit time. We at the Directorate of Onion and Garlic Research (DOGR) are equally concerned about this.

Research and development activities in the past have helped in the growth of both onion and garlic. DOGR was established as National Research Centre for Onion and Garlic in 1994. Statistics indicate that production of onion has increased from 40.4 lakh tons in 1994-95 to 175.11 lakh tons in 2011-12. Similarly in case of garlic, the production increased from 4.03 lakh tons in 1994-95 to 12.26 lakh tons in 2011-12 due to collective efforts of National Agricultural Research System (NARS) of which DOGR is an integral part. This increase, however, has come mainly from increase in area under onion and garlic which in 2011-12 stood at 10.87 and 2.45 lakh hectares, respectively. Although second in onion production after China at world level, we are far behind in productivity compared to many countries. The average productivity of onion in India now stands at only 16.11 t/ha and that of garlic is only 5.00 t/ha, which are lower than world average of 19.79 t/ha and 16.71 t/ha, respectively. The highest productivity of onion has been reported to be 66.16 t/ha in Republic of Korea and in case of garlic it was 24.36 t/ha in Egypt. India once exporting garlic is now importing it for meeting the domestic requirement. There is a need to analyze the factors responsible for lower productivity of these crops in India and come out with a workable plan to improve productivity for meeting the domestic requirements as well as increase export of these important crops, which India has been exporting traditionally. Vision 2050 is an attempt in this direction. It is based on the broad framework outlined in vision 2030, previously brought out by DOGR in June 2011.

It is appropriate that ICAR is bringing out vision documents for all crop based institutes to coincide with the XIIth plan proposals which are also in the final stages of formulation. We at DOGR thank Dr. S. Ayyappan, Secretary, DARE and DG, ICAR, New Delhi for his timely interventions and valuable inputs and guidance in bringing out this document. I am also thankful to Dr. N.K. Krishna Kumar, DDG (Hort.) and Dr. S.K. Malhotra ADG (Hort.) for their critical suggestions for improvement of the Vision 2050. I also acknowledge with thanks the help and the input provided by my colleagues Drs. V. Mahajan, S.J. Gawande, V. Sankar and A. Khar in compiling the relevant information for this document. Secretarial help provided by Mr. DB Mundharikar and Mr. HSC Shaikh is also acknowledged. We look forward to suggestions and active participation from all quarters in the relevant activities of DOGR so that maximum possible could be achieved.

(Jai Gopal)
Director
Directorate of Onion & Garlic Research
Rajgurunagar, Pune – 410 505

Dated the 17th November, 2013

1. Context

Onion and garlic are important vegetable crops and are the integral components of culinary preparations. Biochemical components, viz., thiosulfinates, thiosulfonates, allicin, aliin, ajoene and many others present in onion and garlic make them exclusive medicinal commodities too. The problems of heart diseases, rheumatism, cancer, digestive disorders, blood sugar and prolonged cough are known to be resolved by regular consumption of onion and garlic. The pesticidal and fungicidal properties of garlic are well studied and widely accepted.

India ranks first by area in onion (10.87 lakh hectares) and second in garlic (2.45 lakh hectares). In production, India ranks second in both, onion (175.11 lakh tons) and garlic (12.26 lakh tons), next to China only. However, the productivity of both, onion (16.11 t/ha) and garlic (5.00 t/ha) are far lower as compared to USA, China, Egypt and many other countries. The national scenario shows that production of onion has increased from 40.40 lakh tons in 1994-95 to 175.11 lakh tons in 2011-12. In case of garlic, the production increased from 4.03 lakh tons in 1994-95 to 12.26 lakh tons in 2011-12.

India is projected to have population of 1.7 billion by 2050, and there is no possibility of increase in cultivable land. To cater the requirement of this ever increasing population, keeping per capita consumption, export, processing and losses at existing rate (consumption i.e. 7.83 kg/person/year, export 9% , processing 6.75% and losses 30%; base year 2011-2012), we will require 24.62 million tons of onion in 2050 against 17.51 million tons in 2011-12. This demands an increase in average productivity from 16.11 to 22.65 t/ha, which is about 41% higher than that of in 2011-12 (Table 1). Efforts can be made to reduce losses up to 20%, increase export up to 25% and processing up to 15% by 2050. With these targets, we have to increase production from 17.51 million tons to 33.39 million tons with productivity of 30.72 t/ha (Table 2).

Table 1. Estimated requirement of onion in 2050 with current rate of export, processing and post-harvest losses based on 2011-12 statistics

	Population (Million)	Domestic consumption (MT)	Post-harvest Losses (MT)	Export requirement (MT)	Processing (MT)	Seed bulbs (MT) **	Total production (MT)	Area (MH)	Actual productivity (t/ha)	Deficit %
Utilization rate		7.83kg/ person /year	@30%	@9%	@6.75%					
2011-12*	1210	9.48	5.25	1.55	1.18	0.04	17.51	1.09	16.11	
Estimate 2050	1700	13.31	7.39	2.21	1.66	0.04	24.62	1.09	22.65	40.59

*Source : Horticulture Division, Ministry of Agriculture, Govt. of India, 2012
(MT=Million tons, MH= Million hectares) ** @ 40 Kg bulb/ha to produce 8 Kg seed for 1 ha

Table 2. Estimated requirement of onion in 2050 with increase in export, processing and reduction in post- harvest losses

	Population (Million)	Domestic consumption (MT)	Post-harvest Losses (MT)	Export requirement (MT)	Processing (MT)	Seed bulbs (MT)	Total production (MT)	Area (MH)	Actual productivity (t/ha)	Deficit %
Utilization rate		7.83kg/ person /year	@20%	@25%	@15%	0.04				
Estimate 2050	1700	13.31	6.68	8.35	5.01	0.04	33.39	1.09	30.72	90.68

(MT=Million tons, MH= Million hectares)

In case of garlic in 2011-12, export and processing was about 2% each with post-harvest losses up to 15%. If we keep the export, processing and losses at same rate, then in 2050 the garlic requirement will increase to 1.66 million tons from 1.23 million tons at present. To achieve this target average productivity per hectare needs to be increased to 6.77 t/ha compared with the existing productivity of 5.00 t/ha (Table 3). Though, we are able to fulfill our requirement at present in garlic but there is lot of scope and need to increase production and productivity which will help to increase export and processing.

Keeping per capita consumption at the current level of 0.718 kg garlic/year, increasing the export target to 10%, processing target to 5% and reducing the losses target to 10%, there is need to increase the production to 1.79 million tons and productivity to 7.31 t/ha (Table 4).

Table 3. Estimated requirement of garlic in 2050 with current rate of export, processing and post-harvest losses based on 2011-12 statistics

	Population (Million)	Domestic consumption (MT)	Post-harvest Losses (MT)	Export requirement (MT)	Processing (MT)	Seed bulbs (MT) **	Total production (MT)	Area (MH)	Actual productivity (t/ha)	Deficit %
Utilization rate		@0.718kg/ person /year	@15%	@2%	@2%					
2011-12*	1210	0.87	0.18	0.025	0.025	0.12	1.23	0.25	5.00	
Estimate 2050	1700	1.22	0.25	0.03	0.03	0.12	1.66	0.25	6.77	35.40

*Source : Horticulture Division, Ministry of Agriculture, Govt. of India, 2012
(MT=Million tons, MH=Million hectares) ** @ 500 Kg/ha

Table 4. Estimated requirement of garlic in 2050 with increase in export, processing and reduction in post-harvest losses

	Population (Million)	Domestic consumption (MT)	Post-harvest Losses (MT)	Export requirement (MT)	Processing (MT)	Seed bulbs (MT)	Total production (MT)	Area (MH)	Actual productivity (t/ha)	Deficit %
Utilization rate		@0.718kg/ person /year	@10%	@10%	@5%					
Estimate 2050	1700	1.22	0.18	0.18	0.09	0.12	1.79	0.25	7.31	46.20

(MT=Million tons, MH= Million hectares)

The above facts show that there is need to intensify research in the frontier areas in order to feed the ever increasing population of the country and keeping in view the emerging problems of onion and garlic cultivation including those due to climate change. This requires the development of a long term vision so that R&D activities are tuned to the future needs of not only increasing the production but also the

quality and health and nutraceutical benefits of these crops. These issues are being addressed and strategies to overcome existing and expected problems are being suggested in this document.

