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Message from the Director General, Department of Agriculture, Sri Lanka

I am delighted to send this message at the occasion of international conference in Seed production and Crop husbandry of Onion organized by the Field Crops Research and Development Institute, Mahailluppallama in collaboration with KOPIA. Onion is one of the important cash crops to Sri Lanka, and nearly 300,000 t of both big and red onions are consumed annually by Sri Lankans. Out of this requirement around 80,000 t of big onion and 72,000 t of red onion /cluster onion are produced locally. The main season of big onion harvest is from the month of August and a bumper harvest is
recorded in September leading to drop in farm gate price creating numerous problems in the onion industry.

Department of Agriculture along with provincial Departments of Agriculture has been launching numerous programs in the past to expand the seasonal cultivation of onion in traditional areas. Therefore, the balance was imported annually to meet the domestic demand. Department of Agriculture recently explored the possibility of expanding this cultivation in off seasons in nontraditional areas harnessing the agro ecological diversity of the country to meet the continuous demand. The pilot program carried out in Hambantota area (down south of Sri Lanka) reveled the possibility and encourage us to expand the onion cultivation in off season to achieve steady supply to meet the market demand.

Further research and development is under way to increase the productivity of local onion seed production in view of increasing the national productivity. It is very impotent to develop local varieties of big onion and cluster/red onion with high yielding ability along with resistant to biotic and abiotic stresses. This workshop is a long felt need in order to exchange ideas and to have a fruitful discussion to expand the onion sector in Sri Lanka with other participating countries in the region. With the participation of eminent scientists, extension experts, policy makers and private sector from both local and overseas, the workshop will deliver tangible outputs to develop the onion sector of Sri Lanka.

I wish the workshop a success.

Dr. Rohan Wijekoon
Director General
Onion is an essential part of the daily diet, creating a relatively constant, year-round consumer demand. It is a profitable cash crop which is important to uplift the living standard of the rural community in Sri Lanka, because it is one of the main cash crops grown in the dry zone. Onion cultivated extent and production during last 5 years were 4,876 ha and 69,154 t, respectively, and national average yield was 14.5 t/ha. Government of Sri Lanka has taken a policy decision to increase the local production and extent up to 144,827 t and 9,571 ha, respectively and to reduce the importation to 40% by 2015. Expand the cultivated extent by cultivating nontraditional areas and off season cultivation and increase the productivity are the strategies identified to enhance the local production.

The local big onion production and extent were not stable during past several years due to various reasons such as use of poor quality seeds, unexpected rainy weather conditions, lack of knowledge on appropriate crop management practices and giving low priority to onion cultivation by farmers over rice who cultivate onion in lowland paddy fields. At present, many problems have been raised regarding the quality of seeds produced by self-seed production program as long term use of seed materials without proper selection of mother bulbs and purity maintenance have deteriorated the parental stocks in farmer’s fields. Imported seeds are of poor quality and cause many difficulties to growers such as mixing of seed of different varieties, low adaptability to local conditions, poor germination and seedling vigor and low yield. Considering above facts, it is necessary to produce quality seeds, develop high yielding varieties and technologies to increase seed yield and increase storability and to make aware the farmers on appropriate crop management practices.

Therefore, Korea Project on International Agriculture (KOPIA) will help Department of Agriculture to increase the seed availability of big onion for local farmers by strengthening the self-seed production program, improving seed production technology and the productivity of big onion. These activities will increase the income of the farmhouse which helps to uplift the living standard of the farmers.

Dr. Jang, Byoung Choon
Director
Red and big onions are used as a vegetable in the daily dietary cuisines in Sri Lanka. The total requirement of onion at present is around 300,000 t, of which about 70% is supplied as big onion and the rest as red onion. About 50-60% of this requirement is imported mainly as big onion. In 2012, big onion production in the island was about 83,000 t which had saved about Rs. 2,137 million as foreign exchange but the cost for importing the balance requirement exceeded Rs. 3,100 million. Red onion production in the island which is about 75,000 t at present should be increased to 120,000 t to meet the future demand. Increasing productivity by reducing the yield gap between potential and farmer yield and year round cultivation of onion in selected agro-ecological regions would increase the availability of locally produced onion at affordable price to the consumer.

In the future, the national average productivity of big onion should be increased to about 20 t/ha from the present 15 t/ha. Thus, varieties are needed with a realizable yield potential of around 35 t/ha. Similarly, the realizable potential of shallot onion should be increased to around 18 t/ha from the present level of 13 t/ha. Research and development programs on onion in Sri Lanka are thus geared to increase productivity by identifying high yielding lines with tolerance to both biotic and abiotic stresses and introducing management options to bridge the yield gap in both seed and bulb crops. To achieve these targets, both big and red onion research are being conducted at Agriculture Research Station, Thirunelvely, Regional Agriculture Research and Development Centers, Kilinochchi and Aralaganwila and Field Crops Research and Development Institute, Mahailuppallama of the Department of Agriculture.

This international workshop on “Onion Seed Production and Crop Husbandry” with the participation of renowned scientists, administrators, policy makers and private entrepreneurs would provide a forum to share knowledge for the future development of the onion industry in Sri Lanka.

I wish the workshop a great success.

Dr W.M.W. Weerakoon
Director

PREFACE
Onion is one of the main cash crops grown in the dry zone of Sri Lanka. It is a profitable cash crop which has the potential to uplift the living standard of the rural community of the country. Since both red and big onions are an essential part of the daily diet of Sri Lankan, there exists a relatively constant, year-round consumer demand. However, onion production is seasonal which create a market glut. Review of the present status of onion revealed that the country is almost self-sufficient in red onion but over 70% of big onion requirement is imported spending substantial amount of foreign exchange. Government of Sri Lanka has taken a policy decision to increase the local production and extent of onion to reduce the importation to 40% by 2015. Achieving this target requires strategies such as expansion of onion cultivation in non-traditional areas, off-season cultivation and increase of productivity. Further, the local onion production and extent were not stable during the past several years due to various reasons such as use of poor quality seeds, unexpected rainy weather conditions, lack of knowledge on appropriate crop management practices etc. At present, many problems have been raised regarding the quality of seeds produced by self-seed production program as long term use of seed materials without proper selection of mother bulbs and purity maintenance have deteriorated the parental stocks in farmer’s fields. Imported seeds are of poor quality and cause many difficulties to growers such as mixing of seed of different varieties, low adaptability to local conditions, poor germination and seedling vigor and low yield. This demand production of quality seeds, develop high yielding varieties and technologies to increase seed yield and increase storability and to make aware the farmers on appropriate crop management practices.

The international workshop on “Onion Seed Production and Crop Husbandry” with the participation of renowned scientists, administrators, policy makers and private entrepreneurs provided a forum to share knowledge for the future development of the onion industry in Sri Lanka. The first two papers of the workshop proceedings provide a basis of onion research and development in Indian and Bangladesh perspectives. The proceedings then provided the research and development of onion in Sri Lanka followed by genetic improvement of red and big onions. After discussing integrated pest and disease management of onion in Sri Lanka, proceedings provided the procedure for quality control of onion seed production. The experiences of onion breeding and seed production and integrated pest management for quality onion production in Korea are shared in the proceedings as Power Point slides.

Editors sincerely hope that information in this proceeding will be useful in achieving self-sufficiency in both red and big onions in Sri Lanka.

Editors
ONION RESEARCH AND TECHNOLOGY DEVELOPMENT: 
AN INDIAN PERSPECTIVE

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Introduction

Onion (Allium cepa L.) is one of the oldest cultivated species in use for more than 5,000 years as an integral component of various culinary preparations (Jones, 1983). Historical and cultural significance of onion in India has been well documented in Garuda Purana (Shastri, 1995) where it is regarded as Rajasic (having aphrodisiac quality). Being rich in thiosulfinates, thiosulfonates, allicin, aliin, ajoene and many other biochemical components, onion has medicinal value too. Charak in Charak Samhita (300 B.C.) described onion for diuretic, digestion, heart, eyes and joints problems. The modern medical science also recognized importance of onion in treating diversified ailments, viz. lowering blood sugar, cardiovascular problems, improving gastrointestinal health, fighting cholera, preventing hair loss, improving bone health, tooth disorders, urinary disorders, prevention of blood clot etc. (Corzo-Martinez et al., 2007). The pesticidal and fungicidal properties of onion are well studied and widely accepted (Block, 2010; Begum et al., 2013).

Onion Cultivation in India
The cultivation of onion in India occurred from very early times before the Christian era. Originally though native of temperate region of central Asia with perennial/biennial habit and long day character, it has established well in India under tropical and short day (11-11.5 hours) photoperiodic conditions (Seshadri and Chatterjee, 1996). During its acclimatization, farmers applied selection pressure involuntarily to meet the market preferences. Ability of onion to produce seeds indigenously has played an important role in adaptation. Out breeding mechanism present in onion has promoted selection suited to diverse environments during the process of adaptation and diversification. The adaptation to hardy conditions of high rainfall, high temperature and short photoperiod typical of rainy season crop of western India has been chronologically documented (Seshadri and Chatterjee, 1996). The tropicalization progressed further southwards towards Bellary region of North Karnataka and finally onion got established in Tamil Nadu (6 to 8° N latitude).

Two types of onion are commercially grown in India viz., common onion and multiplier onion. Common onion (A. cepa var. cepa), is the most important in commercial trade. Its bulbs are large, normally single and plants are propagated through seeds. The other group i.e. multiplier onion or shallot type onion (A. cepa var. aggregatum Don.) is vegetatively propagated and produce bulbs of small size and form an aggregated cluster. Multiplier onion is also known as country onion or potato onion or Egyptian ground onion. This is grown from ancient times in India. It has got a Sanskrit equivalent ‘Palandu’, mentioned in Apastamba Dharma Sutra-I (dated 800 B.C. to 300 B.C.), which confirms its early introduction in India.
In India, common onion is grown in three crop seasons i.e. kharif, late kharif and rabi. Main crop in rabi (50-60%) and 20-25% each in kharif and late kharif. Kharif crop is grown during hot and humid months and is ready for harvest when temperatures are low. The bulbs do not mature as growth continues due to cooler temperature and hence have poor storability. Although, the day length during this period is slightly longer than rabi, the critical period available is around 11-11.5 hours due to cloudy weather. Of late, due to delayed monsoon 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, pests and poor storage of kharif produce forced farmers in Western Maharashtra to incline towards late kharif crop commonly called ‘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 bulb development. Warm days during January-February facilitate maturity, as the day length available is again 11-11.5 hours. The yields are high with good bulb size but percentage of bolting and twins is very high resulting in reduced marketable yield. Further, storability of bulbs is also low as compared to rabi produce. In case of rabi crop, seedlings are transplanted in November-December. Low temperatures (20-25 °C) during December-January favour bulb initiation under short day conditions. Bulb growth and maturity occurs in February-March, when nights are cool and days are warm. High temperatures during April-May (35-40 °C) hasten maturity. There is better curing of neck and such bulbs store well up to 5-6 months. In hills of Uttar Pradesh and 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. In hills, days are longer (>13 hours) and temperatures are cool. Crop duration is long (>7 months). Due to congenial climate, growth and development is very good, bulb size is big resulting in higher yields.

**Status of Research and Development on Onion in India**
Systematic research and development (R&D) programs 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), Bengaluru. National Horticultural Research and Development Foundation (NHRDF), at Nashik established by National Agricultural Co-operative Marketing Federation of India Ltd. (NAFED) is carrying out research and development activities on export oriented crops, especially onion and garlic. Development of multiplier onion varieties was done 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, 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 Centre on Onion and Garlic at Nashik in 1994. This centre was shifted to present location at Rajgurunagar in 1998 and upgraded to Directorate with the addition of All India Network Research Project on Onion and Garlic in 2008. Besides concentrating on genetic improvement and biotechnology of onion, Directorate of Onion and Garlic Research (DOGR) is also working on development of agro-technologies including post-harvest management practices. 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. The status of work conducted in India in areas of onion improvement, production, protection and post-harvest management is presented below.

