Onion Improvement in India

Vijay Mahajan, A.J. Gupta, K.E. Lawande, Major Singh

Abstract In India, onion is cultivated in three season’s viz., kharif, late kharif and rahi. Several local types which are very well adapted to specific regions are currently being cultivated on a wide area. Some of them include, Patna White, Bombay Red, Patna Red, Poorna Red, Nasik Red, Bellary Red, Gujarat White, Bangalore Rose, Krishna Puram rose etc. Systematic research on onion was started in 1960 at Pimpalgaon Buswant and later by NARS including ICAR-DOGR. Organised breeding efforts are being made mainly at research centres of NARS viz., ICAR-DOGR (Rajgurunagar), ICAR-IHRI (Bangalore), ICAR-IARI (New Delhi), NHRDF (Nasik), MPKV (Rahuri), PAU (Ludhiana), RARS (Durgapur), VPKAS (Aimora), TNAU (Coimbatore) etc. Various population improvement methods were followed for development of varieties suitable for different seasons, export, processing etc. In India, till now about 70 varieties of onion including 2 F, hybrids and 6 varieties of multiplier onion have been developed and released for different colour of bulb and seasons by various organizations. Some of the work at molecular level were also carried out using RAPD, ISSR, SSR, SSAP, SRAP. Further there is need to develop varieties for specific requirements in India.

Onion is commodity of masses and used as salad and cooked in various ways in curries, fried, boiled, baked and used in soup making and pickles. Besides fresh consumption, onion provides very good raw material for processing industry as it is processed in the form of dehydrated powder, rings, shreds and onion in vinegar or brine. Alliums are among the cultivated plant species under family Alliaceae cultivated for food, medicines and religious purpose since early times. These crops are mostly strong flavoured due to presence of sulphur containing compounds responsible for distinctive smell and pungency (Robinowitch and Currah 2002). Onion as medicinal herb is known to ancient world, as it is mentioned in the medicinal treatises like “Charak Samhita” of third or fourth century A.D. (Ray et al., 1980a and 1980b). Sanskrit language equivalent signifying Vedic period and Aryan usage is available for onion as “Patalu” (Aiyar and Vagyanarayna 1956). The important principle components in onion are allicin, ajoene, allin thiosulfimates, and sulphites etc. which make it a potential herb. These components help fighting cancer, high blood cholesterol and sugar, liver problems, rheumatism and intestinal problems by regular consumption (Corzo-Martinez et al. 2007). It also has the pesticidal and fungicidal properties (Block 2010). Onion has primary centre of origin in Central Asia and secondary centre in the near East (McCollum 1976). It occupies a vast area in Western Asia, extending from Palestine to India. The short day onion produced in India assumes prime importance on account of their spiciness and unique taste in many Asiatic as well as European countries.

Onion Scenario in India

Research and development activity in the past has helped in the growth of onion production in India. Production of onion has increased from 40.4 lakh tons (1994-95) to 215.63 lakh tons (2016-17) due to collective efforts of National Agricultural Research System (NARS) of which ICAR-DOGR is also an integral part. Though, India ranks first by area (12.71 lakh hectares) in onion and second in production (215.63 lakh tons), next to China only, the productivity is 15.8 t/ha is far lower as compared to Netherlands, USA, China and many other countries. During the year 2016-17 India exported around 34.93 lakh tons of onion which was a record (Anonymous 2017). Since last 15 years India has been number one exporter in onion and during last decade India exported onion to the tune of 15 to 18 lakh tons besides fulfilling the demand of domestic population. Maharashtra,
Karnataka, Gujarat, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamil Nadu are the main onion growing states. In general, barring North Eastern states and Kerala, it is cultivated all over the country. But, country's 26% area and 29% production alone come from Maharashtra alone besides 90% export (Agricultural Statistics 2013).

In India, under short day conditions onion is harvested during kharif (Oct-Nov, 20%), Late kharif (Feb-March 30%) and rabi (April-May 50%) only once during rabi (April-May 100%) as a main crop. 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 need to be stored so as to make it available during price hike in market in October-November. There is critical shortage in arrivals of onion in the market during November 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 mainly from Maharashtra is available. 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 (Lawande 2016; Mahajan et al. 2018).

On the basis of average of five year since 1976 area has increase from 2.31 lakh hectare to 12.71 lakh hectare, production from 24.44 to 215.65 lakh tons / hectare with average productivity from 10.58 to 16.97 t/ha in 2016-17 (Fig 1.).

**History of R&D of Onion in India**

Systematic R&D programmes in onion were started in 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 November 3, 1977 under the Society Registration Act, 1860 at New Delhi for carrying out research and development activities on export oriented crops, to begin with onion and garlic. NHRDF developed promising varieties and technology (NHRDF, 2011). Development of multiplier onion varieties was done by Tamil Nadu Agricultural University (TNAU), Coimbatore. Prior to this, research on collection and maintenance of land races and standardization of agro-techniques was attempted by State Agricultural Departments. With the concept of coordinated projects and Agricultural Universities, the work on onion research was strengthened, in terms of varietal development for different seasons and standardization of production techniques in early nineties. The R&D in onion got impetus with the establishment of national research Center on Onion and Garlic at Nashik in 1994. This center was shifted to present location at Rajguranagar in 1998 and upgraded to Directorate with the addition of All India Network Research Project on Onion and Garlic in 2009 (Gopal et al. 2012). Besides concentrating on genetic improvement and biotechnology of onion, ICAR-DOGR's work on development of several agro-technologies including postharvest management practices has strengthened the R&D of onion. This work is also being supplemented by NHRDF and some universities. At present different state agricultural universities, ICAR institutes across the country and private companies are working on different R&D aspects to improve and sustain production and productivity of onion (Gopal and Murkute 2015).