Onion and Garlic : Global Scenario

Onion: Among vegetables, onion is the third most important crop of the world after potato and tomato. Onion is grown in over 140 countries on an area of 43.64 lakh hectares. World onion production in 2011 was 863.44 lakh tons with an average productivity of 19.79 t/ha (Source: FAOSTAT, 2013). China (247.65 lakh tons) and India (159.30 lakh tons) are the major onion producers followed by USA (33.61 lakh tons), Iran (24.97 lakh tons), Egypt (23.04 lakh tons), Turkey (21.41 lakh tons), Russian Federation (21.23 lakh tons), Pakistan (19.40 lakh tons), Netherlands (15.41 lakh tons), Brazil (15.23 lakh tons), Rep. of Korea (15.20 lakh tons) etc. The productivity of onion is maximum in Rep. of Korea (66.16 t/ha) followed by USA (56.26 t/ha), Spain (53.31 t/ha), Netherlands (51.64 t/ha), Egypt (36.16 t/ha), Iran (35.79 t/ha), Turkey (32.73 t/ha), Mexico (29.68 t/ha), Algeria (24.87 t/ha), China (24.39 t/ha), Brazil (24.00 t/ha), Russian Federation (22.23 t/ha), Ukraine (17.64 t/ha), Myanmar (15.88 t/ha), India (14.35 t/ha), Pakistan (13.14 t/ha) and Nigeria (6.45 t/ha). (Fig. 1 - 3)

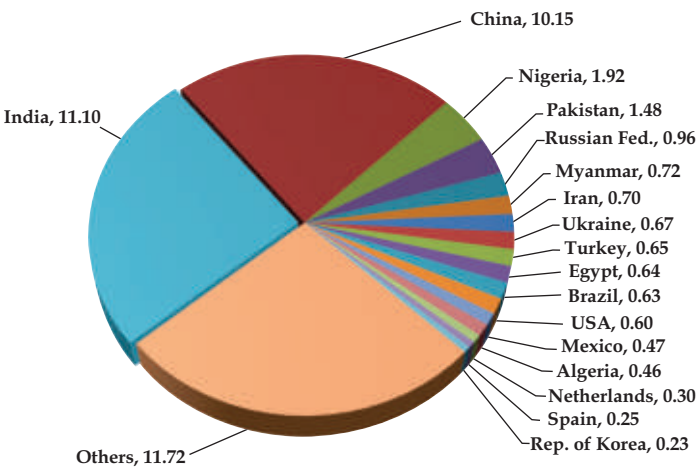

Figure 1:
Area (Lakh Ha) of Major Onion Producing Countries (2011)

Total World Area : 43.64 Lakh Ha

Source: FAOSTAT, 2013

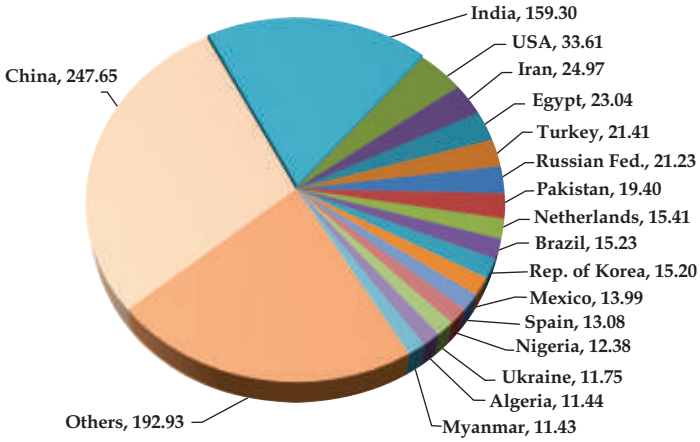

Figure 2: Production (Lakh Tons) of Major Onion Producing Countries (2011)

Total World Production : 863.44 Lakh Tons

Source: FAOSTAT, 2013

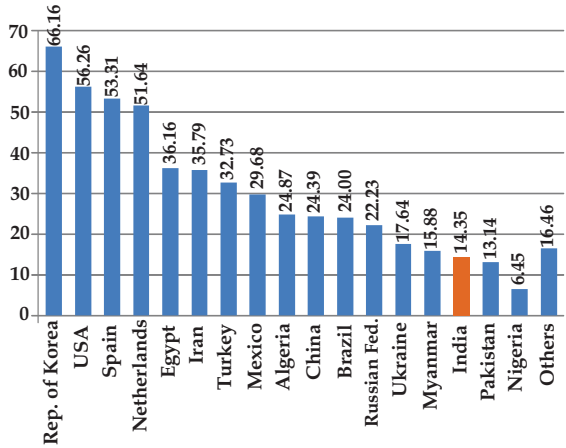

Figure 3: Productivity (Ton/Ha) of Major Onion Producing Countries (2011)

Average Productivity : 19.79 t/ha

Source: FAOSTAT, 2013

India is at 90th place (14.35 t/ha) in onion productivity, although it is the second largest producer of onion in the world. The productivity is high in many European and American countries because they mostly grow long day onions, and have congenial climate for bulb bulking. The sub-tropical countries including India, Pakistan and Bangladesh grow short day onions, which have inherent low yield potential. Non-availability of high yielding hybrid onion varieties, shortage and high cost of quality onion seed, use of old traditional farmers varieties and farmers own onion seed for large-scale production, susceptibility to diseases and pests and their high incidence under tropical conditions, and shortage of irrigation water at critical growth stages reduce productivity in India. Fluctuations in market prices disturb the attitude of farmers towards adoption of input intensive production techniques and good management practices.

Global export trade of onion in 2011 was to the tune of 6.77 million tons worth 2856.31 million dollars. Netherlands is number one exporter with 1.33 million tons worth 522.29 million dollars followed by India with 1.11 million tons worth 370.74 million dollars (Rs. 1964.71 crores @Rs.53/$) and China with 0.75 million tons worth 302.67 million dollars. Malaysia, Russian Federation, USA, Japan, United Kingdom, Saudi Arabia, Germany, Bangladesh, Netherlands, Canada, Sri Lanka, UAE and Colombia are the major importers.

Garlic: Worldwide in 2011, garlic was grown over 14.22 lakh hectares and had a total production of 237.70 lakh tons and an average productivity of 16.71 t/ha (Source: FAOSTAT, 2013). Among 140 countries where garlic is grown, China is world leader in production (80.92%), followed by India (4.45%). Per hectare productivity of garlic is the highest in Egypt (24.36 t/ha) followed by China (23.09 t/ha), U.S.A. (18.73 t/ha), Rep. of Korea (12.27 t/ha), Ethiopia (12.02 t/ha), Brazil (11.08 t/ha), Democratic People's Rep. of Korea (10.69 t/ha), Peru (10.30 t/ha), Argentina (9.83 t/ha), Iran (9.42 t/ha), Spain (8.94 t/ha), Russian Federation (8.73 t/ha), Turkey (8.17 t/ha), Ukraine (8.11 t/ha), Myanmar (7.28 t/ha), India (5.27 t/ha) and Bangladesh (4.98 t/ha). India, although second by area and production, is among the lowest as far as productivity is concerned (Fig. 4–6). The low productivity of garlic in India can be mainly attributed to the non-availability of virus-free planting material, which is of utmost importance in a vegetatively propagated crop like garlic. Further, higher productivity in many countries than in India is due to cultivation of long day type garlic whereas India grows typical short day type garlic, which matures in 130 days in short winter. Further, higher incidence of pests and diseases under tropical conditions also reduce productivity per unit area.

The world trade of garlic through export is 1.98 million tons worth 2834.78 million dollars. China is number one exporter with 84.34% share by quantity (1.67 million tons) and 73.08% by value (2071.74 million dollars). Argentina (0.92 million tons), Spain (0.64 million tons) and Netherlands (0.29 million tons) are the other main exporters of garlic. Major importing countries are Indonesia, Brazil, Vietnam, Malaysia, USA, Thailand, Russian Federation, Pakistan, UAE, Bangladesh, Saudi Arabia, Rep. of Korea and Netherlands. The export

scenario of garlic is frequently fluctuating over the years and many a times in the past India had to import garlic from China.