Crop Improvement
Genetic resources: A large numbers of landraces including some wild species are available in India particularly in the North-eastern states. As per reports from Singh and Rana (1994), National Bureau of Plant Genetic Resources (NBPGR) has conducted extensive plant exploration in different allium-growing states/regions in India. Kale et al. (1994) undertook a detailed survey of traditional and non-traditional onion-growing areas of the state of Maharashtra, and India in general, and collected 148 red-skin and 33 white-skin types of onion, evaluated and identified some lines on the basis of maximum average bulb weight, high TSS and centerness. According to Singh and Rana (1994), some of the cultivated Indian accessions have been identified to be resistant/tolerant to purple blotch (Alternaria species), Stemphylium blight and garlic mosaic virus. However, sources of resistance to many diseases and pests such as neckrot (Botrytis allii Munn.), basal rot (Fusarium species), black mould (Aspergillus niger Tieghem) are yet to be identified.

Many farmers in various parts of the country are growing old landraces of onion. For example, Pune Fursungi, a red coloured landrace is being cultivated in Nashik and Pune areas of Maharashtra in late kharif and rabi seasons. The Junagarh, Saurashtra and Mehsana areas of Gujarat are dominated by Pili Patti, which is commonly grown in rabi season. Bellary Red, another red onion landrace is prevalent in Karnataka and landrace Sukhsagar is being cultivated in West Bengal. K.P. onion dominates in Andhra Pradesh, whereas Nirmal Local occupies large area in Madhya Pradesh. Further, the multiplier type of onion has been a unique feature in Tamil Nadu. This variability is being maintained in national germplasm collection of onion at DOGR, which is the National Active Germplasm site for onion. The present status of collection of germplasm at DOGR is given in Table 1.

Table 1: Status of onion germplasm collection at Directorate of Onion and Garlic Research.
Gopal, J.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Category</th>
<th>No. of accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dark Red</td>
<td>274</td>
</tr>
<tr>
<td>2</td>
<td>Light Red</td>
<td>429</td>
</tr>
<tr>
<td>3</td>
<td>White</td>
<td>450</td>
</tr>
<tr>
<td>4</td>
<td>Yellow</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Exotic onion</td>
<td>237</td>
</tr>
<tr>
<td>6</td>
<td>Wild species</td>
<td>12</td>
</tr>
</tbody>
</table>

**Genetic studies:** Despite the global culinary and economic significance, genetic research in onion has greatly lagged than in other major vegetable crops. Actually, genetic analysis of onions is time consuming because of biennial nature and severe inbreeding depression. This makes it difficult to produce and maintain a large near homozygous inbred populations for genetic linkage analysis. Therefore, only a few qualitative genes with easily visible effects have been described in onion including colour of bulb, foliage, anthers and seed coats, male sterility, restoration in CMS, pink root resistance, ozone damage resistance, dwarf seed stalk and chlorophyll deficient mutants. However, a number of studies have reported inheritance of yield and quality traits, many of which were concerned with the estimation of combining ability in various populations. Additive gene effects for dry matter content, bulb size and maturity and additive and non-additive gene effects for bulb yield and number of leaves per plant were found to play important role (Joshi and Tandon, 1976; Pathak et al., 1987).

**Breeding:** The commonly practiced breeding methods followed in onion are mass selection, recurrent selection, selfing and massing, hybridization followed by different population improvement schemes and heterosis breeding. The varietal improvement programme in India has originated from improvement of the local varieties. As a result more than 50 varieties of onion including 2 F1 hybrids and 6 varieties of multiplier onion have been developed and released (Table 2). Most of these varieties are mainly for rabi season. Development of some kharif growing varieties was earlier done by Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, NHRDF, Nashik and IIHR, Bengaluru and later by DOGR, Rajgurunagar.
Despite reports of high heterosis (Joshi and Tandon, 1976; Aghora, 1985; Veere Gowda, 1988; Netrapal and Singh, 1999; Shashikanth et al., 2007; Abubakar and Adu, 2008), the hybrids in onion have not made headway in India due to non-availability of stable male sterile lines along with maintainers in short day onion. In India, progress in the development of suitable male sterile and fertile inbred lines has remained very slow. Sen and Srivastava (1957) attempted to develop F₁ hybrids in onion as early as in 1948 using exotic male sterile lines and Indian local male stocks. The exotic male sterile lines were found unsuitable in the photo-periodically different environment in India. Later, very few workers attempted to test different hybrid combinations for heterosis and combining ability using male sterile lines (Pathak et al., 1987). Male sterility has been isolated from indigenous germplasm by several workers in India; Patil et al. (1973) in cv. ‘Niphad 2-4-1’ and Pathak et al. (1980) in cv. ‘Nasik White Globe’. Further studies indicated strong cytoplasmic factor responsible for male sterility in cv. ‘Bombay White Globe’ (Pathak et al., 1986). At IARI, the male sterility was isolated in a commercial variety ‘Pusa Red’. This male sterility has been transferred to several breeding lines by backcross breeding method. In a review on use of molecular markers in the improvement of allium crops, Reddy et al. (2013) detailed the information on male sterility system and their utilization in F₁ hybrids production. Only two onion hybrids ‘Arka Kirthiman’ and ‘Arka Lalima’ have been released from IIHR. Some new hybrids are being developed in the country. Gupta et al. (2011) reported that six F₁ hybrids viz. DOGR Hy-1, DOGR Hy-7, DOGR Hy-17, DOGR Hy-27, DOGR Hy-29 and DOGR Hy-41 were superior over standard check.
Table 2: Onion varieties developed by different organizations in India.
<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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agril. Dept., M.S.</td>
<td>N-53</td>
<td>Red</td>
<td>Kharif</td>
<td>1975</td>
</tr>
<tr>
<td>2</td>
<td>*N-2-4-1</td>
<td></td>
<td>Red</td>
<td>Rabi and late Kharif</td>
<td>1985</td>
</tr>
<tr>
<td>3</td>
<td>*N-257-9-1</td>
<td></td>
<td>White</td>
<td>Rabi</td>
<td>1985</td>
</tr>
<tr>
<td>4</td>
<td>MPKV, Rahuri</td>
<td>Baswant -780</td>
<td>Red</td>
<td>Kharif</td>
<td>1989</td>
</tr>
<tr>
<td>5</td>
<td>Phule Safarwana</td>
<td></td>
<td>White</td>
<td>Late Kharif and Rabi</td>
<td>1994</td>
</tr>
<tr>
<td>6</td>
<td>Phule Suvarna</td>
<td></td>
<td>Yellow</td>
<td>Rabi and late Kharif</td>
<td>2001</td>
</tr>
<tr>
<td>7</td>
<td>*Phule Samartha (S-1)</td>
<td></td>
<td>Red</td>
<td>Late Kharif</td>
<td>2006</td>
</tr>
<tr>
<td>8</td>
<td>IARI, N. Delhi</td>
<td>Pusa White Flat</td>
<td>White</td>
<td>Rabi</td>
<td>1975</td>
</tr>
<tr>
<td>9</td>
<td>Pusa White Round</td>
<td></td>
<td>White</td>
<td>Rabi</td>
<td>1975</td>
</tr>
<tr>
<td>10</td>
<td>Early Grano (Long Day type)</td>
<td></td>
<td>Yellow</td>
<td>Late Kharif and Rabi</td>
<td>1975</td>
</tr>
<tr>
<td>11</td>
<td>Brown Spanish (Long Day)</td>
<td></td>
<td>Brown</td>
<td>Hills</td>
<td>1975</td>
</tr>
<tr>
<td>12</td>
<td>*Pusa Red</td>
<td></td>
<td>Red</td>
<td>Late Kharif and Rabi</td>
<td>1975</td>
</tr>
<tr>
<td>13</td>
<td>*Pusa Ratnar</td>
<td></td>
<td>Red</td>
<td>Rabi</td>
<td>1975</td>
</tr>
<tr>
<td>14</td>
<td>*Pusa Madhavi</td>
<td></td>
<td>Red</td>
<td>Rabi</td>
<td>1987</td>
</tr>
<tr>
<td>15</td>
<td>*Selection 126</td>
<td></td>
<td>Brown</td>
<td>Rabi</td>
<td>2012</td>
</tr>
<tr>
<td>16</td>
<td>IIHR, Bangalore</td>
<td>Arka Pragati</td>
<td>Red</td>
<td>Kharif and Rabi</td>
<td>1984</td>
</tr>
<tr>
<td>17</td>
<td>*Arka Niketan</td>
<td></td>
<td>Red</td>
<td>Rabi and late Kharif</td>
<td>1987</td>
</tr>
<tr>
<td>18</td>
<td>*Arka Kalyan</td>
<td></td>
<td>Red</td>
<td>Kharif</td>
<td>1987</td>
</tr>
<tr>
<td>19</td>
<td>Arka Lalima</td>
<td></td>
<td>Red</td>
<td>Rabi</td>
<td>1993</td>
</tr>
<tr>
<td>20</td>
<td>Arka Kirtiman</td>
<td></td>
<td>Red</td>
<td>Rabi</td>
<td>1993</td>
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<tr>
<td>21</td>
<td>Arka Pitamber</td>
<td></td>
<td>Yellow</td>
<td>Rabi</td>
<td>2006</td>
</tr>
<tr>
<td>22</td>
<td>Arka Bindu</td>
<td></td>
<td>Red</td>
<td>Kharif, late Kharif and Rabi</td>
<td>2006</td>
</tr>
</tbody>
</table>
Research and technology development on onion: Indian perspective

<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>
</tr>
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<tbody>
<tr>
<td>23</td>
<td>Arka Ujjwal</td>
<td>(multiplier onion)</td>
<td>Red</td>
<td>Rabi</td>
<td>2010</td>
</tr>
<tr>
<td>24</td>
<td>Arka Swadista</td>
<td></td>
<td>White</td>
<td>Rabi</td>
<td>2010</td>
</tr>
<tr>
<td>25</td>
<td>Arka Vishwas</td>
<td></td>
<td>Dark red</td>
<td>Kharif and Rabi</td>
<td>2011</td>
</tr>
<tr>
<td>26</td>
<td>Arka Sona</td>
<td></td>
<td>Yellow</td>
<td>Rabi</td>
<td>2011</td>
</tr>
<tr>
<td>27</td>
<td>Arka Bhim</td>
<td>(tri-parental synthetic)</td>
<td>Red</td>
<td>Rabi</td>
<td>2011</td>
</tr>
<tr>
<td>28</td>
<td>Arka Akshay</td>
<td>(tri-parental synthetic)</td>
<td>Dark Red</td>
<td>Rabi</td>
<td>2011</td>
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<tr>
<td>29</td>
<td>HAU, Hissar</td>
<td>Hissar- 2</td>
<td>Red</td>
<td>Rabi</td>
<td>1976</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>*HOS-1</td>
<td>Red</td>
<td>Rabi</td>
<td>2006</td>
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* Released through all India Coordinated Research Project on Vegetables or all India Network Research Project on Onion and Garlic.
Some of the exotic hybrids are performing well during late *kharif* under Indian conditions and yields are almost double than the Indian varieties at DOGR, but they have very less TSS, less storage life and are of yellow colour, which has no consumer preference in India. It can be exploited to trap the European and Japanese markets where there is great demand, but it can be possible only through cool chain export. However, the adaptation of the hybrids by farmers has been slow due to inherent problems associated with traditional onion production system in the country (Veere Gowda *et al.*, 2002).
Processed products of onion are in demand in many countries. Dehydration industries demand white onion varieties with globe shaped bulb and high TSS (>18%). Some of the varieties identified as suitable for dehydrated products were Punjab-48 (Bajaj et al., 1979; Verma et al., 1999), Roopali (Maini et al., 1984), S-74 (Kalra et al., 1986), Texas Yellow (Raina et al., 1988) and PWO-1 (Saimbhi and Bal, 1996). After assessing Indian varieties and landraces which do not offer TSS range more than 12%, Jain Food Park Industries, Jalgaon introduced White Creole, which was further subjected to selection for high TSS and developed V-12 with TSS range of 15-18% (Mahajan et al., 2011).