**Domestication**

Adoption of onion in India is carried through from very early times before Christian era. Originally, native of Central Asia of temperate region with perennial/ biennial habit and long day bulbing characters, it has established well in India under tropical and short day (11-11.5 hrs.) photoperiodic conditions (Sheshadri and Chaterjee 1996). During
acclimatization of different kinds of vegetable crops and their varieties, farmers applied selection pressure involuntarily to meet the market preferences. In case of onion, ability to produce seeds indigenously has played an important role in the adaptation. In course of adaptation and diversification, out breeding mechanisms present in onion has promoted selections suited to diverse environments.

In the centre of origin and area between 55 to 40°N latitude, onion is biennial in seed production and requires more than 14 hrs day lengths for bulb production. In subtropical and tropical parts of India between 12 to 25°N latitude, it is biennial but able to produce bulbs under comparatively shorter photoperiod (11-11.5 hrs.) during winter season. Winter season crop accounts for 60 per cent of total production in the country. The concentration of onion growing in Western Maharashtra and Gujarat is very significant, where two crops – one in rainy season (kharif) and other in winter season (rabi) – are regularly grown. The tropicalization progresses further southwards towards Bellary region in Northern Karnataka and finally a vegetatively propagated multiplier onion (aggregatum) type got established in Tamil Nadu (6 – 8°N latitude). The adoption to hardy conditions of high rainfall, high temperature and short day photoperiod typical of rainy (kharif) season of Western India has not been chronologically documented. Export trade from Mumbai and Kandla port mainly to Gulf countries predominantly during November to April coincides with harvest of rainy seasons (kharif) and late rainy seasons (Rangda) crops. This is very typical example that market forces have influenced domestication and diversification to great extend. Demand for highly pungent and pink skinned bulbs from Gulf countries made farmers of Western India to select such type of plants, which can produce seeds under Indian conditions. This kind of adaptations made the crop plant to become annual. This phenomenon resulted in loss of short dormancy of bulbs. This fascinating aspect of onion domestication in Western India had gone unnoticed and unrecorded (Sheshadri and Chaterjee 1996).

There has been spectacular increase in area and production of onion over last 20 years, however, the productivity has almost remained static i.e. 10-16 tonnes per hectare, which is much less as compared to USA, Netherlands, China, etc.

**Breeding Achievements of Open Pollinated Varieties of Onion In India**

Several local types which are very well adapted to specific regions are currently being cultivated on a wide area. Some of them include, Patna White, Bombay Red, Patna Red, Poorna Red, Nasik Red, Bellary Red, Gujarat White, Bangalore Rose, Krishna Puram rose etc. Organised breeding efforts are being made mainly in research centres of NARS viz., ICAR-DOGR (Rajgurunagar), ICAR-IHR (Bangalore), ICAR-IARI (New Delhi), NHIRD (Nasik), MPKV (Rahuri), PAU (Ludhiana) RARS (Durgapur), VPKAS (Almora), TNAU (Coimbatore). In India till now about 70 varieties of onion including two F1 hybrids and six varieties of multiplier onion have been developed and released for different colour of bulb and seasons by various organizations (Pathak et al. 2016) (Table 1 & 2).

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Organization</th>
<th>Variety</th>
<th>Bulb color</th>
<th>Planting season</th>
<th>Year of release</th>
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<td>Red</td>
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<td>1985</td>
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<td></td>
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<td>*N-257-9-1</td>
<td>White</td>
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<td>1985</td>
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<tr>
<td>2</td>
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<td>Baswant -780</td>
<td>Red</td>
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<td></td>
<td></td>
<td>Phule Safed</td>
<td>White</td>
<td>Late Kharif and Rabi</td>
<td>1994</td>
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<td></td>
<td></td>
<td>Phule Suvarna</td>
<td>Yellow</td>
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<td>2001</td>
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<td>Pusa White Round</td>
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<td></td>
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<td>Early Grano (Long Day type)</td>
<td>Yellow</td>
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<td>Brown Spanish (Long Day)</td>
<td>Brown</td>
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Table 1 Onion varieties developed by different organizations
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<th>Year of release</th>
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<td>*Arka Kalyan</td>
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<td></td>
<td></td>
<td>Arka Pitamber</td>
<td>Yellow</td>
<td>Rabi</td>
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<td></td>
<td></td>
<td>Arka Bindu</td>
<td>Red</td>
<td>Kharif, late Kharif and Rabi</td>
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<td></td>
<td>Arka Ujjwal (multiplier onion)</td>
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<td></td>
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<td>Planting season</td>
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*These varieties have been released through All India Coordinated Research Project on Vegetables or All India Network Research Project on Onion and Garlic. Others are identified at institute level.