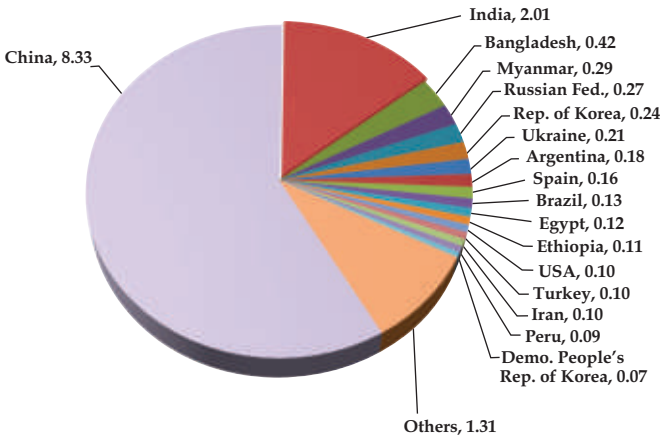

Figure 4:
Area (Lakh Ha) of Major Garlic Producing Countries (2011)

Total World Area : 14.22 Lakh Ha

Source: FAOSTAT, 2013

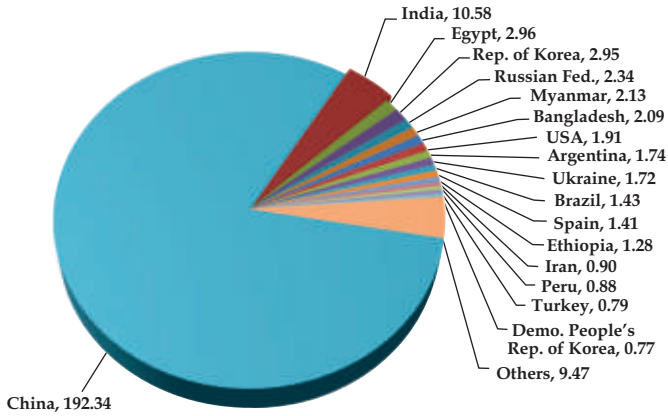

Figure 5:
Production (Lakh Tons) of Major Garlic Producing Countries (2011)

Total World Production : 237.70 Lakh Tons

Source: FAOSTAT, 2013

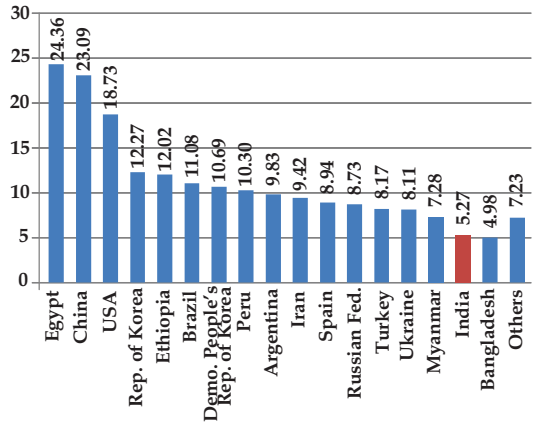

Figure 6:
Productivity (Ton/Ha) of Major Garlic Producing Countries (2011)

Average Productivity : 16.71 t/ha

Source: FAOSTAT, 2013

Onion & Garlic : National Scenario

Onion: In India onion is grown under three crop seasons i.e., *kharif*, late *kharif* and *rabi*. Main crop is in *rabi* (60%) and 20% each is in *kharif* and late *kharif*. During 2011-12, total area under onion was over 10.87 lakh hectares with total production of 175.11 lakh tons (Source: Horticulture Division, Ministry of Agriculture, Govt. of India, 2012). Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Bihar, Andhra Pradesh, Rajasthan, Haryana and Tamil Nadu are the main onion growing states (Fig. 7-8). In general, barring North Eastern states, Jammu & Kashmir and Kerala, all other states grow onion. Country's 40% area and 33% production alone come from Maharashtra. Besides fulfilling the constant demand of domestic population, India exports 13 to 18 lakh tons of onion annually worth around Rs. 2200 crores of foreign exchange revenue. About 90% export of onion is from Maharashtra. There is critical shortage in arrivals of onion in the market during October to January. From May to November stored onions are used for domestic as well as export market. November to December *kharif* onion is available in the market, whereas from January to March late *kharif* crop from Maharashtra is available. The productivity in late *kharif* and *rabi* is around 25 tons per hectare, whereas in *kharif* season it is 8-10 tons per hectare. Cloudy weather and constant drizzling during *kharif* season favour diseases like anthracnose and bulb rotting leading to low productivity. In *rabi* season high incidence of thrips aggravates the problem of purple blotch and *Stemphylium* blight, which again pulls down the productivity.

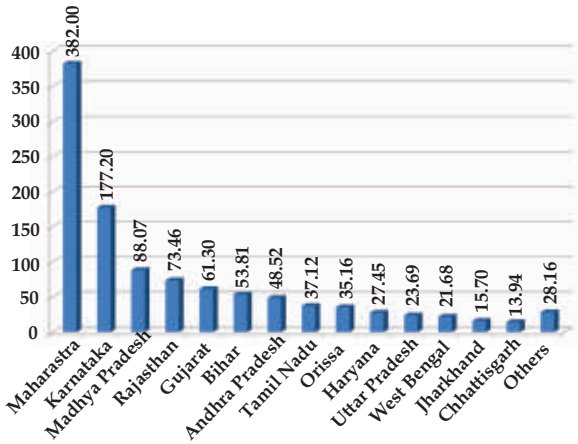

Figure 7: Statewise area ('000 ha) of onion in India (2011-12)

Total Area : 10.87 Lakh Ha

(Source: Horticulture Division, Ministry of Agriculture, Govt. of India, 2012

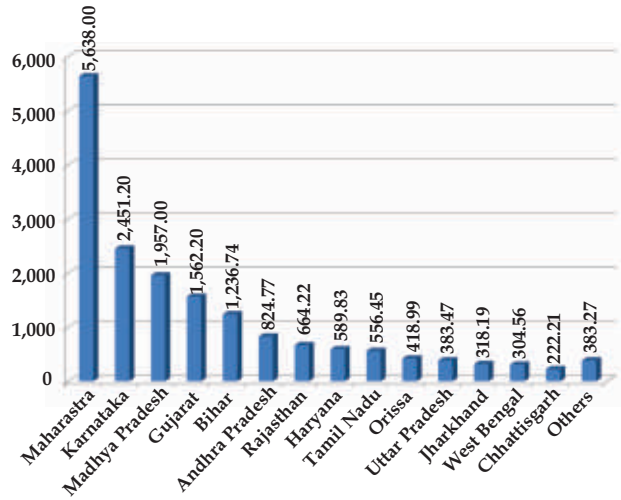

Figure 8: Statewise production ('000 tons) of onion in India (2011-12)

Total Production : 175.11 Lakh Tons

(Source: Horticulture Division, Ministry of Agriculture, Govt. of India, 2012

Garlic: During 2011-12, garlic was grown on 2.45 lakh hectares with a total production of 12.26 lakh tons (Source: NHRDF, Nashik, 2012). Madhya Pradesh, Gujarat, Rajasthan, Uttar Pradesh, Assam, Punjab, Maharashtra, West Bengal and Orissa are the main garlic growing states (Fig. 9-10). Gujarat and Madhya Pradesh produce 40% of country's garlic. Karnataka, Bihar, Tamil Nadu, Punjab, Haryana and Andhra Pradesh also produce sizeable quantity of garlic in cooler regions of the states. Garlic in plains is grown from October to March. The genotypes mostly grown in plains are tropical type, which have very low productivity. Himachal Pradesh, Uttaranchal and Jammu and Kashmir grow long day type garlic from September to June. Per unit yield of this type is high but due to limited area, total production is less.

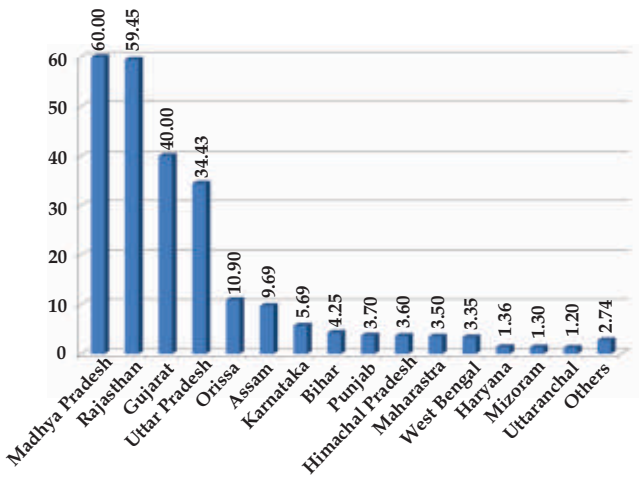

Figure 9: Statewise area ('000 ha) of garlic in India (2011-12)

Total Area : 2.45 Lakh Ha

Source: NHRDF, Nashik, 2012

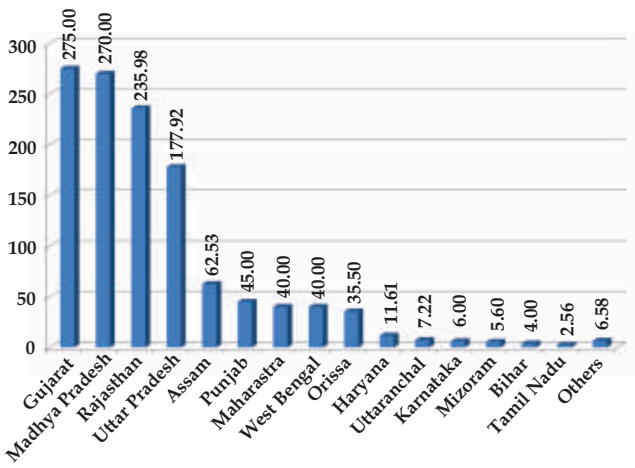

Figure 10: Statewise area ('000 ha) of garlic in India (2011-12)