**Biotechnology:** Biotechnological approaches for crop improvement in onion are still in its nascent stage in India. DOGR has taken lead and has been successful in standardization of protocols for direct and indirect in vitro regeneration in onion. A preliminary insight into onion haploid development through in vitro gynogenesis has been achieved (DOGR, 2012). Somatic embryogenesis through direct regeneration and callusing has been achieved (Aswath et al., 2006). Molecular markers (RAPD, ISSR and SSR) have been identified for estimating genetic diversity in onion, and related wild alliums. Development of core collection, conserving allium biodiversity and development of linkage maps in onion are being targeted. Sangeeta et al. (2006) used 90 RAPD primers and grouped the 24 onion cultivars into northern and southern region of India. Ten varieties of onion were analysed by Maniruzzaman et al. (2010) and found that Bermis and India-2 were most dissimilar while Faridpuri and Bhati were the most similar genetically.

Mitochondrial genome diversity has been evaluated by employing RAPD, SSR and RFLP markers (Chaurasia et al., 2010). Dhanya et al. (2012) used RAPD markers analysis to investigate genetic relatedness among nine sterile (A), maintainer lines (B), and male parents (C) of onion. Radhika et al. (2013) used a computational approach for mining SSRs from ESTs in *A. cepa* and developed a database to store the unigenes, primer pairs, putative annotations and BLAST results, which can be used in studies related to marker assisted selection, detection of polymorphism, DNA fingerprinting and diversity analysis in onion.
Crop Production

In general, onion crop can be grown in the field by transplanting, direct seeding and sets method (Dhesi et al., 1965; Yawalker, 1969). Technologies and practices have been developed for various stages of onion crop from sowing to harvesting.

Transplanting

Seed rate and seedlings: Studies on seed rate showed that depending on the variety, about 6-8 kg seeds would be sufficient for 1 ha by traditional transplanting method. About 0.05 ha area is required to raise the nursery for 1 ha area to be sown by transplanting. Seedlings should be grown on raised bed of 10-15 cm height with 1 m width and length as per convenience. The distance between two beds is kept 30 cm for easy intercultural operations. Seeds are manually sown in rows at 10-15 cm distance and irrigated preferably by drip or sprinklers. Seed treatment with Trichoderma viride at 4 g/kg seed followed by soil application of T. viride at 1,250 g/ha mixed with 50 kg farm yard manure (FYM) is useful for reducing damping off disease in nursery. Soil application of copper oxychloride at 0.25% was also adjudged as an alternative treatment (NHRDF, 2011). Application of Pendimethalin 30 EC, a pre-emergence herbicide at 2 ml/l at the time of sowing seed effectively control weed population in onion nursery compared to other herbicide sprays (DOGR, 2012).

Seed treatment experiments have been undertaken to improve germination. Solid matrix priming and halo priming with 0.3% KNO or coating with Royalflo could enhance the field emergence with more than 75% germination in seed stored for nine months (IARI, 2010). The seed treatment with glycine betaine (2.5 and 5%) increased yield by 14-19%; whereas, the foliar spray with glycine betaine (2.5 and 5%) increased yield by 12-18% (IIHR, 2010).
Seed treatment with vermiwash has been recommended by University of Agricultural Sciences, Dharwad, Karnataka (Jawadagi et al., 2008) as freshly harvested onion seeds treated with vermiwash recorded significantly higher germination (80.6%), numerically high growth rate index (19.3), shoot length (8.5 cm) and seedling dry matter accumulation (22.3 mg). Coating of onion seed with DAP (30 g/kg seed) + Borax (0.1 g/kg seed) + Carbendazim (3 g/kg seed) resulted in 40% higher bulb yield. During kharif season, Karanj leaf powder (500 g/kg seed) is used for higher seed germination (NHRDF, 2011). Gypsum in combination with cow dung or clay or neem or vermicompost powders (1:1 v/v) was used for pelleting of onion seeds. However, germination of pelleted seeds was found to be at par with that of non-pelleted seeds (IIHR, 2010).

**Transplanting and crop geometry:** About 45-50 days old nursery seedlings becomes ready for transplanting in rabi season and in 35-40 days in kharif. Maiti and Sen (1974) found that partial trimming of onion seedlings at the time of transplanting augmented the stand of crop and increased the size of bulb. Similar results were also obtained by Rathore and Kumar (1974). Generally, the uprooted seedlings are cut one third from the top. The seedlings are dipped in solution of Carbosulfan (2 ml/l) and Carbendazim (1.5 g/l) for two hours and gently pressed in the soil. For proper growth of seedlings ample nutrition is a predisposing factor. Thus, crop geometry plays a vital role to ensure optimum crop density in the field. In rabi season the transplanting in flat beds (2 x 3 m) at 10 cm plant to plant spacing with 15 cm row to row spacing is recommended. In kharif the crop geometry of 12 rows at 10 cm distance on broad raised bed of 15 cm height and 120 cm width is recommended (Lawande, 2011). At University of Agriculture Sciences, Dharwad, Karnataka it was revealed that maximum plant height and leaf length was recorded with 15 cm x 7.5 cm spacing followed by 15x10 cm spacing in cv. Bellary red (Jawadagi et al., 2012). Bulb yield, net returns and B:C ratio were maximum when the crop planted at 15 cm x 10 cm spacing was nourished with 12.50 t/ha FYM + 2 t/ha vermicompost + 5 kg/ha biofertilizers.

**Direct Seeding**
Onion can also be grown by direct seeding. Around 12 to 15 kg/ha seed is sown by broadcasting in beds 30 cm apart. The experiments conducted at DOGR revealed that sowing seed in lines manually or with seed drill produced higher yield than broadcasting of seeds. However, seed drills used for direct sowing of onion in India lack precision and their accuracy mostly depends on the skill of person who is performing sowing operations. The Central Institute Agricultural Engineering, Bhopal has imported pneumatic seed drill from Italy. This seed drill is useful for direct sowing of all types of vegetables particularly onion, okra, carrot etc. This versatile and multipurpose machine can be fitted with as many seeding units as needed to meet the specific requirements of the farmers and equipped with everything necessary to handle all the different types of seed. Results of experiment on direct seeding of onion with pneumatic seed drill revealed that among the various sowing methods, the highest bulb size (polar and equatorial diameter), more per cent of A grade bulbs and less number of doubles were researched in direct sown plot using pneumatic seed drill. The highest marketable bulb yield was research in transplanting method only. The less bulb yield in pneumatic seed drilled plots may be due lower seedlings population and crop stand. However, low seed rate, easy sowing, saving in sowing time and early maturity of onion were observed in pneumatic seed drill machine (Sankar et al., 2011).

Sets Planting
Onion production through sets is an innovative technology for *kharif* season where planting coincides with heavy showers, and nursery raising in May is difficult due to hot and humid conditions. In some parts of Gujarat, Maharashtra and Rajasthan, onion is grown in *kharif* by sets to get early crop (Pandey and Singh, 1993). Sets are small size onions produced by allowing the seedlings to mature in the nursery bed as such instead of transplanting them. Seed sowing is done by end of January or February and small bulbs are harvested in the month of April - May. It has been reported that seed sowing in January with 50 g seed/m$^2$ gave maximum quality of sets. The topped and graded sets are stored in hessian cloth bags or in shallow baskets or in racks in layer not more than 8 cm deep. Ten quintals of sets of 1.5 to 2.0 cm diameter are enough for one hectare planting. But higher yield and net returns were obtained with 2.0-2.5 cm size of sets (Pandey *et al*., 1990). The closer distance of planting (15x10 cm) was found to be more beneficial with regard to marketable bulb yield, net income, cost : benefit ratio and cost of cultivation (Singh and Singh, 2002). Planting of sets on loamy sand soil by flat system and ridge and furrow system produced an average bulb yields of 132 and 120 q/ha, respectively, compared to 96 q/ha in broad bed system (Sharma *et al*., 2003). Sets have a shorter growing season than plants from seeds and transplants, and therefore can be exploited when a rapid or early season production is required.

**Nutrient Management**

An onion crop of bulb yields 35 t/ha removes approximately 120 kg nitrogen, 50 kg phosphorus and 160 kg potash (Tandon, 1987). However, the experiments carried out at Rajgurunagar by DOGR showed that onion crop removes about 90-95 kg N, 30-35 kg of P$_2$O$_5$ and 50-55 kg of K$_2$O to produce 40 t onion bulbs/ha (DOGR, 2012). In addition to NPK, sulphur is also a plant nutrient important for onion crop for improving yield and the pungency of bulbs. Sulphur is absorbed in the form of sulfate ions (SO$_4^{2-}$). Leaf tissue sulphur level of 0.3 to 0.5% is required during active vegetative growth stage (20-45 DAT), whereas 0.2-0.3% during bulb initiation to development stages (45-75 DAT).
It is reported that application of FYM at 20t/ha + Neem cake at 1 t/ha + S at 20 kg/ha + NPK at 50:50:50 kg/ha as basal application and spray of polyfeed at 1% at 30 and 45 DAP and Multi K at 1% at 60 and 70 DAP was useful for higher bulb yield (NHRDF, 2011). However, DOGR results showed that application of 75% recommended dose of fertilizer (RDF), FYM (5 t), poultry manure (2.5 t) and vermicompost (2.5 t)/ ha gave marketable bulb yield, nutrient content and uptake equal to that of 100% RDF (150:50:80:50 kg NPKS/ha) + 20 t FYM/ha or 100% RDF alone (DOGR, 2012). Based on these results, nitrogen 110 kg/ha in three splits i.e. at the time of planting and 30 and 45 DAP with basal application of phosphorus (40 kg/ha), potash (60 kg/ha) and sulphur (40 kg/ha) has been recommended (AINRPOG, 2013). Soil application of sulphur beyond 20 kg/ha to onion successively for two years increased the soil available sulphur levels slightly over the initial sulphur level (Thangasamy et al., 2013).

Supplementation of chemical fertilizers with biofertilizers proved beneficial for onion crop (Yogita and Ram, 2012). The maximum plant height, number of leaves, neck thickness, bulb diameter, bulb weight, number of scales and yield and minimum number of days required for bulb formation and number of days taken to maturity were recorded with the application of 100 kg N + 50 kg P + 70 kg K/ha + 2 kg/ha Azotobacter + 1.9 kg/ha VAM. Use of biofertilizers viz. Azospirillum and Azotobacter increased the growth and yield as compared to corresponding control (Sharma et al., 2010).

To enhance the quality of onion bulbs, the application of plant hormones was evaluated at Anand Agricultural University, Gujarat (Patel et al., 2010). The application of GA3 50 mg/l as root dipping followed by foliar spray significantly increased volume of bulb, equatorial and polar diameter of bulb as well as bulb yield. Use of cytozyme at 0.2% as root dip before transplanting followed by foliar sprays (0.2%) at 15, 45 and 75 days after transplanting has been standardized for higher yield in onion (NHRDF, 2011). Root dipping treatment of NAA 100 mg/l was found effective to reduce the physiological loss of weight, spoilage loss and finally total loss as compared to control.
Organic farming has been found to increase the soil fertility (Subbarao et al., 2011). The use of green manuring with crops like sesbania, cowpea, berseem, wild indigo, green gram, black gram, dhaincha etc. has been advocated by Subbarao et al. (2011). Among the various organic growth stimulants viz. Panchagavya, Dashparni, Amrutparni, Vermiwash, Seeweed extract, EM Solution, Humic acid, Bio Potash and microbial extract, applied under organic production system, it was concluded that foliar application of Panchagavya (5%) at 30, 45 and 60 days after planting improved the marketable bulb yield in onion (20.2 t/ha) (DOGR, 2011, 2012).