**Table 2 Onion varieties recommended for cultivation and release through AICRP & AINRPOG.**

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<th>S.No.</th>
<th>Varieties</th>
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<td>11</td>
<td>VL-3</td>
<td>VPKAS, Almora</td>
<td>I</td>
<td>1990</td>
</tr>
<tr>
<td>12</td>
<td>Agrifound Light Red</td>
<td>NHRDF, Nashik</td>
<td>VI, VIII</td>
<td>1993</td>
</tr>
<tr>
<td>13</td>
<td>Punjab Red Round</td>
<td>PAU, Ludhiana</td>
<td>IV</td>
<td>1993</td>
</tr>
<tr>
<td>14</td>
<td>PBR-5</td>
<td>PAU, Ludhiana</td>
<td>VI</td>
<td>1997</td>
</tr>
<tr>
<td>15</td>
<td>L-28</td>
<td>NHRDF, Nashik</td>
<td>IV &amp; VII</td>
<td>2006</td>
</tr>
<tr>
<td>16</td>
<td>HOS-1</td>
<td>HAU, Hisar</td>
<td>VI</td>
<td>2006</td>
</tr>
<tr>
<td>17</td>
<td>Bhima Raj</td>
<td>NRCOG, Rajgurunagar</td>
<td>VI</td>
<td>2007</td>
</tr>
<tr>
<td>S.No.</td>
<td>Varieties</td>
<td>Organization</td>
<td>Recommended Zones</td>
<td>Year of identification</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------</td>
<td>--------------</td>
<td>------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>19</td>
<td>PKV White</td>
<td>PDKV, Akola</td>
<td>VI</td>
<td>2009</td>
</tr>
<tr>
<td>20</td>
<td>RHOR-S11 (Phule Samarth)</td>
<td>MPKV, Rahuri</td>
<td>VI, VIII</td>
<td>2009</td>
</tr>
<tr>
<td>21</td>
<td>Bhima Kiran</td>
<td>DOGR, Raigurmarag</td>
<td>III &amp; VI*</td>
<td>2010</td>
</tr>
<tr>
<td>22</td>
<td>Line-355</td>
<td>NHRDF, Nashik</td>
<td>III, IV &amp; VI*</td>
<td>2010</td>
</tr>
<tr>
<td>23</td>
<td>Bhima Shakti</td>
<td>DOGR, Raigurmarag</td>
<td>III, IV, V, VI*</td>
<td>2011</td>
</tr>
<tr>
<td>25</td>
<td>Sel-126</td>
<td>IARI, N. Delhi</td>
<td>III, IV, V*</td>
<td>2011</td>
</tr>
<tr>
<td>26</td>
<td>Bhima Super</td>
<td>DOGR, Raigurmarag</td>
<td>II, IV, V &amp; VI** for kharif</td>
<td>2012</td>
</tr>
<tr>
<td>27</td>
<td>Bhima Dark Red</td>
<td>DOGR, Raigurmarag</td>
<td>II, IV, V &amp; VI**</td>
<td>2012</td>
</tr>
<tr>
<td>28</td>
<td>Bhima Shubra</td>
<td>DOGR, Raigurmarag</td>
<td>IV, V &amp; VI** for kharif</td>
<td>2012</td>
</tr>
<tr>
<td>29</td>
<td>Bhima Safed</td>
<td>DOGR, Raigurmarag</td>
<td>IV, V &amp; VI** for kharif</td>
<td>2014</td>
</tr>
<tr>
<td>30</td>
<td>Bhima Light Red</td>
<td>DOGR, Raigurmarag</td>
<td>VI</td>
<td>2015</td>
</tr>
</tbody>
</table>

* These varieties have been released through All India Coordinated Research Project on Vegetables or All India Network Research Project on Onion and Garlic. Others are identified at institute level.

Details of the Zones under AICRP Vegetables:

Zone I = Himachal Pradesh & U.P. Hills, Zone II = West Bengal & Assam, Zone III = Sikkim, Meghalaya, Manipur, Nagaland, Mizoram, Tripura, Arunachal Pradesh and Andaman & Nicobar Islands, Zone IV = Punjab, Tarai region of U.P. & Bihar, Zone V = Chhattisgarh, Orissa & Andhra Pradesh, Zone VI = Rajasthan, Gujarat, Haryana & Delhi, Zone VII = Madhya Pradesh & Maharashtra, Zone VIII = Karnataka, Tamil Nadu & Kerala

* New zones were decided during 2010 under AINRPOG: Zone III = Delhi, UP, Haryana, Bihar and Punjab, Zone IV = Rajasthan & Gujarat, Zone V = MP, Chhattisgarh & Orissa, Zone VI = Maharashtra, Karnataka and Andhra Pradesh

** Further zones were reclassified in 2011 comprising following centres in different states: Zone I: Srinagar, Almora, Mukteshwar, Palampur, Ooty, Zone II: Jammu, Ludhiana, Delhi, Karnal, Hisar, Durgapur, Zone IV: Jabalpur, Raipur, Chipilma, Akola, Jhalawar, Zone V: Junagadh, Nasik, Rahuri, Pune, Zone VI: Bagalkot, Bangalore, Coimbatore, Dharwad.