Total Production : 12.26 Lakh Tons

Source: NHRDF, Nashik, 2012

History of R&D on onion and garlic

Systematic breeding programme in onion was started as early as 1960 at Pimpalgaon Baswant, Nashik and later on at Indian Agricultural Research Institute (IARI), New Delhi and Indian Institute of Horticultural Research (IIHR), Bangalore. National Horticultural Research and Development Foundation (NHRDF), Nashik was established by National Agricultural Co-operative Marketing Federation of India Ltd. (NAFED) and its Associate Shippers of onion on 3rd November, 1977 under the Society Registration Act, 1860 at New Delhi for carrying out research and development activities on export oriented horticultural crops; to begin with onion and garlic. NHRDF developed promising varieties and technology. Development of multiplier onion varieties was concentrated by Tamil Nadu Agricultural University (TNAU), Coimbatore. Prior to this, research on collection and maintenance of landraces and standardization of agro-techniques was attempted by State Agricultural Departments. With the concept of coordinated projects and Agricultural Universities, in early nineties the work on onion and garlic research was strengthened in terms of varietal development for different seasons and standardization of production techniques. As a result more than 45 varieties of onion including 2 F_1 hybrids and 6 varieties of multiplier onion have been developed and released. Onion is mainly *rabi* season crop, but it can be cultivated in *kharif* and late *kharif* seasons also.

Development of some *kharif* growing varieties was earlier done by Mahatam Phule Krishi Vidyapeeth (MPKV), Rahuri, NHRDF, Nashik and IIHR, Bangalore and later by DOGR, Rajgurunagar.

Garlic being an asexually propagated crop, method of improvement through cross-pollination is not viable. Most of the varieties developed are through introductions and clonal selection in India. NHRDF, Nashik has been at the forefront of garlic research (with maximum number of varieties developed under their research programmes), followed by agricultural universities, viz., Gujarat Agricultural University (GAU), Punjab Agricultural University (PAU), MPKV, Rahuri, etc. Most of the varieties developed in these institutes are short day type and can be grown under tropical and sub-tropical climates. Temperate varieties of significance have been developed by NHRDF, Nashik; Vivekanand Parvitya Krishi Anusandhan Sansthan (VPKAS), Almora; Shere Kashmir University of Agricultural Science and Technology (SKUAST), Srinagar and Yaswant Singh Parmar University of Horticulture and Forestry (YSPUHF), Solan. Besides these, varieties selected by farmers over the years are also available in the market. At present, there are about 25 varieties of garlic.

Despite the release of a number of varieties in onion and garlic, the productivity remained low. Limited spread of quality seed of released varieties, their susceptibility to diseases and pests, poor marketable share and poor storage life are some of the important bottlenecks for low productivity. Maintenance breeding, resistance breeding against biotic and abiotic stresses, breeding for quality characters for processing and value addition, and breeding for export worthy stock remained only debatable issues till the establishment of NRC for Onion and Garlic. Keeping these in view, DOGR planned its strategic research programmes through series of IRC and RAC meetings and brainstorming sessions in the various areas of onion and garlic research from production to post-harvest management.

2. Challenges

Onion and garlic are among the challenging crops from research point of view due to the following reasons.

a) Maintenance of onion germplasm is difficult due to highly cross-pollination nature.
b) *Rabi* onion is a biannual crop which takes two years to complete one cycle.
c) Development of inbreed lines is difficult due to high inbreeding depression.
d) Crossability with wild sources is difficult.
e) Bulbs are required to be stored where there are chances of losses due to rotting or sprouting.
f) Viability of seed is hardly up to 15 to 18 months under ambient conditions.
g) Commercial seed production of onion requires isolation distance of about 1.5 km to maintain purity
h) Crop is very sensitive to photoperiod and temperature
i) Problem of flowering in garlic is a big hindrance in improvement

Keeping the above inherent problems of these crops in view, and the changing ecological, environmental, and socio-economic scenario and requirements of various stakeholders, the following general and specific challenges have been identified by DOGR for short-, medium- and long-term research solutions.

A. General

1. *Climate change:* Erratic rainfall pattern, fluctuation in temperature and deteriorated ecosystem affect onion and garlic production. Both crops are sensitive to temperature and photoperiod. There is

need to develop varieties which can sustain adverse or changing climatic conditions. Technologies or cultural practices which can mitigate these problems need to be developed. This challenge needs long-term attention of all concerned.

2. ***Biodiversity:*** Reduction of biodiversity is another big challenge. Limited high yielding varieties being popularized by public and private sector though will increase production and productivity; there is big threat of reduction in biodiversity and increased epidemics of pests and diseases. There is thus need to broaden the genetic base of the varieties being recommended. This is being partly taken care of by DOGR by collecting and conserving the existing variability of onion and garlic, and utilizing it in breeding programmes. DOGR is also concentrating on evaluating both onion and garlic germplasm for various biotic and abiotic stresses including adaptability. Need is to do this work more systematically. Wild *Allium* species are also being collected, characterized and pre-bred for using in the breeding programmes. Development of genetically broad based varieties can be considered as medium-term problem.

3. ***Marketing:*** Sharp fluctuations in prices of onion and garlic in market disturb the attitude of farmers towards adoption of improved production techniques and good management practices, which add to the cost of production, besides it results in fluctuation in production and export. There is a need of firm production and export policy to sustain in a competitive word trade. Synergy between R&D, State Government Department, Agricultural Universities, NGOs, private sector, farmer cooperative groups and other agencies will help in fast dissemination of the technology developed. The challenge needs immediate attention of all concerned.

4. ***Storage:*** Onion and garlic are perishable crops and can be stored for a few months. *Kharif* onion produce can not be stored even for a month and needs to be utilized immediately after harvest. Storage losses in onion can be as high as 30-40% under ambient storage

conditions. These range between 15-20% in garlic. DOGR has recommended bottom and side ventilated storage structures for onion and garlic. Cold-storage technology is now picking up particularly with private sector. These cold storages are ventilated types with controlled atmosphere wherein gases particularly carbon dioxide, which is the product of bulb respiration, needs to be monitored and controlled regularly. This technology is expensive and not in the reach of small and marginal farmers. It needs to be made economical and perfected so that it is available on large scale for routine use by the farmers. This aspect needs an urgent attention, and solution in short-term needs to be developed for storage and transport of these perishable commodities.

5. ***Seed:*** Inferior local genotypes are still predominant in onion cultivation. This is mainly due to poor seed multiplication programme of the released varieties in the country due to requirement of large isolation distance. Further, seed produced by the universities as well as research organization like NHRDF and DOGR is not being channelized to the farmers through an established system of seed distribution. The seed from the research organization should be procured by the state and national seed certification agencies for multiplication and distribution to the famers at reasonable rates. A complete system of seed production, multiplication and distribution as existing in other major crops, is still absent in onion and garlic. Such a system needs to be started at the earliest possible for onion and garlic also. There is also a need to popularize seed village concept particularly for quality seed production in onion.

B. Specific

1. ***Garlic planting material:*** Degeneration of garlic seed stock is a big problem as garlic is vegetatively propagated and host to a number of viruses which cause significant reduction in yield. All seed stocks presently being used for garlic production are infected with viruses. There is an urgent need to develop virus-free seed production protocols. Meristem-tip culture needs to be standardized for its

routine use in production of virus-free plants. Rapid multiplication of virus-free plants through micro-propagation needs to be developed and commercialized on large scale. Such a hi-tech seed production technology as available in some other vegetatively propagated crops like potato needs to be developed on priority for garlic.

2. ***Hybrids of onion:*** Development of hybrid onion varieties for production of uniform high yielding bulb crop of onion is urgently needed. At present only open-pollinated varieties are in cultivation. Some hybrid varieties are being promoted by some private seed companies, but those are not much in demand due to their little advantage over the commercial open-pollinated varieties and high seed cost. Non-availability of inbred lines due to inbreeding depression hampers hybrid production. Development of male sterile inbred lines with appropriate maintainer is a long term programme, but some progress in this direction has already been made at DOGR. The hybrids of onion need to developed on priority and this can be achieved in a medium-term.

3. ***Somaclones and flowering in garlic:*** Development of improved varieties of garlic by conventional methods has not progressed much as garlic rarely flowers and is sterile. So the present varieties are only clonal selections from the existing natural variability. These selections thus have very narrow genetic base and not much headway can be made with this variability in improving yield and disease and pest resistance in garlic. There is need to explore innovative approaches for creating genetic variability in garlic so that selection for improved types can be made effective. Induction of somaclones can be one of the possible approaches for creating genetic variability in garlic. This needs to be explored urgently and results can be achieved in a medium term. Forcing garlic to flower and production of true seed is a long-term challenge, which will help in creating variability for fast improvement.