Irrigation and Fertigation

Irrigation requirement of onion depends on the season, soil type, method of irrigation and age of the crop. Onion being a shallow rooted crop needs frequent light irrigation to maintain optimum soil moisture for proper growth and development. For crop establishment, irrigating field 8 hours before transplanting is essential (NHRDF, 2011). Water deficit at crucial growth stages of crop reduces productivity. Studies carried out at Bangalore indicated that maintenance of soil water potential of – 0.85 bar or less either during pre-bulb development (20-60 days after transplanting) or bulb development stages (60-110 days after transplanting) significantly reduced onion bulb yield, and bulb development stage was found to be more sensitive to moisture stress than pre-bulb development stage (Hegde, 1986). According to Saha et al. (1997) for optimum exploitation of the yield potential of Taherpuri onion, with maximum efficiency of irrigation water use, 10 to 20% depletion of field capacity moisture might be the most suitable criteria for irrigation. Irrigation at 0.55 atmospheric tension at 6-8 day intervals was found to give the highest yield (199 q/ha) in cv. Sukhsagar at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur (Deb et al., 2009). In cv. Telagi Red significantly higher bulb yield (54.91 t/ha), number of leaves, leaf area, LAI and neck girth per plant and equatorial diameter, polar diameter and bulb weight was recorded when field was irrigated at one day interval at 100% PE at University of Agricultural Sciences, Dharwad (Bagali et al., 2012).
Several research workers reported that through micro-irrigation higher crop yields can be obtained along with considerable saving in irrigation water (Bhonde et al., 2003, Sankar et al., 2008). Micro-irrigation likes drip and sprinklers have been successfully tried in onion by DOGR. Drip irrigation method produced significantly higher marketable bulb yield than other methods of irrigation. There was around 30% water saving in drip irrigation system as compared with surface system. The highest water-use efficiency (770 kg/ha cm) and minimum storage losses were recorded in drip irrigation system followed by sprinkler irrigation (386.5 kg/ha cm) and the lowest in the surface irrigation (252.5 kg/ha cm). The highest B:C ratio was found in drip irrigation which was 1.98 followed by surface irrigation (1.35) (Tripathi et al., 2010). To maximize the fertilizers use efficiency in onion, the drip fertigation with combined application of organic manures (FYM at 7 t/ha, poultry manure at 3.5 t/ha and vermicompost at 3.5 t/ha) along with 80% recommended dose of water soluble fertilizers have been recommended (DOGR, 2012).

**Weed Management**

Frequent irrigation and fertilizer application to onion crop favour severe crop-weed competition. Onion crop exhibits greater susceptibility to weed competition than most other crops, mainly due to its slow growth at initial stages and inherent characteristics such as short stature, non-branching, sparse foliage and shallow root system. Major monocotyledonous weed flora in onion are *Cynodon dactylon*, *Echino clucrosogalli*, *E. colacolonum*, *Sorghum halpense* and *Digitariao bsendens* (Vashi et al., 2010). Whereas the major dicotyledonous weeds in onion are *Phyllanthus maderaspatien*, *Ephorbia hirta*, *Amaranthus viridis*, *Digera arvensis*, *Trianthem aportulacastrum*, *Convolvulus arvensis* and *Physalis minima*. Sinha et al. (1999) recorded 33 weed species in an onion field at Patna, Bihar and among those, *Cyperus rotundus* and *Cynodon dactylon* were the most prominent weeds that limited the bulb production. Dicotyledonous weed numbers were found to increase with advancement in crop age in a sandy loam soil of Varanasi (Singh and Singh, 1994).
The critical period of crop-weed competition in onion occurred from 45 to 90 days after transplanting (Sankar et al., 2011). Because of labour scarcity, chemical control of weeds along with cultural methods is inevitable. Singh et al., (1991) reported that combined application of fluchloralin@1.25-2.50 kg/ha incorporated in soil 4 days before transplanting followed by pendimethalin at 1.25-2.50 kg/ha applied 1 day after transplanting in addition to one hoeing gave effective control of weeds in onion and resulted in higher bulb yield in a sandy loam soil. Application of pendimethalin at 0.75 kg/ha at pre-emergence stage and at 30 days after transplanting has also been found promising for weed control in onion in some other studies (Pandey et al., 1991; IARI, 2010).

A field experiment with *kharif* onion (*cv*. Bellary Red) on vertisols of Karnataka revealed that pre-emergence application of pendimethalin (1.0 kg/ha) + hand weeding at 45 days after sowing resulted in highest weed control efficacy (93.5%), bulb yield (13.16 t/ha), benefit: cost ratio (4.87) and the lowest weed index (11.8%) (Nadagouda et al., 1996). According to Saikia et al. (1997) maximum cost-benefit ratio (1:1.27) was obtained with fluchloralin (1.0 kg/ha) + hand weeding. However, Singh et al. (1997) reported soil application of Pendimethalin at 1.0 kg a.i./ha + 1 manual weeding at 60 days after transplanting as the most economical with a cost benefit ratio of 2:3.1.
Abdallah (1998) reported that if well prepared and pre-irrigated onion seedbed plots are covered with 50 µm-thick transparent polyethylene mulch for 6 weeks prior to seed sowing, it would result in the lowest number and weight of weeds/m² and higher seedling emergence. Pre-emergence application of Pendimethalin, Metolachlor and Oxyfluorfen at 1.0, 0.75 and 0.15 kg/ha and each supplemented with one hand weeding at 35 days after transplanting was observed significantly superior over the single application of these herbicides at higher rates in reducing weed dry matter and in enhancing bulb yield of onion (Kolhe, 2001). It was observed at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur that hand weeding at 40 days after transplanting along with application of quizalofop-ethyl 5% EC at 2.5 ml/l of water at 20 DAP significantly reduced weed density (25.5) and dry weight (55.3 g) of weed compared to other treatments. It also resulted in the highest bulb diameter (4.09 cm), bulb weight (13.42 kg) and bulb yield (335.64 q/ha) in cv. Arka Kalyan (Yumnam et al., 2009). NHRDF (2011) has recommended the use of rice straw mulch + pendimethalin at 3.5 l/ha at 3DAP for better weed control and higher yield of onion during rabi season and in case of its non-availability, wheat straw mulch + Oxyfluorfen at 0.15 kg a.i./ha could also be used. However, DOGR (2012) recommended application of Oxyfluorfen 23.5% EC at 1.5ml/l before planting and one hand weeding at 40-60 days after transplanting for good weed control efficiency (73.6 %), higher marketable bulb yield (36.1 t/ha) and the highest B:C ratio (2.54).

**Crop sequence**
Crop sequences vary depending upon the agro-climatic conditions of the particular location. Normally cauliflower, aster, tomato, potato, bajra, wheat and groundnut are good preceding crops for onion because they require much organic matter in the soil. In western Maharashtra, aster - onion, marigold - onion, groundnut - onion, bajra - onion, onion - wheat, potato - onion, and cucumber - onion sequences are popularly followed among farmers. Crop rotation of egg plant as preceding crop followed by onion as succeeding crop recorded the maximum number of micro-organisms in the onion rhizosphere whereas the minimum numbers of bacteria, actinomycetes and other microorganisms were observed in monoculture (Rankev and Surlekov, 1976). Vetrivelkalai and Subramanian (2006) studied the population dynamics of seven plant parasitic nematodes under onion based cropping sequences in Coimbatore, Tamil Nadu. The results revealed that in onion - maize - onion cropping sequence, the populations of *R. reniformis* and *P. delattrei* were increased whereas in onion - tomato - okra cropping sequence, the populations of *H. dihystera*, *H. seinhorsti* and *M. incognita* were increased.

Arya and Bakashi (1999) conducted an experiment at Palampur to find out a suitable onion based cropping sequence along with traditional cropping systems. The results revealed that onion cultivation is more profitable when okra and radish form one of the component vegetables in the vegetable sequences. The crop sequences consisting of aubergine - Chinese cabbage - onion and okra – radish - onion gave significantly higher gross returns than other sequences. The same crop sequences also produced the highest net returns and benefit: cost ratio in Himachal Pradesh. Groundnut - potato - onion cropping system was the best crop sequence with higher yield, more remunerative and land use efficiency (90%) in Punjab (Roy et al., 1999).
Studies conducted at DOGR, Rajgurunagar revealed that among the various cropping sequences evaluated, soyabean in *kharif* season followed by onion in *rabi* season was the best under western Maharashtra conditions in terms of yield, soil health and cost:benefit ratio. There was a tremendous improvement in physical and chemical properties of soil in legume based cropping sequences particularly soybean followed by *rabi* onion and groundnut followed by late *kharif* onion (Sankar *et al.*, 2014). However, growing soybean in *kharif* followed by onion in *rabi* was more remunerative and cost effective than other sequences (DOGR, 2012).

**Intercropping**

Sugarcane based intercropping with onion has been suggested (NRCOG, 2004). Onion is very much suited to grow as an intercrop in sugarcane under paired row planting system during winter season (November - December planting). Since this crop is shallow rooted bulb forming vegetable having low canopy, it does not compete with deep-rooted long duration crop like sugarcane. Sugarcane-onion intercropping is a common practice in some pockets of Haryana, Maharashtra and Tamil Nadu. Singh (1996) reported that cane equivalent yield and net returns were high when sugarcane planted in autumn was intercropped with onions.
In Karnataka, onion is grown as an intercrop with chilli or cotton. Chilli intercropped with one row of multiplier onion *cv. Co 2* recorded the highest yield of chilli pods and more net income per unit area per unit time compared to monoculture (Elangovan *et al.*, 1985; Dodamani *et al.*, 1993). Intercropping of onion with tomato decreased the level of thrips infestation by 79-85% and marketable yield increased by 104 to 284% (Afifi and Haydar, 1990). Khurana and Bhatia (1991) reported higher net returns in potato *cv. Kufri Badshah* intercropped with onion *cv. Hisar-2* than fennel crop. Kothari *et al.* (2000) reported that mint (*cv. Hy-77*) intercropped with one, two and three rows of onion (*cv. Nasik 58*) increased the net return, land utilization efficiency, improved soil moisture (0-15 cm) and utilization of solar radiation than sole cropping. Ibrahim *et al.* (2005) reported the highest intercrop yield when sugar beet plants were arranged in ridges at 60 cm apart, and with distance of 25 cm between sugar beet and onion. Mollah *et al.* (2007) reported the highest groundnut equivalent yield and benefit:cost ratio from groundnut was intercropped with two rows of onion or garlic.