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 varieties with high total soluble solids suitable for dehydration, short day yellow varieties for export and varieties resistant to diseases and insect pests and suitability to different seasons. Barring few exceptions, the breeder stock of many varieties are not being maintained properly. Some of them never reached to farmers. However, few varieties always remained on the forefront. Despite release of high number of varieties, area under them is not more than 30 per cent. Remaining area is covered with the types maintained by the farmers themselves. Easier seed production for home requirement, at farmers' site is the main hurdle for spread of improved varieties. Non-availability of sufficient seed at reasonable price is the secondary one and finally, probably farmers have not overcome the presumption that all new varieties are on par with their material being maintained traditionally. All varieties developed so far and local types maintained by farmers suffer from all disease and pest, high percentage of twins, bolters and multi-centered bulbs and minor variations in colour, shape and maturity. The improvement of onion crop has not received any attraction of the breeders in India. Perhaps, it is because of biennial habit of the crop requiring longer time for breeding and difficulties in attaining and maintaining genetic uniformity due to high nature cross pollination and rapid inbreeding depression. Besides, lack of facilities for storage of selected bulbs of breeding lines in controlled storage conditions is another factor for slow progress in onion breeding programme (Swarup 1990).
Population Improvement in Onion

Being cross-pollinated, onion always provides a scope for using new population improvement methods, as natural variability is created constantly. Tremendous amount of variability is being utilised in onion using various breeding procedures. Different gene actions and gene combinations identified by genetic studies are being employed for generating new varieties and developing material for making new hybrids. Information on the nature and extent of genetic variability and degree of transmission of traits is of paramount importance in enhancing the efficiency of selection. Population improvement in onion utilizing conventional and new techniques for developing varieties and hybrids in India suitable for different purposes have been summarized by Mahajan and Lawande (2011) and Rao et al. (2015) (Table 3). It is expected that new open pollinated varieties will continue to be required in those countries where the growers are unable to pay for high cost of F1 hybrid seeds (Brewster 2008).

Table 3 List of different Onion varieties released in India using population improvement methods

<table>
<thead>
<tr>
<th>S No.</th>
<th>Variety released</th>
<th>Improvement Method Used</th>
<th>Institute/or Scientists Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N - 53</td>
<td>Mass Selection</td>
<td>MPKV, Rahuri, 1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Collection from Nashik, Maharashtra)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Punjab Selection</td>
<td>Mass Selection in indigenous material (Collection from Punjab)</td>
<td>PAU, Ludhiana, 1975</td>
</tr>
<tr>
<td>3</td>
<td>Pusa White Flat</td>
<td>Mass Selection (Local Collection)</td>
<td>IARI, New Delhi, 1975</td>
</tr>
<tr>
<td>4</td>
<td>Pusa White Round</td>
<td>Mass Selection Local collection (106)</td>
<td>IARI, New Delhi, 1975</td>
</tr>
<tr>
<td>5</td>
<td>Co 2</td>
<td>Mass Selection (Collection from Tamil Nadu)</td>
<td>TNAU, Coimbatore, 1978</td>
</tr>
<tr>
<td>6</td>
<td>Punjab - 48</td>
<td>Mass Selection (Collection from Punjab)</td>
<td>PAU, Ludhiana, 1978</td>
</tr>
<tr>
<td>7</td>
<td>Pusa Ratnvar</td>
<td>Mass Selection (Selection from Red Granex from USA)</td>
<td>IARI, New Delhi, 1978</td>
</tr>
<tr>
<td>8</td>
<td>Pusa Red</td>
<td>Mass Selection (Local Collection)</td>
<td>IARI, New Delhi, 1978</td>
</tr>
<tr>
<td>9</td>
<td>Co 3</td>
<td>Mass Selection (Collection from Tamil Nadu)</td>
<td>TNAU, Coimbatore, 1982</td>
</tr>
<tr>
<td>10</td>
<td>Kalyanpur Red Round</td>
<td>Mass Selection (Collection from U P)</td>
<td>CSUAT, Kanpur, 1983</td>
</tr>
<tr>
<td>11</td>
<td>Arka Pragati</td>
<td>Mass Selection (Collection from Nashik, Maharashtra)</td>
<td>IIHR, Bangalore, 1984</td>
</tr>
<tr>
<td>12</td>
<td>N - 2 – 4 - 1</td>
<td>Mass Selection (Collection from Pune, Maharashtra)</td>
<td>MPKV, Bangalore, 1985</td>
</tr>
<tr>
<td>14</td>
<td>Agrisound Dark Red</td>
<td>Mass Selection (Collection from Nashik, Maharashtra)</td>
<td>NHIRD, Nashik, 1987</td>
</tr>
<tr>
<td>15</td>
<td>Pusa Madhavi</td>
<td>Mass Selection (Collection from Muzaffarnagar, U P)</td>
<td>IARI, New Delhi, 1987</td>
</tr>
<tr>
<td>16</td>
<td>Arka Kalyan (Sel-14)</td>
<td>Mass Selection (Mass selection from a local collection IIHR – 145)</td>
<td>IIHR, Bangalore, 1987</td>
</tr>
<tr>
<td>17</td>
<td>Baswant – 780</td>
<td>Mass Selection (Collection from Pimpalgaon, Maharashtra)</td>
<td>MPKV, Rahuri, 1989</td>
</tr>
<tr>
<td>18</td>
<td>'VL Piaz 3'</td>
<td>3 cycles of Mass selection after F, of cross 'In-13 x L-43'</td>
<td>VPKS, Almora, Mani et al., 1999</td>
</tr>
<tr>
<td>19</td>
<td>Arka Pitambar</td>
<td>Pedigree selection from the cross U.D. 102 x IIIR-396</td>
<td>IIIR, Bangalore</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.iihr.res.in/frmVarieties.aspx">http://www.iihr.res.in/frmVarieties.aspx</a></td>
<td></td>
</tr>
<tr>
<td>S No.</td>
<td>Variety released</td>
<td>Improvement Method Used</td>
<td>Institute/or Scientists Involved</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>20</td>
<td>Bhima Super</td>
<td>Rigorous mass selection for single centeredness &amp; bulb shape</td>
<td>ICAR-DOGR, Pune, Lawande et al., 2007</td>
</tr>
<tr>
<td>21</td>
<td>Bhima Red &amp; Bhima Raj</td>
<td>Single bulb selection up to three generations followed by mass selection for all the three seasons viz. kharif, late kharif &amp; rabi</td>
<td>DOGR, Pune, Lawande et al., 2009</td>
</tr>
<tr>
<td>22</td>
<td>Bhima Shakti &amp; Bhima Kiran</td>
<td>Mass selection for late kharif and rabi season with better storability &amp; mass selection for rabi with good keeping quality</td>
<td>ICAR-DOGR, Pune, Lawande et al., 2010a &amp; b</td>
</tr>
<tr>
<td>23</td>
<td>Bhima Shweta</td>
<td>Selection of elite lines from germplasm followed by random matting and mass selection for rabi season white onion</td>
<td>ICAR-DOGR, Pune, Mahajan et al., 2010</td>
</tr>
<tr>
<td>24</td>
<td>Bhima Shubra</td>
<td>Selection of white segregating bulb from red germplasm followed by mass selection for white populations for kharif &amp; late kharif season</td>
<td>ICAR-DOGR, Pune, Mahajan et al., 2010</td>
</tr>
</tbody>
</table>