4. ***Disease and pest resistance:*** Breeding for disease and pest resistance is an area which needs an urgent attention. All onion and garlic

varieties presently in cultivation in India are susceptible to various diseases and pests. Sources of durable resistance to various diseases and pests are not well known. There is need to screen all available germplasm including the wild *Allium* species for various diseases and pests, systematically. Resistant or the tolerant types so identified need to be adopted and used in breeding for developing disease and pest resistant varieties of onion and garlic. Molecular breeding involving marker-assisted selection can also be made use of for accelerating the development of disease and pest resistant varieties. In the first phase emphasis can be given to more important diseases like purple bloch, anthracanose and *Stemphillium* blight, and pest like thrips, which besides causing direct damage to the standing onion and garlic crops, are also the vectors of a number of viruses. DOGR has already started working on this aspect, but keeping in view the nature of the problem it can be solved in a long-term basis only.

5. ***Processing varieties:*** Both onion and garlic have high processing and export potential. There is a need to develop varieties suitable for these purposes. DOGR has achieved good progress in developing high TSS onion lines. Development of export oriented red, white and yellow onion bulb varieties is also required as onion is exported to Gulf and South East Asian countries and has potential of export to European market also. The efforts in this direction, however, need to be continued till suitable varieties for processing and export are released. This target is likely to be achieved in a medium-term.

6. ***IPM/IDM*:** IPM/IDM module for emerging onion and garlic insect pests and pathogens are being developed at DOGR. Though, some recommendations have already been made, this work is of continuous nature as new pathogens and races continue to emerge and resistance breaking down is a common phenomenon. The work is of short-term nature and recommendations will be forth coming regularly.

7. ***Production technology:*** As is evident from the significant

achievements listed above, production technology both for bulb and seed onion crops, as well as for garlic crop has been developed. Production of successful onion crop during *kharif* is still a challenge as productivity in *kharif* is quite low (10-12 t/ha) as the crop is mainly rainfed and is severely attacked by many diseases and pests. *Kharif* production technology thus needs to be further refined. The work though of continuous nature, good progress can be achieved in a medium-term.

8. ***Value addition:*** Development of value added nutritionally rich onion and garlic varieties and products or exploitation of functional food value of these crops are challenges requiring urgent attention. Till now, varieties and technologies being developed by DOGR were aimed at increasing production and productivity. But, keeping in view the medicinal importance of both the crops, varieties rich in certain nutraceuticals and having high pharmaceutical values need to be developed. This perhaps can be achieved only in a long-term as the work will involve a lot of evaluations starting with the germplasm and subsequent use in breeding.

3. Operating Environment

Realizing the importance of these commodities in the country, Indian Council of Agricultural Research established National Research Centre for Onion and Garlic in VIII Plan with its headquarter at Nasik. However, due to technical and working constraints, the Centre could not be established well at Nasik and was shifted to Rajgurunagar in June 1998. It is located at 18.32° N (latitude) and 73.51° E (longitude) at 553.8 m above MSL with a temperature range of 5.5°C - 42.0°C having annual mean rainfall of 669 mm. Considering the achievements of the centre, 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 (AINRPOG) having 13 centers including coordinating unit at DOGR and 16 voluntary centers. Over a decade, the centre 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.

For resolving major constraints in production of onion and garlic in major growing areas, the centre has following mandate:

Mandate

- To act as a repository of genetic resources and scientific information of onion and garlic
- To undertake basic and applied research for enhancing production and productivity of onion and garlic
- To undertake strategic research for technology development and production of quality seed of onion and garlic

- To promote utilisation and development of value added products through processing and post-harvest management practices
- To disseminate technology, provide advisory and consultancy services and promote entrepreneurship
- To develop linkages with national, international and private organizations in network mode for collaborative research programme

Significant achievements of DOGR

Crop Improvement and Biotechnology

DOGR is the National Active Germplasm Site (NAGS) for onion and garlic germplasm. The present collection exceeds 1500 accessions of red, white and yellow onions and 600 accessions of garlic collected from different parts of the country. Under-utilized and wild *Allium* species, viz., *A. ampeloprasum, A. tuberosum, A. chinense, A. ascalonicum, A. hookeri* and *A. cepa* var. *aggregatum* are being multiplied and characterized for utilization in breeding programmes.

Development of onion and garlic varieties: DOGR has developed six red and two white onion varieties (Fig. 11), and these have been identified for release at national level. Two varieties of garlic were recommended at national level under AINRPOG. Bhima Omkar has been recommended for cultivation in AICRP (VC) group meeting 2008-09 at Coimbatore. Bhima Purple was identified at national level for release in AINRPOG group meeting at Ooty (TNAU, Coimbatore) during 2011.

Bhima Raj

Bhima Super

Bhima Shakti

Bhima Red

Bhima Kiran

Bhima Dark Red

Bhima Shubra

Bhima Shweta

Bhima Omkar

Bhima Purple

Figure 11: Onion and Garlic varieties developed by DOGR

Molecular markers (RAPD, ISSR and SSR) have been identified for estimating genetic diversity in onion, garlic and related wild *Alliums*. New SSRs identified by searching through garlic ESTs have been validated for estimation of genetic diversity. Markers Internal Transcribed Spacers (ITS) and External Transcribed spacers (ETS) are being used to check the phylogenic evolution of the indigenous wild species. A preliminary insight into onion haploid development through *in vitro* gynogenesis, somatic embryogenesis (Fig. 12) and production of virus-free garlic through meristem tip culture (Fig. 13) has been achieved.

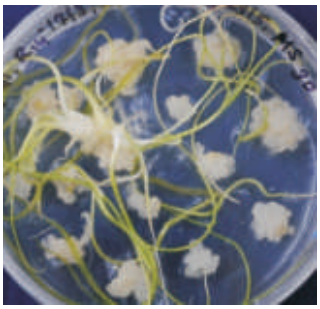

Figure 12: Somatic embryogenesis in garlic

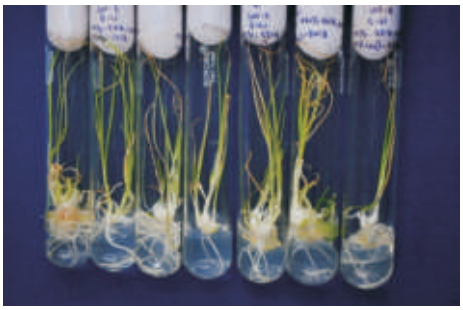

Figure 13: Garlic meristem tip culture

Crop Production and Post-harvest Technology

Legume based cropping sequence was the best for sustainable and cost effective onion production.

Figure 14: Drip irrigation in onion

Micro-irrigation like drip and sprinkler for closely spaced onion and garlic crops have been successfully developed by this Directorate. Among the different irrigation systems evaluated, drip irrigation method (Fig. 14) at 100% PE produced significantly higher marketable bulb yield than other methods of irrigation. There was around 30% water saving in drip irrigation system as compared to surface system.

The highest B:C ratio was found in drip irrigation which was 1.92 followed by surface irrigation (1.35).

Kharif onion production technology has been standardized at DOGR. This includes raising of nursery in summer on broad based furrows (BBF) with drip or sprinkler under shade nets and keeping the seedlings ready for transplanting in the first week of June, transplanting of seedlings on BBF with drip or sprinkler irrigation, application of FYM or vermi compost pre-mixed with *Trichoderma viride* before preparation of beds, and application of pre-emergence weedicides. This technology ensures 25 tons of yields per hectare without hampering the quality of bulbs.

Fertigation in onion and garlic: To maximize the fertilizers use efficiency, the drip fertigation with combined application of organic manures (FYM @ 7.0 t/ha, poultry manure @ 3.5 t/ha and vermicompost @ 3.5 t/ha) along with 80% recommended dose of water soluble fertilizers in onion, and in case of garlic, application of poultry manure @ 10.0 t/ha along with 80% of recommended dose of water soluble fertilizers through drip irrigation recorded the highest marketable bulb yield and minimum post-harvest losses.

Organic cultivation in onion: Among the various organic growth stimulants, *viz.*, Panchgavya, Dasparni, Amruthparni, Vermiwash, Seeweed extract, EM Solution, Humic acid, Bio Potash and microbial extract, applied under organic production system, it was concluded that foliar application of P*anchagavya* (5%) at 30, 45 and 60 days after planting improved the marketable bulb yield in onion (20.2 t/ha) and garlic (5.01 t/ha).