**Farm Mechanization**

The shortage of labour at the crucial time and increasing labour cost make onion mechanization inevitable. This intervention is mainly solicited in labour intensive work *viz.*, sowing, transplanting, harvesting etc. Direct seed sowing with the local and pneumatic seed drill machine was compared with manual direct seed sowing (broadcasting) and seedling transplanting methods (DOGR, 2013). Among various direct sowing methods, bigger bulbs, more A grade bulbs and fewer double bulbs were observed in sowing using pneumatic seed drill. However, transplanting method of onion production recorded the highest marketable yield, which was significantly higher over the direct sowing with pneumatic seed drill. But low seed rate, easy sowing, saving in time and early maturity of onion were observed in sowing with pneumatic seed drill. The lowest marketable yield was observed in Poona seed drill followed by manual sowing (broadcasting) method.
A six-row tractor operated onion transplanter for flatbed has been designed and fabricated (IIHR, 2010). The six roller wheels press the root of the seedlings in soil and shovels cover the roots with soil. The row spacing in the present prototype is 15 cm and seedling spacing is 10 cm. The expected working speed is 1 km/hour and field capacity is 0.8 ha/day. Manual onion harvesting is also full of drudgery and the mechanization is essentially needed. Prototype of onion digger with length 1.2 m, speed ratio 1.25:1 and slope of the elevator 15 degrees, was found to have digging efficiency 97.7%, separation index 79.1%, bulb damage 3.5%, fuel consumption 4.1 l/ha (12.81 l/ha) and draft 10.78 kN (Khura et al., 2011). Onion detopper was designed and developed at Haryana Agricultural University, Hissar to facilitate the digging and top removal (Rani and Srivastava, 2012). The onion bulbs were fed through a chute type feeding unit to the belt conveyor moving at a speed of 0.53 m/s which ensures uniform transport of the bulbs to an oscillating conveyor. The cutter was provided at the downward side of the oscillating conveyor. The speed of the cutter could be varied and output capacity was 300 kg/hour with the de-topping efficiency of 79%. The belt conveyor had two rollers and an end-less conveyor belt.

For mechanical extraction of onion seeds, experiments were conducted with spike tooth extraction mechanism in a laboratory test set-up (IARI, 2010). The mechanism gave an extraction efficiency of 99% and cleaning efficiency of 97%. The seed loss ranged between 2.2% and 3.1% at cylinder speeds of 3-5 m/s. The costs of seed extraction by mechanical onion seed extractor and manual/conventional method were Rs. 1,800 and Rs. 9,000 per tonne of onion umbels, respectively. The break-even point for seed extractor was 78.77 hours with 31% of annual utility. The payback period of seed extractor was 2.4 years.
Grading of bulbs helps to improve the marketability of the produce. However, hand grading is an expensive operation. To reduce the cost of grading and increase the precision, two onion graders viz. manually operated and motorized graders were designed and evaluated by DOGR (Tripathi and Lawande, 2009). These have increased efficiency of 5 and 20 times, respectively, over hand grading. The precision of grading achieved by graders is 98% against 50% in hand grading. The capacity of manual grader is 5 quintals per person per hour with 90% accuracy. The capacity of motorized grader is two tons per hour with 90% accuracy.

Peeling of onion is essential to prepare different processed products viz. dehydrated onions, onion powder, onion flakes, onion salt, onion rings, and pickled and canned onions. Onion peeling machine would enhance efficiency of the processing. Central Institute of Agricultural Engineering, Bhopal has developed a batch type multiplier onion peeler (Naik et al., 2007). The multiplier onion needs to have the ends cut with a sharp knife and soaked in clean water for a period of 10 minutes to assist the loosening of peel followed by air drying for 1-2 minutes to remove the surface water. With 92% peeling, and unpeeled and damaged percentage being 6% and 2%, respectively, the capacity of the peeler was found 50-60 kg/h.

The adoption of above mentioned machinery, however, remains to be seen at farmers’ fields, because of high initial costs and utility restricted mainly to onion crop.

**Crop Protection**

Onion is reported to be infected by 29 fungal, four viral and four bacterial pathogens in India. (Gupta et al., 1994). Diseases such as Anthracnose, Purple Blotch and *Stemphylium* Blight cause extensive crop losses and are important throughout the onion producing areas of the country (Anon, 1986). Pink root and *Fusarium* basal rot also have significant impact on onion yield reduction in the country. Iris yellow spot and Onion yellow dwarf viruses are major viruses common and prevalent in major onion growing regions of the country. There are a few diseases of local importance such as downy mildew in temperate zones viz., Jammu and Kashmir and Uttarakhand.
These diseases are responsible for production and storage losses up to 50% or more annually depending upon the location, environment, cultivar and pathogen involved (Srinivas and Lawande, 2007). The amount of economic losses due to diseases varies significantly across three seasons. *Kharif* onion suffers heavily and losses reach as high as 50-60%, late *kharif* is comparatively safe, whereas *rabi* crop losses reach up to 20-30%. Apart from causing direct production losses, these pathogens significantly reduce marketable quality.

Onion is attacked by many insect pests also, which cause damage to leaves, bulbs, flowers and developing seed. Among these thrips and mites are the most damaging, which besides causing direct damage, also act as vectors of various viruses. No reliable source of host resistance in Indian short day onions against major diseases is recorded or reported. It makes imperative to resort only to chemical method of disease control. The symptoms caused and the control measures recommended (Sankar *et al.*, 2014) to control the diseases and pests of onion are given in Table 3.

**Postharvest Handling and Storage**
Post-harvest management is a crucial operation in the production chain. Although, the pre-harvest cultural practices such as fertilizer application, irrigation etc. have profound role on storage life of bulbs, these factors cannot be managed easily. Thus, proper post-harvest management practices become imperative. The studies revealed that post-harvest losses can range from 45-50% if proper care of the harvested produce is not taken. These losses mainly consist of physiological weight loss (20-25%), sprouting (8-10%) and decay (10-12%) (Gopal, 2014). The estimation of seasonal variation in storage losses revealed that the kharif onions were more prone to losses than late kharif and rabi seasons produce. The total losses which include physiological loss of weight, rotting and sprouting reached almost 70% in kharif after three months storage (DOGR, 2013). The light red varieties have more storability than dark red and white bulb varieties (Tripathi and Lawande, 2010). Besides, varietal difference in storability, the losses were also related with bulb size, neck thickness and neck length. A significant reduction in storage losses was observed when the last irrigation was applied five days before harvesting over irrigation applied just before harvesting (Sharma et al., 2007). The crop grown with drip irrigation was reported to have significantly lower losses than the crop grown with surface irrigation (Tripathi et al., 2010). Also, even slight damage to the dry outer scales may hasten loss of water during storage (Sidhu, 2008).

Curing is an important post-harvest management operation which decides the fate of storage. The windrow method of field curing for 3-5 days followed by shade curing for 7 to 10 days has been recommended. The curing of bulbs under poly-tunnel in kharif season and pits in rabi season was found effective in reduction of losses. Artificial curing of bulbs in curing chamber with full load at 35°C and airflow velocity of 3.2 m/s cured the bulb efficiently. These cured bulbs performed superior in storage as compared to curing under ambient condition during kharif season (NHRDF, 2011).
Pre-harvest application of isopropyl–N (3-chlorophenyl) carbamate (CIPC) (2%) at 75 days after planting has been found to reduce sprouting significantly in kharif onion varieties viz. Bhima Raj and Bhima Red after three months of storage (DOGR, 2012, 2013). However, its application in rabi crop was ineffective. Further, post-harvest application of CIPC (hot fogging) could not restrict the sprouting (DOGr, 2012). The gamma-irradiation of some varieties revealed that it could effectively check the sprouting and rotting in all onion varieties (Tripathi et al., 2011). However, no significant effect was observed on weight loss and black mould. It was observed that sulphur fumigation significantly reduced the black mould infestation.
| Category | Pest             | Symptoms                                                                                                                                  | Control measures                                                                 |
|----------|------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Insect   | Thrips (Thrips tabaci) | 1. Thrips infestation at the early stage (transplanting to 45 days) can be identified by curling and twisting of leaves  
2. Typical symptoms are the presence of white or silvery patches on leaves  
3. In severe infestation, whole plant looks blemished and turns white. | 1. Planting of two rows of maize or one outer row of maize and one inner row of wheat as a barrier crop surrounding onion crop (250 m²) at least 30 days prior to transplanting helps block the movement of adult thrips  
2. Foliar spray of insecticides like Profenofos @ 0.1%, Carbosulfan (0.2%) or Fipronil (0.1%) depending upon the severity of infestation |
| Eriophyid mite | | 1. Leaves do not open completely. Whole plant shows curling.  
2. Yellow mottling is seen mostly on the edges of the leaves. | 1. Foliar spray of Dicofol (0.2%) or sulphur @0.05% after 15 days interval, if necessary. |
| Fungal   | Purple blotch (Alternaria porri) | 1. Initially small, elliptical lesions or spots that often turn purplish-brown which are surrounded by chlorotic margin.  
2. If the spots enlarge, chlorotic margin extend above and below the actual lesion. Lesions usually girdle leaves, causing them to fall over. Lesions may also start at the tips of older leaves. | Foliar spray of Mancozeb @ 0.25% / Tricyclozole @ 0.1% / Hexaconazole @ 0.1% /Propiconazole @ 0.1% at 10-15 days intervals from 30 days after transplanting or as soon as disease appears |
| Fungal   | Stemphylium blight | 1. Small yellow to orange flecks or streaks develop in the middle of the leaf which soon enlarge into | Foliar spray of Mancozeb @ 0.25% / Tricyclozole @ 0.1% / Hexaconazole @ 0.1% |
### Research and technology development on onion: Indian perspective

<table>
<thead>
<tr>
<th>Disease</th>
<th>Symptoms</th>
<th>Control Measures</th>
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<tbody>
<tr>
<td><strong>(Stemphylium vesicarium)</strong></td>
<td>elongated, spindle shaped to ovate diffused spots surrounded by characteristic pinkish margin. 2. The spots progress from tip to the base of the leaves, blighting the leaves and gradually the entire foliage.</td>
<td>/Propiconazole @ 0.1% at 10-15 days interval from 30 days after transplanting or as soon as disease appears.</td>
</tr>
<tr>
<td><strong>Anthracnose/ Twister Disease (Colletotrichum gleosporiodes)</strong></td>
<td>1. The characteristic symptoms are curling, twisting, chlorosis of leaves, and abnormal elongation of the neck (false stem). 2. Initially pale yellow water soaked oval sunken lesions appear on leaf blades. Numerous black coloured slightly raised structures are produced in the central portion, which may be arranged in concentric rings. The affected leaves shrivel, droop down and finally wither.</td>
<td>1. Planting on raised beds 2. Avoid water logging 3. Foliar Spray of Mancozeb @ 0.25% 4. Soil treatment with Benomyl @ 0.2%</td>
</tr>
<tr>
<td><strong>Damping off (Pythium spp, Fusarium spp. and Rhizoctonia solani)</strong></td>
<td>1. Seedlings topple over after they emerge from the soil. It usually occurs at or below the ground level and infected tissues appear soft and water soaked</td>
<td>1. Planting onion on the raised beds 2. Seed treatment with Thiram or Captan @ 0.3%. 3. Drenching the nursery beds with Captan or Thiram @ 0.2% or Carbendazim @ 0.1% or Copper oxychloride @ 0.3%</td>
</tr>
<tr>
<td><strong>Viral disease</strong></td>
<td>Irish Yellow Spot Virus (IYSV) 1. Straw-coloured, dry, tan, spindle or diamond-shaped lesions, with or without distinct green centers with yellow or tan borders on leaves. The symptoms are more pronounced on flower stalks. Infected leaves and stalks lodge during the latter part of the growing season.</td>
<td>1. Plant high quality transplants free from thrips and Iris yellow spot virus. 2. Practice three years or longer rotations between onion crops. 3. Eliminate volunteers, culls, and weeds in and around onion fields.</td>
</tr>
<tr>
<td>Onion yellow dwarf virus (OYDV)</td>
<td>Mild chlorotic stripes to bright yellow stripes, mosaic, curling of leaves and stunted growth</td>
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1. Use virus free planting material
2. Use resistant cultivars
3. Aphid control will reduce the incidence which is a vector for OYDV
4. Foliar spray of Profenofos @ 0.1%, Carbosulfan (0.2%) or Fipronil (0.1%) for controlling aphids

4. Avoid crop stress.
5. Thrips control will reduce virus incidence as thrips are vectors.
At DOGR, a trial was conducted to assess the effect of different storage structures i.e. traditional, bottom ventilated, mud plastered and chain linked storage structures on storage losses. The packing materials *viz.* stakes, hessain cloth bags, netlon bags and plastic crates were compared for packaging. The results revealed that mud plastered top and bottom ventilated storage structure was superior in reduction of losses *i.e.* weight loss, rotting and sprouting over other structures irrespective of packing materials. Among single row structures, low cost bottom ventilated structure was found to be the best in reduction of losses and increase in net profit. Low cost storage model of 5 to 10 t capacity and high cost model of 25 to 50 t capacity with bottom and side ventilation recommended by DOGR have become popular among the farmers (Murkute and Gopal, 2013). Considering minimal storage losses, subsidy is being advanced to these models by different state governments. Cold storage is the most efficient way to restrict physiological weight loss. However, conducive atmosphere for sprouting in cold storages restricts its use.