**Breeding for Seasonal Adaptability**

In India pink skinned and pungent types are preferred essentially for cooking, due to its strong flavour. In contrast for salad, yellow skinned and sweet onion varieties of western countries are not liked in India and these long day onions do not have such flavour. Incidentally, high productivity in western countries is favoured by long maturity season and long day photoperiodic conditions, which in turn promote high quality (high TSS) and very compact bulbs. Tropical onions maturing under short day conditions and short growing season yield less with somewhat poor quality bulbs. Hence, Indian average is only 10-12 tonnes/ha against 30 tonnes in countries located between 25 to 30°N latitude (Sheshadri and Chaterjee 1996).

*Kharif* crop is grown during hot and humid months and ready for harvest when temperatures are low. The bulbs do not become mature as growth continues due to shorter days and cooler temperature. The bulbs of *Kharif* season do not have good *storability*. Although, the day length during this period is slightly more than *rabi*, the critical value of day length available is around 11-11.5 hrs due to cloudy weather. Through centuries of selection the types, which can respond to warm and humid days with 11-11.5 hrs, have been identified and maintained by farmers. From the same material superior genotypes like N-53, Agri found Dark Red, Basavant 780, Bhima Super, Bhima Red, Bhima Dark Red, Bhima Shubra, Bhima Shweta and Arka Kalyan have been developed.

Recently due to late monsoon or irregularities of rain in *kharif* season there has been shift in planting from Kharif to late *kharif*. Availability of irrigation water from September to February, failure of *kharif* crop due to high rainfall coupled with high incidence of diseases and pest and poor storage of *Kharif* produce, farmers in Western Maharashtra are inclining towards late *kharif* crop commonly called as *Rangda* onion. Seedlings are transplanted in September-October and bulbs are ready for harvest in January-February. Low temperature during November-December favours bulb initiation and good development. Warm days during January-February facilitate maturity, as the day length available is again 11-11.5 hrs. The yields are high with good bulb size but percentage of bolting and twins is very high and therefore reduce marketable yield. Further, *storability* of bulbs is also low as compared to *rabi* produce. Some of the varieties like Bhima Shakti and Bhima Shubra developed by ICAR-DOGR and Phule Samarthis developed by MPKV, Rahuri was recently recommended for late *kharif* season. Still there is need to intensify research work in India for different location for late *kharif* season for early arrivals in market. In case of winter (*rabi*) crop almost all genotypes grown are of light red colour. But now a day demand is changing towards dark red and white onions during *rabi* season also. Hence, there is need to develop dark red and white onion varieties with good storage during *rabi*. Bhima Shakti is among these recently recommended having medium red bulbs with good keeping quality and Bhima Shweta white onion with medium storage during *rabi* season. In hills of Uttar Pradesh, Himachal Pradesh, winter
crop is transplanted in October-November and harvested in June-July, while summer crop is planted in February-March and harvested in August-October under long day conditions. Very few Gramex types with red and yellow colour varieties are developed and need more attention for development of varieties suitable for long day conditions (Pathak et al. 2016).