Weed management in onion: Onion is more prone to weed menace in nursery. Application of Pendimethalin 30 EC, a pre-emergence herbicide @ 2 ml/l at the time of seed sowing effectively controlled weed population in onion nursery compared to other herbicide sprays. In onion bulb crop, among the various weedicides, application of Oxyflurofen 23.5% EC @ 1.5 ml/l before planting and one hand weeding at 55 days after transplanting recorded higher marketable bulb yield of 36.1 t/ha coupled with good weed control efficiency (73.6%) and B:C ratio (2.54).

Integrated nutrient management for onion: INM module involving combined application of 75% recommended dose of fertilizer (RDF), FYM (5 tons), poultry manure (2.5 tons) and vermicompost (2.5 tons) per hectare recorded marketable bulb yield, nutrient content and uptake equal to that of 100% RDF (150:50:80:50 kg NPKS ha^{-1}) + 20 t FYM ha^{-1} or 100% RDF alone.

Post harvest handling and storage: Low cost storage model of 5 to 10 tons capacity (Fig. 15) and high cost model of 25 to 50 tons capacity (Fig. 16) with bottom and side ventilation designed and tested by DOGR have become popular among the farmers. Considering minimal storage losses subsidy is being advanced to these models by different state governments.

Figure 15:
Low volume low cost onion storage structure

Figure 16:
High volume bottom and side ventilated onion storage structure

Value addition by grading: Hand operated (Fig.17) as well as motorized (Fig. 18) onion graders have been developed by this centre. These have increased efficiency by 5 and 20 times, respectively over hand grading. The precision of grading achieved by graders is 98% as against 50% in hand grading. Both the graders have become popular with the onion growers as well as traders.

Figure 17:
Hand operated onion grader

Figure 18:
Motorized onion grader

Crop Protection

Population Dynamics of thrips in onion and garlic: Two population peaks, a small one in August and a big one in February are observed in onion crop. Data on thrips incidence at different dates of planting were recorded for 10 years and forecasting model is being developed in collaboration with Indian Agricultural Statistics Research Institute, New Delhi.

IPM module: An IPM module for controlling pest and diseases has been recommended for the onion. Module consists of seed treatment with thiram + carbendazim (2:1) @ 3 g/kg seed or *Trichoderma* @ 4-6 g/kg seed. Multiply 2 kg of *Trichoderma* sp in 1 quintal of FYM and apply in one hectare. Transplant onion crop between 15 September – 15 October to avoid high incidence of thrips and diseases. Dip the seedlings in 0.025% carbosulfan + 0.1% carbendazim solution for 2 hours before transplanting in the main field. Plant 2 rows of maize or outer row of maize and inner row of wheat surrounding onion crop (250 sq.m) at least 30 days prior to transplanting to block adult thrips (Fig. 19). Initiate foliar sprays of pesticides from 30 days after transplanting or as soon as the pest/disease appears in the field. Spray insecticides when thrips population crosses ETL of 30/plant. Spray fungicides, mancozeb

Figure 19: Barrier crop reduces the incidence of thrips

@ 0.25% / chlorthalonil @ 0.25% / iprodione @ 0.2% / propiconazole @ 0.1% to control diseases like purple blotch and *Stemphylium* blight. Spray insecticides, dimethoate @ 0.06% / profenofos @ 0.05% / carbosulfan @ 0.05% / cypermethrin @ 60g ai/ha / methomyl @ 0.05% / spinosad @ 56 g ai/ha to control thrips. Spraying at bulbing stage (45-75 DAS) is very crucial to minimize yield losses. Spray 500-900 l/ha depending on age of the crop. Spray at 10-15 days interval depending on insect pest/disease intensity. Always add spreader @ 0.5-1.0% to spray solution. Avoid repeated application of pesticides belonging to same class.

Development of molecular diagnostics for the detection of Onion and Garlic viruses: Double Antibody Sandwich Enzyme Linked Immunosorbent Assay (DAS-ELISA) based protocol and RT-PCR protocol for the detection of Irish Yellow Spot Virus (IYSV) and Onion Yellow Dwarf Virus (OYDV) have been standardized. Further, highly sensitive and rapid quantitative real-time PCR (qRT-PCR) based protocol by using SyBr Green dye has been standardized for the detection of OYDV. DAS-ELISA based protocol for the detection of Shallot Latent Virus and Garlic Common Latent Virus has also been standardized.

First report of IYSV on garlic: DOGR was the first to report the natural infection of garlic with IYSV in India. The symptomatic leaves of infected plants were tested by DAS-ELISA and RT-PCR and were found positive for the IYSV virus. The recombinant clone was sequenced (GenBank Accession No. HM173691) and comparisons showed 98-100% nucleotide identity with other Indian onion IYSV N gene sequences available in GenBank (EU310294, EU310286).

Figure 20: Symptoms of IYSV on garlic

Disease map of OYDV: A survey was done to determine the presence of OYDV on garlic and related *Allium* spp. from 12 garlic growing states of India based on DAS-ELISA, RT-PCR and qRT-PCR. The highest percentage of OYDV positives were recorded from Maharashtra (96%) followed by Gujarat (75%) and Madhya Pradesh (75%). The least percentage of OYDV positives were recorded from Rajasthan (25%) followed by Delhi (40%). Out of a total 13 wild *Allium*s tested for natural incidence of OYDV, 10 species were found positive for the virus. Three species, viz., *A. senescens, A. cepa* var. *aggregatum* (Multiplier Onion) and *A. fistulosum* were found negative for the OYDV.

Protocol for laboratory screening for Fusarium and pink root: A protocol has been developed to screen genotypes for *Fusarium* and pink root resistance under laboratory conditions.

Disease-free onion seed production: The onion seeds during harvest and post-harvest operations may be infected with storage fungi like *Penicillium, Aspergillus* etc. It is also reported that anthracnose caused by *Colletotrichum gleosporiodes* is also seed borne. The seeds obtained from umbels treated with systemic fungicide (iprodione + bavistin @ 0.2% before harvesting) produced completely disease-free seeds. The germination test revealed that the vigour of seedlings was also more than that of other treatments and control.

A firm determination and focused work has definitely given significant results and DOGR is working to fulfill the projected demands by creating operating environment conducive to work culture. Some of the projected demands of the stake holders including

private sector, consumers and farmers and the operating environment created by these are described below.

I. Processing industries are emerging at a faster rate and would demand more raw materials in future. Onion flakes, granules, powder, rings, onion in brine, garlic flakes, powder, paste and oils are the products prepared out of onion and garlic. The estimated world market for processed onion is to the tune of 2.5 lakh tons which will be increasing by 2050. However, the present processing units in Maharashtra and Gujarat are processing to the tune of one lakh ton only. There is tremendous scope for processing in future. Further, the onion and garlic blended food products, which are otherwise unexploited areas, have enormous commercial potential in domestic and export markets. The processing units are facing problems of year round supply of high TSS white onion (>18%) varieties. Research support by development of high TSS white onion varieties and contract farming for continuous and assured supply will strengthen the processing units. The culled market waste could be used for energy generation. However, the dearth of an appropriate technology demands exclusive R&D to make such project commercially viable.

ii. Onion and garlic are the commodities used for flavouring dishes and adding taste. Besides, low pungent onions are used as salad. The quantum of flavouring and taste components in any commodity largely depends upon the genotypes and input management. Excess use of inorganic fertilizers reduces these components. Further, pesticides make them unfit from health security point of view. So demand for organic products of onion and garlic will increase.

iii. India has very old and strong tradition of export of onion and garlic, and exports 14-18 lakh tons of onion mostly to Gulf and South East Asian countries. Red and light red onion varieties are exported to these destinations. Rose and multiplier onions from A.P., Karnataka and Tamil Nadu have got overseas market. If channelized systematically, the present level of onion export can be increased to

the tune of about 83 lakh tons in 2050. Besides red onion, yellow onion for export to European market has remained grey area for long time. Presently European Union requires 18 to 20 lakh tons onion coming from New Zealand, Tasmania, South Africa, which are far off. India can be in advantageous position since it is half way nearer to Europe. Further, it has been amply proved by DOGR that we can grow good quality yellow onion from October to February. There is critical gap in supply in Europe from February to June where as India has ample production during these months. European market being stringent, lot of market-oriented research would be needed in production, grading, packing and shipment.

iv. Till 1997, India was exporting sizable quantity of garlic to neighboring countries. Due to increased cost of production and lowering market rates, domestic production has remained almost static. Sometimes, we import big cloved temperate garlic from China. Nutritional quality and flavoring component-wise Indian garlic is much better and as a result there is better demand in ethnic markets in Singapore, Indonesia, Bangladesh, Sri Lanka, Philippines and U.K. Constant production, packing and forwarding can create export market to the tune of 1.8 lakh tons in garlic from present export of 0.2 lakh tons.