**Processing**
Processing is an efficient way to increase shelf life without compromising the freshness and quality. Dehydrated products such as flakes, rings, granules, powder etc. and processed onions like onion in vinegar and brine are the important products being prepared and marketed worldwide. Onion can also be processed into oil, vinegar and wine etc. However, dehydration of onions is the oldest method of producing concentrated product which has longer shelf life when packaged properly, and can be simply reconstituted without any substantial loss of flavour, taste, colour and aroma. Onions are generally dried from an initial moisture content of about 86% (wet basis) to 7% or less for efficient storage and processing (Sarsavadia et al., 1999). Different methods used for dehydration of onion are solar drying, convective air drying, freeze drying, fluidized bed drying, microwave drying, vacuum drying, infra red drying and osmotic dehydration etc. All onion varieties are not suitable for dehydration. Specific characteristics recommended for drying are white flesh, 15-20% total solid content, high pungency, high insoluble solids and low reducing to non-reducing sugars ratio (Mitra et al., 2012). Based on the recovery and quality of red and white onion flakes, cabinet drying method has been recommended (DOGR, 2011). The white onions were found to give higher recovery (11%) than red onions (10%). Sun drying had the disadvantage of scorching and brownish colour due to direct exposure to sun light. Time required for drying is maximum in sun drying followed by solar drying and the minimum for cabinet drying. Cabinet dried onion flakes were found superior for shelf life and in rehydration ratio of flakes as compared to other drying methods.

Bulk trial on white onion dehydration using 50 kg lot indicated that dried onion yield of 9.9% on fresh weight basis could be obtained. Sensory evaluation studies using 9-point hedonic scale revealed that curry prepared from dehydrated onion was acceptable in terms of colour, taste/pungency and texture compared to fresh and rehydrated samples. Storage studies of dried white onion in three different packages, viz., PET jar (100 g), 150 gauge polyethylene pouch and plastic pallet at room temperature showed that at the end of 6 months storage period, samples packed in PET jar and plastic pallet retained original colour, whereas sample packed in polythene pouch developed browning (IIHR, 2010).

Marketing and Export
A number of agencies including producers, commission agents, merchants, wholesalers and cooperatives etc. are involved in marketing of onions. The onion bulbs are produced all over India but marketing is well organized only in Maharashtra, Karnataka, Delhi, Gujarat and Rajasthan. In these states, the cooperatives and NAFED are playing significant role in the marketing of onion bulbs. NAFED intervenes in the domestic marketing whenever there is glut in the market and prices reach uneconomical levels. The Agricultural Produce Marketing Committees (APMCs) were established in each state by the respective state governments with a view to regulate the marketing of agricultural produce. The regulation of markets had several positive features such as sale through auction method, reliable weighing, standardized market charges, payment of cash to farmers without undue deductions, dispute settlement mechanism, and reduction in physical losses of produce and availability of several amenities in market yards. Onion bulbs from different places of the country are assembled and distributed through (i) open auction system (Lasalgaon, Chakan, Pune, Mysore, Bellary); (ii) under cover or hatha system (Vashi, Mumbai); (iii) tender system (Mysore, Bellary and Hubli); (iv) open agreement system. Properly graded, well cured and cleaned bulbs should be marketed for fetching better price in the market.

Besides fulfilling the constant demand of domestic population, India exported 18.22 lakh tons of onion worth Rs. 2,294 crores during 2011-12 (NAFED, 2013). About 90% export of onion is from Maharashtra. 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 from Maharashtra is available. Export trade from Mumbai and Kandla port mainly to Gulf countries predominantly during November to April coincides with harvest of rainy season and late rainy season crops.
India is the third biggest exporter of onion, next to Netherlands and Spain, in the world and contributes about 12% of the global market. Mainly onion bulbs having dark and light red colour are exported from India. The major countries importing onion bulbs from India are Malaysia, Bangladesh, Indonesia, Kuwait, Maldives, Mauritius, Nepal, Quatar, Saudi Arabia, Seychelles, Singapore, UAE, UK etc. The specific requirements of export onion are 4-6 cm bulb diameter, light to dark red colour, round shape, strong pungency for gulf markets and South East Asian markets. Whereas for Bangladesh, bulbs of 3-4 cm diameter and having light red and round shape are preferred. Yellow/brown colour bulbs of 7-8 cm diameter and having round or spindle shape are preferred in the European and Japanese markets. Small onions (Agrifound Rose and Bangalore Rose) grown in Karnataka and Andhra Pradesh, and Multiplier onion (Co4 and Co5) grown in Tamil Nadu are exported to Malaysia, Singapore and Gulf countries. Onion is an unique example where market forces have influenced domestication and diversification of the crop largely.

**Future Challenges**

Although research and development has helped in enhancing production and export of onion, in productivity there is marginal increase. Statistics (Figure 1) indicate that in India production of onion has increased from 47.21 lakh tons in year 2000 to 175.11 lakh tons in 2012 (DES, 2013). This increase, however, has come mainly from increase in area which in 2012 stood at 10.87 lakh ha. 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, which is lower than world average of 18.67 t/ha. The highest productivity of onion has been reported to be 62.50 t/ha in Ireland (DES, 2013). Maharashtra, Karnataka, Gujarat, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamil Nadu are the main onion growing states of India. In general, barring North Eastern states and Kerala, all other states grow onion. Country’s 26% area and 29% production alone come from Maharashtra (Figure 2).
Figure 1: Year-wise area, production and productivity of onion in India.
Source: DES, 2013.
The main reasons for low productivity of onion in India are listed below.

1. Inherent low yield potential of short day onion varieties.
2. Non-availability of suitable F1 hybrids.
3. Susceptibility of all cultivars to diseases, pests and abiotic stresses.
4. Tropical climate is more congenial for diseases and pests.
5. Non – availability of genuine seeds of released varieties.
7. Shortage of irrigation at critical stages.
8. Poor storage capacity of present day varieties and poor storage facilities.
9. *Kharif* crop always pull down country’s average productivity.
10. Fluctuation of prices distracts the attitude of farmers towards use of inputs and modern technology.
India is projected to have population of 1.7 billion by 2050, and there is limited possibility to increase the cultivable land. To cater to 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 2010-2011), we will require 24.62 million t of onion in 2050 against 19.29 million t in 2013-14. This demands an increase in average productivity from 15.85 to 22.7 t/ha, which is 42.9% higher than that of in 2013-14. 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 19.29 to 33.39 million t with productivity of 30.72 t/ha.

Thus, there is need is to explore the innovative measures to improve productivity and stabilize production of onion in India. The following interventions may help to improve the productivity and prospects of onion cultivation in India.

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

ii. Biennial nature, high cross-pollination and sharp inbreeding depression in onion are still challenges for breeders using 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 onion seed 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 exist 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.
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iv. Thrust is required to increase the national storage capacity. Infrastructure facilities need to be created that about 30-40% produce is stored in the cold storages to significantly reduce the post-harvest losses.

Focus should also be to evolve a robust supply chain based on domestic demand, export and a quantum for processing to avoid price fluctuations by harnessing available resources, modern infrastructures, improved technologies and innovative endeavours. Policy makers will have to work hard to provide amicable solutions on pricing which should lead to higher profits to farmers but not at the cost of consumers.

References


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Introduction

In Bangladesh, onion (*Allium cepa* L.) is a high value spice crop. It ranks first in production among the spice crops cultivated in the country. It is used as salad while in green stage cooked in various ways in all curries. It is also used in pickles, chutney, stew, cooked vegetables or sauces, and for the preparation of certain other products. It contains little vitamin 'B' and 'C' and traces of iron and calcium. Besides, it has many medicinal values too. In Bangladesh the total production of onion is 18.72 lakh mt with an average yield of 10.54 t/ha which is very low as compared to the world production. The average world production of bulb onion in the last three years was approximate 73 million mt (FAO, 2010). In terms of productivity among major onion producing countries, Korean Republic tops the list with 67.25 t/ha followed by USA 53.91, Spain 52.06, Japan 47.55, Netherlands 43.13, Iran 34.0, Egypt 32.18, Mexico 29.13, Turkey 26.76 and Brazil 21.38 t/ha, respectively (FAO, 2008). But in terms of total production China ranks first followed by India (Asrey *et al.*, 2008). The yield of onion seed varies from 370 to 500 kg/ha in Bangladesh which is very low compared to 1,000 to 1,200 kg/ha in other countries of the world (Brewster, 1994).

Several factors are responsible for low productivity in onion *viz.* low yielding variety compared with other onion producing countries, lack of variation in local cultivar, lack of hybrid as well as open pollinated (OP) high yielding varieties, low keeping quality of summer onion, disease and insect attack, adverse climate, non-availability of seeds etc. Considering the above, a long term research program was undertaken at the Spices Research Centre, Shibganj, Bogra, Bangladesh with several objectives to create genetic variability, increase shelf life, tolerance to purple
leaf blotch, searching male sterile line for hybrid seed production and to develop superior variety(s) with higher yield.

**Background of Spices Research in Bangladesh**

Research on spice crops was not emphasized in earlier in Bangladesh. During 50\textsuperscript{th} decade a temporary research project of 3 year duration was undertaken with the financial assistance of the Agriculture Funding Coordinated Project (FACP). At the end of 60\textsuperscript{th} decade-another project-“Black and White Pepper Scheme” was initiated with the financial assistance of Agricultural Research Coordination Project (ARCP) which ended in 1966. After 15 years, another spice research scheme named, “Collection and Evaluation of Spices and Culinary Herbs of Bangladesh” was initiated with the financial assistance of the Bangladesh Agricultural Research Council (BARC). In that period, a survey was conducted for collection of germplasm and to document information on farmer’s practices of spice crops. This scheme ended in June, 1986. Thereafter, the research activities on spice crops continued in a very limited scale during 1987-1994.

**Research and Technology Development of Onion in Bangladesh**

*Research in private sector:* The limited research has been done on onion in the private sector. Recently, Lal Teer, Suprim Seed and ACI companies have started research in onion on a small scale. Lal Teer recently developed one winter onion variety named Taherpuri King through selection. Recently, some of the private seed companies have established research and development (R&D) divisions for different crop research. Yet, no variety was released. Hence, research information on these aspects is still in infancy.

*Research in public universities:* Many agricultural universities in Bangladesh have initiated research on vegetables, fruits, flowers, pulses, oils and grain crops. Among them, Bangladesh Agricultural University (BAU), Mymensingh is conducting research on soil and fertilizer management, water requirement, agronomic practices, insect and disease management of onion through M.Sc. and Ph.D. research programmes.
Chowdhury, M.N.A.

**Research in Spices Research Centre (SRC):** SRC established in 1995 under the Bangladesh Agricultural Research Institute (BARI) is mandated for spices research and development. SRC has developed 16 varieties of 8 types of spices and a number of technologies (210) on varietal improvement, soil and fertilizer management, water requirement, agronomic practices, insect pest and disease management, post-harvest storage and processing of different spice crops.