**Breeding for Processing Qualities**

Dehydrated products such as flakes, rings, granules, powder etc. and processed onion as onion in vinegar and brine are the important by-products being prepared and marketed world wide. Processing industries in any commodity play an important role in stabilizing prices in domestic markets. Dehydration industries demand for white onion varieties with globose shape of bulb and high TSS (>18%). All Indian white onion genotypes are having TSS range between 11-13%. Model variety for dehydration should be pure white, with globose shape, thin neck, free from greening and moulds, high pungency and high T.S.S. The variety should be high yielding with field tolerance resistance to diseases and pests. Wider seasonal adaptability is also an important character from continuous supply point of view. T.S.S. and pungency is a function of genotype, cultural practices and environment. Indian varieties are short day type mature within 90-120 days. They are basically low T.S.S. varieties. The T.S.S. varies from 10 to 14% in Indian material. Some of the long day varieties which mature within 150-180 days offer high T.S.S. range from 15 to 24%. But long day varieties do not produce bulbs under Indian short day conditions. However, intermediate short day varieties produce good bulbs but seed production is not possible under plains. In plains of India varieties mature in high temperature, which facilitates high sulphur built up and therefore Indian varieties are more pungent. In India attempts were made for development of white onion varieties by different research institutes (Mahajan and Lawande 2011; Gopal and Murkute 2015). The details are given in Table 4.

**Table 4 Performance of white onion varieties developed in India**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Variety</th>
<th>Source</th>
<th>T.S.S. %</th>
<th>Average yield q/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Pusa White Round</td>
<td>IARI, New Delhi</td>
<td>11.13</td>
<td>300–325</td>
</tr>
<tr>
<td>2.</td>
<td>Pusa White Flat</td>
<td>IARI, New Delhi</td>
<td>10.00</td>
<td>325–350</td>
</tr>
<tr>
<td>3.</td>
<td>Udaipur 102</td>
<td>RAU, Udaipur</td>
<td>10.06</td>
<td>300–350</td>
</tr>
<tr>
<td>4.</td>
<td>Agrifound White</td>
<td>NHRDF, Nashik</td>
<td>10.76</td>
<td>200–250</td>
</tr>
<tr>
<td>5.</td>
<td>Phule Safed</td>
<td>MPKV, Rahuri</td>
<td>10.13</td>
<td>250–300</td>
</tr>
<tr>
<td>6.</td>
<td>PKV White</td>
<td>PDKV, Akola</td>
<td>09.55</td>
<td>250–300</td>
</tr>
<tr>
<td>7.</td>
<td>Gujarat White</td>
<td>JAU, Junagadh</td>
<td>-</td>
<td>300–325</td>
</tr>
<tr>
<td>8.</td>
<td>N-257-9-1</td>
<td>Agril. Deptt., M.S.</td>
<td>10.00</td>
<td>250–300</td>
</tr>
<tr>
<td>9.</td>
<td>Punjab-48</td>
<td>PAU, Ludhiana</td>
<td>11.00</td>
<td>300–325</td>
</tr>
<tr>
<td>10.</td>
<td>V-12</td>
<td>Jain Food Park</td>
<td>15.00</td>
<td>350–400</td>
</tr>
<tr>
<td>11.</td>
<td>Nimar Local</td>
<td>Land Race, M.P.</td>
<td>12.50</td>
<td>250–300</td>
</tr>
<tr>
<td>12.</td>
<td>Talaja Local</td>
<td>Land Race Bhavnagar</td>
<td>12.00</td>
<td>250–300</td>
</tr>
</tbody>
</table>

Sandhu et al. (1976) studied storage quality of ten red and white onion varieties. Average sprouting percentage was slightly greater in red cvs. and their TSS content were lower. Bajaj et al. (1979) identified cv. Punjab-48 as most suitable for dehydration on account of its TSS (14.6%). Maini et al. (1984) out of 4 genotypes Roopali was better suited both for storage and dehydration. Kalra et al. (1986) found S-74 to be most suitable, followed by Punjab-48 for dehydration, with TSS 14.3 and 13%, respectively. Raina et al. (1988) recorded maximum (15.8%) TSS in Texas Yellow, followed by Punjab Selection (13.3%), Udaipur-102 (13.5%) and Punjab-48 (13.4%). Sainbhi and Bal (1996) observed TSS ranging from 14.0 to 16.2% and cultivar PWO-1 suitable for processing. Bhagchandani et al. (1980) reported Pusa White
Flat and Pusa White Round as suitable variety with least losses in storage. Storage losses in variety Punjab-48 was studied by Sainbhi and Randhawa (1982), where the losses in storage were greatest in large bulbs and least in small ones. Verma et al. (1999) evaluated 5 red and 3 white onion varieties for dehydration and Punjab-48 found to be superior among these varieties followed by Pusa White Flat. But after assessing Indian varieties and land races which do not offer T.S.S. range more than 12 per cent. Jain Food Park Industries, Jalgon introduced White Creole, which further subjected to selection pressure, for high T.S.S. character and developed V-12 variety with T.S.S. range from 15-18%.