v. Onion and garlic are perishable commodities. Post-harvest losses in onion are to the tune of 30 to 40% and in garlic 15 to 20%. Storage of onion and garlic is the function of genotypes, season, cultural practices adopted and storage environment. Loss prevention can add to net availability. DOGR has done good work in development of genotypes having better storage life, standardized cultural practices which can minimize storage losses and designed storage structures by which storage losses can be checked by 50%. India needs storage of onion from May to November and garlic from April to March. For domestic supply, export as well as storage of seed bulbs, about 40 lakh tons of onion and 5 lakh tons of garlic need to be stored at present. The survey conducted by DOGR indicated that there are 34% permanent structures, 30% semi-permanent and 36% are temporary structures in onion growing states. Out of these

structures only 22% are bottom and side ventilated structures as per recommendations. There is an urgent need for popularization of storage structures and providing financial assistance to the onion growers in different states. Cold storage of onion and garlic with back up of irradiation for suppression of sprouts would be new area of research. The development of technology package for pre-cooling and establishment of cool chain for overseas trans-shipment is imperative to boost the export. The innovations in the designs of referred containers will also be crucial to reduce the transit losses. Development of these facilities in strategic production areas would help reduction in post-harvest losses remarkably. There is need to develop and standardize technology for storing onion and garlic in controlled atmosphere cold storages, where there is scope to reduce storage losses drastically in both the crops.

vi. Emerging labour problem is becoming a big hindrance for small and medium scale farmers. Electricity shortage is another challenge for successful cultivation. There is demand for development of machines and tool for small and medium level farmers besides the large one to minimize labour use with increase in efficiency. Development of eco-friendly low-cost storage structures for small, medium and large scale is another need to reduce the post-harvest losses which will also help in price regulation in the market. Short duration uniform maturing varieties suitable for mechanical harvesting will be required in near future.

Looking into the above listed issues, DOGR will strive to achieve the estimated production and productivity in both onion and garlic in 2050 as per current rate as well as increased rate of export, processing and post-harvest losses. This requires firm determination and proper planning. We have potential varieties which can give yield up to 40 t/ha in onion and 12 t/ha in garlic. We can also extend cultivation by producing onion during *kharif* as well as in late *kharif* seasons and promote onion and garlic in non-traditional areas. There is a need to focus on production of quality seed in both the crops with varieties resistant to pest and diseases, and having good keeping quality.

To tackle these challenges the major source of funding is from the Indian Council of Agricultural Research under 'Plan' and 'Non-Plan' and in addition from lateral sources like Department of Biotechnology, Ministry of Science and Technology etc.

The Directorate at present has new laboratory-cum-administrative building constructed at Rajgurunagar. Horticulture, biotechnology, plant protection, post-harvest management, physiology, biochemistry laboratories are set-up with contemporary high precision and modern scientific equipments. These laboratories are assisted by PME Cell, ARIS Cell, Farm Management and Library/Information centre. Further, there is need to upgrade laboratories with advanced equipments in future along with trained scientific and technical man-power to achieve the goal. Various prototypes of storage structures are constructed for prevention of post-harvest losses.

The Directorate has All India Network Research Project on Onion & Garlic (AINRPOG) having 13 centers including Co-ordinating unit at DOGR and 16 voluntary centres functioning in different parts of the country. It is proposed to establish field centers at long day locations and also for multiplier type of onion. Keeping in view the charter as well as the importance of both onion and garlic, DOGR should be upgraded to a full-fledged "Institute of Alliums" along with regional centers with the provision of staff as per ICAR norms to prepare ourselves for vision 2050.

As a resource base the Directorate possesses 22 ha area at Rajgurunagar, Pune, 5.5 ha area at NRC for Grapes, Manjri, Pune, 1 acre area at IARI RS, Baner, Pune and 22 ha area at Kalus. Perennial irrigation facilities are available at all the locations. Facilities for field experiments, seed production of different varieties in isolation and maintenance of germplasm are created by land shaping, installation of pipelines for surface as well as micro-irrigation, fencing and watch and ward.

There is need of close coordination between State Govt. Departments, NGOs, extension agencies, universities, public and

private sector research and extension organizations, self help groups, farmers cooperative groups and educated youth to face the challenges. There is need to generate information on research projects going on in the universities, various institutes and private sectors in India for synchronization and harmony in research work. A firm policy is required to be developed with a suitable module for collaboration between public and private sector research and development wing in India and abroad to prepare ourselves for fulfilling the targets in vision 2050. Collaboration is required in India and other countries in various areas as proposed in table 5.

Table 5. Proposed areas of collaboration with institutes abroad

Area of Collaboration	Name of Institutes
Genetics and Genomics	UW, USA; CGN, Netherlands; NRI, UK; IPK, Germany; Japan; New Zealand
Micro-irrigation and Fertigation	Volcani Centre, Israel
Value Chain Management	NRI, U.K.
Virus Diagnostics and Functional Genomics	Washington State University, USA
Insect Molecular Taxonomy	UK
Policy Research	Netherlands; FAO, Italy

4. Opportunities

Research and development always help in growth of commodities. Preliminary R&D has helped in enhancing production and export of onion. However, in productivity there is marginal increase. In case of garlic, there is no spectacular growth. Thus following opportunities exist in filling the existing gaps.

I. Basic research in breeding for resistance, processing qualities and export worthy varieties are lacking. Thrust in these areas can help to improve onion and garlic productivity and export.

ii. Biennial nature of onion, high cross-pollination, sharp inbreeding depression in onion and asexual mode of propagation in garlic are still challenges for breeders with conventional approaches. There is thus an opportunity to use biotechnology particularly molecular approaches and functional genomics to overcome these problems.

iii. Due to poor maintenance of breeders' stock, many varieties are out of production chain or could not even make entry into the chain. Farmers find easy and economical to produce their own seed of onion but due to ignorance of out-crossing they are not able to maintain purity. Due to supply of spurious seed by many seed merchants, the spread of good varieties has been hampered. Thus there exit opportunity to produce and distribute good quality seed of true-to-type varieties and capture the market of onion seed. Seed multiplying agencies working in public sector need to be sensitized in this regard.

Besides the above facts, onion and garlic have following strengths which provide opportunities to intensify research work on these crops.

- Onion and garlic being dual purpose crops used as vegetable and spices are in high demand within the country and outside.

- Onion is a crop of low input and high returns.
- Moderately diverse climate permits onion production almost all over the country barring few coastal pockets.
- Year round production is possible in Western India and Indo-Gangetic plains due to development of diverse genotypes.
- Most of the farmers in India are small and marginal. Onion and garlic cultivation is more suitable to them as these crops have higher cost benefit ratio than cereals.
- Being short duration crops, these crops can fit in any cropping system and juvenile orchards.
- Possibility of onion cultivation in non-traditional areas.
- Onion and garlic have got strong processing traits and attract good agro-based industries. Expansion of processing industries will demand production of more onion and garlic with generation of employment.
- Onion and garlic have got high export potential. Promotion of export of onion and garlic to European countries needs attention.
- Possibility of promotion of export of onion seed.

In our earlier vision documents, viz., VISION 2020, 2025 and 2030, emphasis of this Directorate was to develop high yielding varieties, application of biotechnological interventions, integrated nutrient and pest management practices, diagnostics, improved storage environment and efficient extension system. Our emphasis was to improve production and productivity. In VISION 2050, our idea is to work more on the functional aspects of these commodities. How the nutraceutical and pharmaceutical values can be exploited to cater to the health industry? Opportunities exists to employ futuristic technologies like nanotechnology, sensor based technology, transgenics, climate resilient practices, aeroponics, metabolite engineering, input management and Good Agricultural Practices to improve the overall quality of the produce to satisfy the ever increasing demand of the stakeholders.

5. Goals/Targets, Focus and Priorities

Based on critical gaps analysis and research results from previous experience which forms the baseline for future research, DOGR proposes to double the production of onion and garlic in India by 2050. For this besides extending the onion and garlic cultivation to non-traditional areas and non-conventional seasons, the productivity of these crops will be increased substantially by setting and achieving the following goals.

- Increasing productivity through genetic improvement.
- Further, increasing productivity of improved varieties/hybrids through better agronomic innovations.
- Sustenance of productivity under abiotic & biotic stresses through resistance breeding, and integrated pest and disease management programmes.
- Organic production of onion and garlic.
- Loss prevention through genetic improvement, cultural management and improvement in storage and packaging conditions.
- Value addition through processing of the bulbs in the form of dehydrated flakes, dehydrated powder, paste, etc.
- Development of export-worthy varieties.
- Making available ample quantity of seed at reasonable rates of newly developed varieties and enhancement of seed life.

To achieve the above set goals the following targets are set.

- Promising varieties will be developed by exploiting the genetic variability including the exotic germplasm characterized to meet the challenges of biotic and abiotic stresses, which sustain the impact of climate change besides yield, quality and nutritive values.