**Goals of Spice Research Centre (SRC)**

- To increase spices production through varietal improvement and development of production technologies
- To introduce new lines/races of different spices from exotic sources
- To reduce import of spices and save foreign exchange

**Research and development areas of SRC**

- Variety development
- Crop management
- Disease and insect management
- Seed production and distribution
- Socio-economic studies
- Technology validation and transfer and impact study at the farmers field level

**Research objectives of SRC**

- Collection, evaluation and conservation of different indigenous and exotic germplasm of spices crops.
- To develop high yielding varieties of different spices crops having high degree of tolerance/ resistance to common insect pests and diseases.
To develop somaclonal variation, diseases free plantlet production, haploid production for hybridization program, virus cleaning through meristem culture of different spices crops using biotechnology.

To develop appropriate and improved sustainable production technologies of spices crops including cultural, soil, water, disease and insect pest management.

To develop improved post harvest handling, processing and preservation technologies of different spice crops.

To strengthen farm research of newly released varieties in different agro-ecological zones for transfer of technologies to end users.

To strengthen adaptive research of newly released spices varieties in different agro-ecological zones.

Breeder seed production and distribution for Bangladesh Agriculture Development Corporation (BADC).

Technologies Developed

Variety development / improvement: Variety of any crops is a key factor in crop cultivation and directly related to its productivity. SRC developed six onion varieties through conventional breeding, including selection. Among them, two are winter varieties (BARI Onion-1 and BARI Onion-4), three are summer varieties (BARI Onion-2, 3 and 5) the other one is BARI Pata Piaj-1. Salient features of those varieties are presented in Table 1.

Breeding program: The objective of this program was to create genetic variability, increase shelflife, tolerance to purple leaf blotch and identify male sterile lines of onion. During the last two years, there were no remarkable findings but some inbred lines developed were used as good breeding materials. Different breeding programs-mass selection, modified mass selection, family selection, hybridization addressing increased shelflife, yield potential, insect and disease tolerant are also in progress.

In Bangladesh the onion growers use the available open pollinated local varieties viz. Taherpuri, Faridpuri, Jitka, Suksagar etc. All the open pollinated varieties are low yielders. Hybrid technology by utilizing CMS mechanisms is
being used worldwide for improvement of yield in onion. There is also a scope of development of high yielding hybrid varieties in tropical onion. Considering the scope, problems and necessity of hybrid variety, a series of experiments have been conducted both on station of SRC and the farmer’s field. It was noted that about 70-80% male sterility was found in the onion growing region of Faridpur, Rajshai and Pabna districts of Bangladesh. Thirty onion germplasm were collected from home and abroad in 2011-2013 for male sterility study. Salient features of those germplasm are presented in Table 2. To develop the male sterile lines, it was observed that spraying with GA$_3$ (500 ppm) at 30, 45 and 60 days after sowing showed about 30-50% male sterility in BARI Onion-1, 3 and 4. Spraying with MH (150 ppm) at 30, 45 and 60 days after sowing showed about 60-70% male sterility in BARI Onion-1, 2 and 5.

Table 1. Main characteristics of released onion varieties

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of variety</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BARI Onion-1</td>
<td>i) Winter variety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) Flat and medium size (30-40 g)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) Thin neck</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv) Long shelflife and high pungency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>v) Yield: 12-16 t/ha (bulb), 800-1,000 kg/ha (Seed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vi) Crop duration: 120-140 days (Seed-bulb)</td>
</tr>
<tr>
<td>2</td>
<td>BARI Onion-2</td>
<td>i) Round with reddish colour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) High yield potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) Year round production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv) Keeping quality very low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>v) Yield: 10-13 t/ha (bulb), 600-700 kg/ha (Seed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vi) Crop duration: 60-70 days (Seedlings-bulb)</td>
</tr>
<tr>
<td>3</td>
<td>BARI Onion-3</td>
<td>i) Oblong with reddish colour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) High yield potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) Year round</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv) Keeping quality very low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>v) Yield: 10-12 t/ha (bulb), 600-700 kg/ha (Seed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vi) Crop duration: 60-70 days (Seedlings-bulb)</td>
</tr>
<tr>
<td>4</td>
<td>BARI Onion-4</td>
<td>i) Winter variety, reddish in colour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) Globular and big size (70-80g)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) Thin neck and longer shelflife</td>
</tr>
</tbody>
</table>
iv) Yield: 18-20 t/ha (bulb), 700-900 kg/ha (Seed)
v) Crop duration: 130-140 days (Seed-bulb)

5  BARI Onion-5
i) Lower portion flat, upper portion slightly elongated
ii) Bulbs are dark red, globular with tight skin, moderately pungent
iii) High yield potential and year round production
iv) Low keeping quality
v) Matures in 65-75 days after transplanting in kharif-1
vi) Matures in 90-120 days after transplanting in kharif-2
vii) Average yield 12-16 t/ha in kharif-1
viii) Average yield 22-25 t/ha in kharif-2
ix) Suitable for fresh market
x) Seed yield 500-700 kg/ha
xii) Recommended for kharif season (summer)

6  BARI Pata Piaj-1
i) No bulb formation
ii) Year round for leaf production
iii) Tolerant to purple leaf blotch disease
iv) Leaf yield 15-20 kg/ha
v) Seed yield 1,000-1,200 kg/ha
vi) Commercial cultivation: Throughout the country

Table 2. Main characteristics of germplasm of onion in Bangladesh

<table>
<thead>
<tr>
<th>Germplasm</th>
<th>Bulb Characters</th>
<th>Male sterility (%)</th>
<th>Germination (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON0297</td>
<td>Flat, large size, brownish</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>ON0298</td>
<td>Flat, medium size, light reddish</td>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>ON0299</td>
<td>Flat medium size, light reddish</td>
<td>15</td>
<td>72</td>
</tr>
<tr>
<td>ON0300</td>
<td>Flat, large size, brownish</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td>ON0301</td>
<td>Upper portion elliptical-lower portion flat, medium size, brownish</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>ON0302</td>
<td>Upper portion elliptical-lower portion flat, medium size, pinkish</td>
<td>15</td>
<td>72</td>
</tr>
<tr>
<td>ON0303</td>
<td>Upper portion elliptical, medium size, pinkish</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>ON0304</td>
<td>Lower portion flat, medium size, pinkish</td>
<td>25</td>
<td>83</td>
</tr>
<tr>
<td>ON0305</td>
<td>Round shape, brownish</td>
<td>10</td>
<td>75</td>
</tr>
</tbody>
</table>
For increasing the shelflife, BARI Piaj-2, 3 and 5 (summer onion) was crossed with BARI Piaj-1 and 4 (winter onion). In this year F₁ bulbs have been planted to produce bulbs for the shelflife study. To create genetic variation, crossing was made in full diallel fashion with BARI Piaj-1 and 4 (winter onion) and 2, 3 and 5 (summer onion) in 2011-2012. From this study some variation has been found in respect of bulb colour, shape and size. The existing winter variety BARI Onion-4 has higher bulb yield potential than BARI Onion-1 but shorter shelflife. Due to low shelflife farmers cannot store these varieties for long time. BARI Onion-1 has longer shelflife than BARI Onion-4. BARI Onion-4 has thick necked bulb with high moisture percentage resulting in rotting and poor keeping quality. In view of this random crossing was made between above mentioned varieties in previous years and advancing up to F₄ generation with six types (F₄-1, F₄-2, F₄-3, F₄-4, F₄-5 and F₄-6). It was found that F₄-3 generation gave the highest bulb yield (22.68 t/ha) and zero rotten percentage (From April to 20 October 2014).

**Development of Production Packages**

Cultural management as well as production practices are very important for higher yield, quality seed and bulb production in onion. The production technology is key factor for increased the onion production and the following production practices have been developed.

*For bulb production:*

- Seeds should be sown on November in seed beds for raising seedlings for winter bulb production
- Seedlings are transplanted at 40-45 days
Seedlings were transplanted on 20 December to 10 January along with 10 cm x 8 cm or 7.5 cm x 7.5 cm spacing increased bulb yield.

The land should be fertilized with cow dung 10 t/ha and N\textsubscript{120}, P\textsubscript{50}, K\textsubscript{75} and S\textsubscript{20} kg/ha.

Irrigation should be applied at 30, 50 and 70 days after planting for quality bulb production.

After bulb formation forced toppling should be done to stop the growth up to 7 - 10 days before harvesting.

After harvest, bulb should be kept in shade for 5-7 days for curing.

**For seed production**

- Bulb to seed method for seed production
- Disease free single bulb with thin neck should be selected for quality seed production. Split/double bulb should be discarded
- Medium size bulb of 15-20 g for BARI Onion- 1, 2, 3 and 5 and 25-30 g for BARI Onion-4 increase seed yield.
- Dipping and spraying of summer onion bulb in GA3 solution at 50 and 100 ppm, respectively, favours uniform bolting, bursting, increasing number of stalks and seed weight/plant.
- Traditionally, mother bulbs are planted at the end of October. However, due to change in environmental temperature the planting time is to be shifted to 10-20 November results in increased seed yield. Early planting reduces the number of flowering stalks and florets in the umbel. Late planting (December) retards the vegetative growth and reduces the number of florets in the umbel, increase incidence of purple blotch disease and thrips infestation resulting poor seed quality. Moreover, the crop may be damaged by hail storm.
- The highest seed yield was recorded with the spacing of 20 cm x 15 cm.
- Efficient and balanced nutrient management is needed for good seed yield of onion. Cow dung (5 t/ha) with N\textsubscript{115}, P\textsubscript{54}, K\textsubscript{75}, S\textsubscript{20}, Zn\textsubscript{3} and B\textsubscript{2} kg/ha increase seed yield.
- Seed plot must be kept weed free. Three hand weeding at 20-25, 35-45, and 60-75 days after emergence reduce the weeds infestation. Infestation of
Cyperus rotundus is a serious problem for onion seed crops. Onion is a shallow rooted crop so frequent weeding may damage the root system and thus hamper growth and reduce yield.

- Irrigation at vegetative + scape initiation + flowering + milking stage is the best option in respect of seed yield and economic performance
- Flowering stage is the critical for irrigation of onion seed production
- Poultry manure at 3 t/ha as side dressing increase yield of onion by 12-20% and also increase keeping quality.
- Diseased and unhealthy plants with slender flower stalks should be rouged out before flowering
- To avoid lodging of flower stalks due to strong wind and irrigation, support should be provided with bamboo stick and nylon rope.
- When temperature rises at flowering, seed crops are attacked by thrips that suck the sap from flower stalk and florets resulting in poor seed set and deteriorate the seed quality, hence effective control measures should be undertaken to control thrips.
- The seed should be harvested when the fruit opens and exposes the black seed. According to Howthorn and Pollard (1954), a field is considered ready to harvest when about 10% of the heads have exposed black seed. At this stage practically all the seed is well matured to give a good germination. Two to three pickings may be necessary to harvest the heads.
- After harvest seed heads should be properly dried, threshed and seeds are cleaned
- Before storage the seed must dried at 6-8% moisture content.

For bulblets production

- Seeds at 10 g/m² are seeded on flat beds.
- The best time of sowing seed for getting quality bulblets is mid February to beginning of March depending upon the area.
- The plants are left in nursery bed up to April-May till there is top fall. Carbandazim has to be sprayed at 0.1% at 10-20 days before harvesting to reduce decay in storage bulblets.
Harvesting is done along with the tops and selected bulblets are stored by hanging method till September-October in a well ventilated house. The large size (4-10 g) bulblets are used for seed production and small size (1-3 g) bulblets are used for fresh bulb production in Kharif-2 season (July-September).

**Others Technologies**

- Intercropping onion with aroids was economically profitable. Farmers may get 60,000 to 70,000 Taka/ha as additional income.
- Cultivation of turmeric with lalshak-yardlong bean - bottle gourd and turmeric with summer onion-snake gourd-country bean are the best intercrop/companion crop combinations in respect of yield and economics. It will give 39% additional profit than mono crop system.
- Cultivation of ginger with summer onion-yardlong bean-bottle gourd and ginger with chilli-yardlong bean-bottle gourd are the best intercrop combinations in respect of yield and economics. It will give 44% additional profit than mono crop system.