This variety is under contract production for processing but seed production is not possible under Indian plains. Since, establishment of NRC for Onion and Garlic in 1998 at Rajgurunagar, a special programme for development of high T.S.S. white onion variety was launched through selfing and massing from available germplasm. In the year 2000 about 7199 bulbs were examined for T.S.S. range. Only 2.72% bulbs recorded T.S.S. more than 14 per cent. 109 bulbs offering T.S.S. range from 15 to 23% were selfed and populations were developed. After rejecting poor performing populations, 30 populations having 16 to 19% T.S.S. are advanced. In the 6th generation of selection cycle we are able to achieve more than 85% bulbs having average TSS about 18% or even more in about 15 populations in short day onion. Hence, it would be possible to develop high T.S.S. open pollinated varieties suitable for rabi and late kharif seasons (Mahajan and Lawande 2011; Mahajan and Gupta 2016a; Mahajan et al. 2016). Other options of mutation breeding are also being tried. Kataria (1990) reported three white mutants developed through chemical and physical mutagens viz. 22-5-1-1, 22-9-2-2 and 106-13-1-1 having TSS range from 25-30 per cent. This excellent material never reflected further in the form of either commercial variety or breeding material for varietal improvement.

Breeding for Export Quality Onion

India is number one in export of onion followed by Netherlands. India's export is mostly to South East Asian and Gulf countries. Dark red and light red onions with globe shape are mostly preferred with various diameter sizes. The present practice of export is grading and packing from the total bulk arriving in various onion markets. Uniformity in shape size and colour is seldom attained, as there no systematic control over planting of required varieties. Further, there is lack in varieties, which can suit to exclusive markets. European markets require yellow or brown onion with big size. There are hardly any indigenous varieties, which can meet to these standards. ICAR-DOGR has initiated work in this direction and recommended Mercedez, Linda Vista, Cougre and Collina from exotic material for growing in late kharif season. There is need for development of varieties in dark red and light red colour exclusively for export markets. Breeding work using long day and intermediate day exotic varieties with aim to transfer desirable characters in short day onion varieties is undertaken by this Directorate in collaboration with CITU Srinagar. Crosses were made and further selections for desirable characters were done which is further followed by mass selection.

Indians do not prefer yellow onion but these find international market in European. Minimum requirements for export are: bigger sized (>60 mm diameter), less pungent and single-centered types. As is evident, most work has been done in European countries and USA whereas, in India, research on onion has not been of any great significance. Very little work has been done in India for development of yellow onion varieties, particularly for export. Only two varieties were developed, viz., Phule Swarna from MPKV, Rahuri and Arka Pitambar from IHRI, Bangalore and were released at the state / institute level (Anonymous 2000). Yield of these varieties was comparatively less than in commercial red onion varieties. Mohanty et al. (2000) assessed 12 varieties of onion during kharif season and found lowest bulb diameter of 4.2 cm in Arka Pitambar, along with low yields (Mahajan and Lawande 2011).

Varietal Development with Special Reference to Climate Change

Climate change due to global warming and pollution has become major concern to the crop scientists and how to address this and prepare for is an important issue. Effect on total ecology and subsequently on certain important commodities is really not being studied. Onion and garlic are no bar to this shortcoming. No systematic studies are done in this regard. However, visible effect on distribution of rainfall has been noticed, which had exercised effect on increasing disease and pest in kharif onion. Kharif onion is a very sensitive and crucial crop in meeting domestic supply from October to January. Failure of kharif crop leads to hike in prices. Sudden rise in temperature in rabi season during December-January result in poor bulb initiation and bulb development of rabi onion and garlic. Dry weather with high
temperature favours incidence of thrips and mites on these crop. Very high temperatures in March-April-May lead to reducing keeping quality of onion and garlic bulbs. Detailed studies under simulated conditions of weather parameters need to be initiated for understanding critical impact of climate change on different crops.

Work on development of photo and thermo insensitive varieties is undertaken at ICAR-Directorate of Onion and Garlic Research, Raigurunagar to tackle the changing climatic situations. Some of the germplasm were found promising and can be grown in all the three season’s viz., Kharif, late Kharif and Rabi seasons is being exploited for such situations. In short day onion, normally bulb initiation takes place between 10-15°C night and 20-25°C day temperatures. Bulb development is at its best at 18-20°C night and 25-30°C day temperatures and for maturity day temperatures between 35-38°C is required. Many varieties have been developed worldwide but they are restricted for cultivation to specific season or climate and are sensitive to climate change. In India, about 70 varieties have been developed but they are cannot be cultivated in different photoperiod or temperature conditions. Even fluctuating climate is affecting within the season of cultivation. Looking to these challenges efforts were initiated to develop varieties which can sustain environmental vagaries and different varieties were tested in all the three seasons from 2002 to 2007 in red onion and white onion germplasm were identified 2002 – 2008 tested for at least years and three seasons. The results were encouraging and variety Bhima Super and Bhima Red was the outcome of the findings and were found promising (Lavande et al., 2007, 2009). In white onion out of 75 lines, 8 lines found suitable for all the three seasons. These varieties can be grown from sunshine hours of 2.48 to 9.66 hrs with monthly average temperature range of 10.51 to 36.34°C and rainfall from 0 to 273.71 mm. They can be grown in all the three seasons viz. kharif (May to October), late kharif (August to February) and rabi (October to April). These varieties have less effect of photoperiod and temperature and can sustain up to greater extent in changing climate with little modifications in cultivation and management practices. This shows a path and has scope to identify potential germplasm which can be exploited for development of varieties to face environmental challenges in 21st century with the aim to develop photo and thermo insensitive varieties of onion for different locations (Lavande et al. 2010b; Mahajan and Gupta 2016b). Besides this Bhima Shakti a red onion variety has been recommended for cultivation during late kharif and rabi in 2011 and Bhima Shubha a first white variety for kharif and late kharif 2010.