- Appropriate eco-friendly agro-techniques specific to various agro-climatic regions for maximum productivity will be developed along with distribution of quality planting material of promising varieties.
- Cost-effective and eco-friendly tools including diagnostic techniques against biotic stresses to augment the precision towards marketable yield will be identified or developed.
- Pre- and post-harvest techniques to reduce the storage losses, increase shelf life and augment export will be developed and standardized.
- Effective mechanism to transfer technology with participatory approach by empowering all stake-holders will be achieved.
- Relevant information in proper time among targeted clientele will be disseminated.
- Human resource will be trained to handle the daunting problems to lead the cutting edge research and development programmes.

The vision and the mission of the DOGR give highest priority to farmers and entire strategy is based on '*farmer first*' with following priority areas.

- Development of high yielding onion and garlic varieties resistant to biotic and abiotic stresses with desirable processing qualities through conventional and biotechnological approaches.
- Development of high yielding hybrid varieties of onion tolerant to biotic and abiotic stresses.
- Development of high TSS white onion varieties for processing
- Development of high-tech technology for production of quality pathogen-free seed and planting material in onion and garlic.
- Refinement of production technologies for sustainable production of onion and garlic
- Impact assessment of climate change on onion and garlic production.

- Development of organic modules for onion and garlic production.
- Development of diagnostics including highly sensitive serological and nucleic acid based diagnostics kits for the detection of emerged and emerging pathogens particularly for viruses.
- IPM/IDM module for emerging onion and garlic insect pests and pathogens for effective disease management
- Enhancement of storage life of onion and garlic through conventional and non-conventional approaches.
- Exploitation of functional food value of onion and garlic.
- Disseminate and demonstrate the technologies developed by DOGR particularly by developing DSS and ICT for rapid dissemination of technologies.

6. Way Forward

For resolving major constraints in production of onion and garlic in major growing areas, the centre has mission mode approach. A systematic approach will definitely help to achieve the goals of vision 2050. Following strategies will be adopted by implementing the framework detailed in table 6.

- For varietal development, besides conventional breeding, biotechnological approaches will have to be adopted for introgression of genes from wild species for disease resistance, male sterility, high T.S.S., salt and drought tolerance and creation of variability.
- Genetic resources need to be managed under IPR regime through *ex-situ* as well as *in-situ* conservation.
- Long term trials on INM, IPM, IDM and organic production should be started for enhancing and sustenance of productivity in both the crops.
- For pushing new varieties ahead, frontline demonstrations will have to be arranged *vis-à-vis* sufficient seed should be made available through seed village concept.
- Facilities for long-term storage of seed need to be created for maintaining buffer stock.
- Creation of facilities for on-farm storage of onion and garlic through government support by adopting storage structures recommended by DOGR.
- For sustenance of prices, government should have crop plan for effective supply chain management and adopt firm policy on export, promotion of export to European markets, creation of facilities for quick transport, provision of ventilated

containers, cargo clearance through agri-export zones, and promotion of processing industries.

- Strengthening of research base by providing sufficient manpower to DOGR.

Considering the aspects of natural resource degradation, climate change and associated stresses, world trade and markets, IP regimes and human resource needs, following aspects will be covered looking to the Vision 2050 pertaining to onion & garlic:

Table 6. Strategic framework/ road map to achieve targets in Vision 2050

Programmes	Approach	Performance measure
Genetic Resource Management and Crop Improvement	Evolving promising varieties by exploiting the genetic variability including the exotic germplasm characterized to meet the challenges of biotic and abiotic stresses, which sustain the impact of climate change besides yield, quality and nutritive values.	Germplasm collection, evaluation, characterization and maintenance Development of high yielding varieties/hybrids in red and light red onion suitable for different seasons and export coupled with resistance to biotic and abiotic stresses Development of white onion varieties/ hybrids for processing and desirable horticultural traits suitable for different seasons coupled with resistance to biotic and abiotic stresses Development of varieties/hybrids in yellow onion for export to European markets Development of varieties in Bangalore Rose onion and multiplier onion Development of big clove garlic varieties for short day conditions DNA fingerprinting of onion and garlic varieties

Programmes	Approach	Performance measure
		In vitro screening for biotic and abiotic stresses Development of haploids and doubled haploids in onion for variety/inbred development programme Development of resistant varieties for diseases through biotechnological approaches Production of disease free garlic through meristem-tip culture Population structure and genetic differentiation in onion and garlic using molecular markers and next generation sequencing Development of linkage maps in onion for important horticultural and resistant traits Identification of genotypes to withstand climatic aberrations and genome probing for climate resilience Development of heat, drought and flood tolerant varieties Multiple disease and pest tolerant onion and garlic cultivars Identification of non-heavy metal accumulating genotypes Allele mining for desirable traits Novel *Alliums* with enhanced functional values Metabolic profiling for mitigation of human diseases using *Alliums* Transgenics for stress resistance

Programmes	Approach	Performance measure
Crop Production and Physiology	Development of appropriate agro-techniques specific to various agro-climatic regions for maximum productivity of available natural and other resources *vis-à-vis* distribution of quality planting material of promising varieties.	Basic physiological studies on adaptation of short day onion Studies on seed physiology for storage enhancement Productivity enhancement through integrated nutrient and water management Improvement of fertilizer nutrient use efficiency Organic production of onion and garlic Mechanization in onion and garlic production Year round production technology for onion and garlic under changing global climate Sensor based input management practices in onion and garlic Quality seed production in view of climate change Good Agricultural Practices (GAP) for onion and garlic export Standardization of technology for garlic through true seed production Site specific nutrient management and yield targeting modules
Crop Protection	Identification and development of cost effective and eco-friendly effective tools including diagnostic techniques against biotic stresses to augment marketable yield.	Seasonal incidence studies on diseases and pests, and development of forecasting models Integrated pest and disease management Collection and characterization of isolates of different onion and garlic diseases

Programmes	Approach	Performance measure
		Antagonism studies in controlling diseases of onion and garlic Development of high throughput and robust diagnostics for detection of onion and garlic pathogens Host pathogen interaction studies in onion particularly in case of *Alterneria, Stemphylium* and Iris Yellow Spot Virus (IYSV) Utilization of Pathogen Derived Resistance (PDR) for the development of major fungal and viral disease resistance in onion Impact assessment of minor and emerging diseases, viz., White tip, Powdery Mildew, Downy Mildew and Botrytis Blight Exploration of nano molecules for pathogen probing and management Micro array based multiple pathogen detection system Exploitation of virus induced gene silencing for management of virus diseases Identification of virus promoters for transgene expression Development of ultra virulent strains of insect pathogens through genetic manipulation for efficient management Development of sensor based personal digital assistance (PDA) system for assessment of damage due to insect pest and diseases

Programmes	Approach	Performance measure
Post-harvest Management	Development and standardization of pre- and post-harvest techniques to reduce the storage losses, increase shelf life and augment export	Standardization of pre- and post-harvest practices for enhancement of storage life of onion and garlic Improvement in storage structures Standardization of techniques for grading and packing for domestic as well as export market Standardization of pre-cooling technology and establishment of cool chain for export Solid waste management technology to use onion and garlic waste Standardization of preliminary processing techniques in onion and garlic for cottage industries Controlled Atmosphere Storage (CAS) technology Processed products with functional food and nutraceutical values
Transfer of Technology	Development of participatory approach for transfer of technology by empowering all stake-holders	Collection, documentation and validation of ITKs in production and post-harvest management of onion and garlic Impact analysis of DOGR developed technologies on socio-economic status of onion and garlic growers Identification of socio-economic, operational and institutional constraints in transfer of technology Frontline demonstrations 'On farm' research and village adoption Farmers participatory research for technology generation

Programmes	Approach	Performance measure
Seed Technology	Ensuring the provision of quality planting material	Enhancement of seed yield through physiological and agronomic intervention Seed quality enhancement through seed treatments Development of nano-molecule based trait specific technology for acquisition of desirable traits Aeroponics for production of pathogen-free planting material
Information Technology	Dissemination of relevant information in proper time among targeted clientele	Collection and documentation of information from primary and secondary sources on all aspects of research, development, market and trade Development of appropriate information retrieval system Development of linkages with other national and international agencies for sharing information
Human Resource Development	Training of HR to handle the daunting problems to lead the cutting edge research and development programmes	Development of research skills through training/advance studies inside country and overseas Visiting scientists exchange programme Trainers training programme

In next forty years we have the potential to become leader in onion and garlic production and increase production and productivity along with increase in export and processing. The enhanced productivity, profitability, quality and sustenance will improve the financial status of the onion and garlic growers of our country. It will help to generate additional employment through value addition, processing and export. Increased social status will further help them to open their mind set towards adoption of improved technologies.


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