Though onion is biannual in nature, extremely cross-pollinated crop, shows inbreeding depression, have less storage life of seed etc. But looking to the methods exploited in onion improvement in the world, there is lot of scope for population improvement in India also in following areas but one has to work with patience. There is need for identification of areas where off season seed can be produced or to standardize techniques of seed production during kharif season to reduce the time of breeding from biannual to annual particularly for late kharif and rabi season varieties. Some of the reports are available where efforts were made to produce seed during kharif season which was successful (Mahajan et al. 2002) and can be exploited for population improvement for rabi and late kharif onion varieties.

**Molecular Markers in Onion**

Knowledge on molecular genetic diversity helps in the efficient management of germplasm pool, drawing of mini pool and selection of parents for crossing to various commercial traits Reddy et al., 2015. Very few attempts were made in India on this aspect. The RAPD markers were useful for assessing relatedness and genetic diversity in onion cultivars. Sangeeta et al. (2006) used 96 RAPD primers and grouped the 24 onion cultivars into northern and southern region of India. Mahajan et al. (2009) studied 14 short day and 2 long day cultivars of onion at 24 microsatellite loci. Twenty-one primer pairs were polymorphic. Based on Jaccard’s coefficient for SSRs, cultivars were grouped into 5 main groups. Exotic cultivars Alisa Craig and Brigham Yellow Globe were different compared to the Indian cultivars. Nashik Red and Poona Red were indistinguishable and similarly N-53 and Bombay Red were quite close. The diversity assessment of tropical Indian onion and cross amplification of genomic and EST-SSR markers in distantly related native wild species were estimated. Clustering revealed five groups and indigenous short day onion formed separate cluster from the exotic short day and long day onions. (Khar et al. 2010). Genomic and mitochondrial genome diversity was evaluated by employing RAPD, SSR and RFLP markers (Chaurasia et al. 2010). Genetic relatedness among nine sterile (A), maintainer lines (B), and male parents (C) of onion was analyzed with RAPD markers by Bhanja et al. (2013). Out of 180 arbitrary primers screened, 20 primers were selected which yielded 812 bands, 45.34 percent of which were found to be polymorphic. Squared-Euclidean Distance matrix revealed a minimum
genetic distance between the genotypes MS 48A and MF 65C and a maximum genetic distance between the genotypes MLT 84C and MF 65B. Cluster analysis grouped the nine onion genotypes into two major clusters. The first cluster consisted of two male sterile groups, i.e. MS-65 (Arka Lalima) and MS-48 (Arka Kirthiman) of single bulb onions. The second cluster consisted of MLT (Multiplier) group. None of the primers produced unique banding patterns to distinguish all nine genotypes. Sequence specific amplification polymorphism (SSAP) is more useful in revealing polymorphism which was developed in onion at ICAR-DOGR based on Copia like element (Anandhan et al. 1996). Sequence of Copia like elements in onion is available in database. The primers were designed based on LTR sequences. The DNA of different varieties of onion was digested with Taq1 restriction enzyme and adapter ligated to digested DNA. The DNA was amplified with retrotransposon specific primer and adapter specific primer. The amplicons were re-amplified with selective primer from the adapter based sequence and labelled retrotransposon primer. The SSAP could able to detect around 300 polymorphic loci per primer set. Similarity between varieties varied from 0.08 to 0.65. Highest similarity was found between Pusa White Flat and ALR and lowest being Pusa White flat and Cadillac. The marker could able to detect high level of polymorphism between varieties. The detection of polymorphism is higher than any earlier reported TRAP marker. The newly developed marker will be great use for diversity analysis genetic and mapping studies in onion.

Sequence Relation Amplification Polymorphism (SRAP) on 35 accessions of Allium species including edible species like onion, garlic and minor edible Alliums. The SRAP marker uses arbitrary primers with longer length and use and has been demonstrated across many species where genome information is lacking. Ten combination SARP primers were evaluated on the accessions included in the study. Number of polymorphic fragments varied from 5-13 for each primer set. The size range of amplicons varied from 250 to 1500 bp. The PIC value of the primer set were from 0.33 to 0.44. Analysis of SRAP marker showed that the genetic similarity values ranged from 0.09 to 0.96. The SRAP marker could capture wide variability among the Allium germplasm. This will be great aid in breeding experiments for identification of interspecific hybrids and mapping studies (Anandhan et al. 2016).


References