**Disease Management**

Onion is attacked by 66 diseases including 10 bacterial, 38 fungal, 6 nematode, 3 viral and 1 phytomlasm, 1 parasitic and 7 miscellaneous diseases and disorders (Mohan and Moyer, 2004). In Bangladesh the common diseases such as purple leaf blotch (*Alternaria porri*), stemphyllum leaf blight, downy mildew (*Peronospora destructor*), and basal/ stem rot (*Fusarium* spp., *Sclerotium* spp., *Rhizoctonia* spp.), damping off. Purple leaf blotch, stemphyllum leaf blight and damping off in the seedling stage are the most destructive and reduce the bulb and seed yield, sometimes up to 100%. These diseases occur in both seasons, *Rabi* (October-March) and Kharif I (April-June) and II (July-September). Some of the research findings on disease management are as follows:

- Rubral at 2g/l of water at 15 day intervals has been effective for the management of purple leaf blotch disease.
Stemphylium blight can be controlled by using Ridomil MZ at 2g/l of water at 10 days intervals.

For controlling seedlings disease, the seed should be treated with Provex (carboxin + thiram) at 2 g/kg of seed before sowing.

The seed bed should be drenched with Provax at 2 g/l of water at fortnightly intervals.

Application of bio-control agent (*Trichoderma viride*) in the seed bed or main field can reduce the disease.

Bavistin at 2-3 g/l of water at 15 days intervals after sowing effectively reduced the damping off in the seed bed.

**Insect Management**

Thrips are the major insect pest in onion. Other insects such as white fly, head borer, onion maggot, and army worm are occasional problems. Thrips cause significant yield loss during heavy infestation on bulb and seed production. Control of this sucking insect is very difficult during flowering stage because spraying insecticides at this stage may reduce pollinators or wash out viscosity attributes of the gynoecium that reduce pollen receptivity. Some of the research findings on insect and pest management are as follows:

- Botanical insecticides and entomo-pathogenic fungal (EPF) insecticides are highly effective, safe and ecologically acceptable (Nathan et al., 2004). A study has been undertaken to find out the best performing organic insecticide against thrips in onion and found that Tobacco leaf extract treated (12 thrips/plant) and neem seed extract (12 thrips/plant) reduce the thrips infestation.
- ONO 281 showed minimum thrips infestation and gave identical bulb yield.
- Carrot and Safflower were most effective in controlling thrips on onion.
- Spinoside (Tracer 45SC) at 0.4 ml/l of water performed best in controlling thrips in onion.
- In integrated management aspect sticky white trap+ Fipronil (Tracer 45SC) have been found most effective in controlling thrips in onion with higher yield and highest marginal benefit cost ratio (MBCR)
Temperature was positively correlated with thrips population in onion and garlic. Thrips population increase rapidly from mid February to mid March when temperature rises above 30°C with lower relative humidity. During this period onion should be sprayed with Karate (lambda-cyhalothrin) at 1 ml/l or Admare at 0.5 ml/l at 7-10 days intervals for controlling thrips infestation.

Pollination

Onion is a highly cross pollinated and pollinators are essential for higher seed set and increased seed yield. Honey bees, blow flies, syrphid flies and house flies are the common insect pollinators of onion. Pollination of onion seed crops has been studied in India. Trigona iridipennis, a stingless bee, Apis cerana and A. florea and two tropical bees were the principal onion pollinators (Rao and Lazar, 1983). Onion nectar is rich in potassium and its viscosity tends to increase as the temperature increases. So, bee prefers alternate nectar source. Spices Research Centre has found that sowing one/two lines coriander, dill or fennel around the border or every 10 alternative rows of onion can increased seed setting to about 67-69 % compared to control (55 %). Dill and fennel should be planted at the time of onion planting and coriander should be planted 18 days after onion planting (Uddin et al., 2011; 2012). Supplementary pollination using honey bee hives in the seed fields cross-pollinated by insects ensure good seed set and increased seed yields.

Harvesting and Drying

Harvesting of onion is critical and crucial for obtaining good quality seed. In early harvest, some seeds remain immature, light weight, poor vigour or non-viable. If harvesting is delayed some seed may fall by shattering. Harvesting is commonly done when 10% of the heads have black seed exposed (Howthorn and Pollard, 1954) or 20-25% capsule in each umbel expose black seed. Two to three picking is needed to collect the whole seed head. The harvested umbels are thoroughly dried on a tray (made of wood with net at the base) or on a canvas before threshing. The seeds can be separated by floating or by rubbing by rubber sole over gunny bags. The seeds are then dipped into water for few seconds to
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remove dust or empty seed and sun dried for 2-3 days under mild heat. The moisture content of the seed should be 5-6 % before packaging. After drying and cooling (shade) they are packed in moisture proof package like aluminium foil or in opaque plastic drum.

**Constraints for Quality Bulb and Seed Production**

- Lack of indigenous and exotic germplasm
- Lack of variation in local cultivars
- Inadequate lands under spices production
- Inadequate supply of seeds at farmer’s level
- Lack of storage facilities and technical know-how at farmer’s level
- Very little scope to collect exotic germplasm
- Problems of thrips at flowering stage.
- Scarcity of insect pollinators.
- Thrips- white fly - sooty mold complex.
- High seedling mortality during summer onion bulb production.
- Lower storability/shelflife of summer onion.
- Purple blotch-*Stemhylium* blight complex.
- Rainfall/storm during harvest of bulb and umbel.
- Seed drying problem in cloudy weather.
- Poor water management in farmer’s field.
- Varietal admixture at farmers level
- Premature bolting

**Future Plan**

- Development of specific purpose varieties (high pungency, heat and drought tolerant etc.)
- Development of improved varieties against thrips and purple leaf blotch
- Marker assisted breeding for identification of duplicate germplasm
- Variety development through biotechnological approaches
 Participatory research approaches for quality seed production
 Postharvest management
 Development national seed production system
 Increasing supply the breeder/ foundation seed for the BADC

References

DAE 2013. Krishi Diary. AIS. Khamar Bari, Dhaka, Bangladesh
Abstract

Onion is an important cash crop in Sri Lankan agriculture and attention is given to increase the production through increasing productivity and area under cultivation to achieve market demand in big onion and self-sufficiency in red/cluster onion. Several technologies have been identified to increase the productivity while massive production campaigns have been launched to achieve this task. Expansion of true seed production of big onion and red/cluster onion has been identified as one of the key factor to increase productivity while expansion of cultivation in non-traditional areas is identified as an appropriate strategy to ascertain continuous production to meet the market demand. Department of Agriculture with the Provincial Departments of Agriculture is engaged in a systematic program to achieve this task to reduce the dependency on imports to reduce foreign exchange incurred on seed and bulb imports to meet the consumer demand of onion.

Introduction

Onion is one of the important spice crops of Sri Lanka and is extensively used in all Sri Lankan cuisines. Further, onion is used for different purposes in Ayurvedic medicine and therapies. The crop is well adapted to Sri Lankan conditions with long days (>12 hours/day) and cultivated in dry and intermediate zones. Two main types of onions are consumed by Sri Lankans namely, big onion (Allium cepa L. var. cepa) and red/cluster onion (Allium cepa L. var. aggregatum). The annual requirements of big and red onion are 220,000 t and 80,000 t, respectively in 2013 (Tables 1 and 2; DCS, 2013). Average per capita requirement of onion is around 10-11 kg. Based on the availability and the market price of big
and red onion, consumer demand for big and red/cluster onion change to meet the domestic demand. Sri Lanka produces about 80,000 t of big onion, which accounts for the 36% of national requirement. The average annual production of cluster/red onion is around 72,000 t which is close to self-sufficiency.

Table 1: Big onion production, imports and seed requirement - 2000 to 2013.

<table>
<thead>
<tr>
<th>Year</th>
<th>Ext (ha)</th>
<th>Prod (mt)</th>
<th>Av. Yld (mt/ha)</th>
<th>Quantity (mt)</th>
<th>Value (Rs. 000)</th>
<th>Seed Requirement (kg) (@ 6.5 kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2,796</td>
<td>36,560</td>
<td>13</td>
<td>117,500</td>
<td>1,501,538</td>
<td>18,174</td>
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<td>2001</td>
<td>2,815</td>
<td>31,966</td>
<td>11</td>
<td>110,181</td>
<td>1,749,368</td>
<td>18,298</td>
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<tr>
<td>2002</td>
<td>2,906</td>
<td>31,560</td>
<td>11</td>
<td>131,851</td>
<td>1,900,174</td>
<td>18,889</td>
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<td>2003</td>
<td>2,770</td>
<td>32,301</td>
<td>12</td>
<td>130,535</td>
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<td>3,075</td>
<td>37,508</td>
<td>12</td>
<td>115,120</td>
<td>2,168,760</td>
<td>19,988</td>
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<td>2005</td>
<td>4,552</td>
<td>55,552</td>
<td>12</td>
<td>110,713</td>
<td>1,826,136</td>
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<td>2006</td>
<td>6,814</td>
<td>73,616</td>
<td>11</td>
<td>119,478</td>
<td>1,940,185</td>
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<td>2007</td>
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<td>92,167</td>
<td>13</td>
<td>140,773</td>
<td>4,392,183</td>
<td>45,422</td>
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<td>2008</td>
<td>4,091</td>
<td>57,371</td>
<td>14</td>
<td>146,623</td>
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<td>26,592</td>
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<td>2009</td>
<td>5,081</td>
<td>81,707</td>
<td>16</td>
<td>143,274</td>
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<td>4,158</td>
<td>58,930</td>
<td>14</td>
<td>158,086</td>
<td>6,649,347</td>
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<td>2011</td>
<td>3,451</td>
<td>45,682</td>
<td>13</td>
<td>170,731</td>
<td>6,556,191</td>
<td>22,432</td>
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<tr>
<td>2013</td>
<td>4,223</td>
<td>69,638</td>
<td>16</td>
<td>168,874</td>
<td>9,179,011</td>
<td>27,450</td>
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</table>

Source: SEPC, 2013

Varieties

Before early 1980's big onion cultivators mainly used imported seeds from India and the varieties were Pusa Red, Puna Red, Nasik Red and Red Creyol. During 1992, Department of Agriculture released the first big onion variety Kalpitiya to the farmers. The main advantage of this variety was that it flowers and produces viable seeds under dry zone conditions without vernalization of mother bulbs (Kuruppuwarachchi and Fernando, 1993). Therefore, this variety attracted many farmers in some of the onion growing areas and replaced the Indian varieties to some extent. Meanwhile selecting better mother bulbs either from imported Pusa
Red or Puna Red, farmers of Dambulla area started producing seed, designating a cultivar called Dambulla Red. Few farmers initiated self-seed production in Dambulla area during mid 1980's and expanded season by season to replace the Indian seed market. Similarly, farmers in the Galewela area have also undertaken mother bulb selection using imported variety Agrifound Light Red and named a new cultivar as Galewela Light Red. This cultivar is dominant in the Galewela area. With the initiation of onion breeding program in mid 70's, Field Crops Research and Development Institute (FCRDI), Mahailuppallama released variety Dambulla Selection in 2009 (DOA, 2009). In 2014, FCRDI released another big onion variety namely MI BO 01.

Table 2: Red onion production, imports and seed requirement - 2000 to 2013.

<table>
<thead>
<tr>
<th>Year</th>
<th>Ext (ha)</th>
<th>Prod (mt)</th>
<th>Av. yld (mt/ha)</th>
<th>Imports Quantity (mt)</th>
<th>Value (Rs. 000)</th>
<th>Seed requirement (kg) (@ 1.5 mt/ha)</th>
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<tbody>
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<td>2,726</td>
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<td>1,583,309</td>
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<td>4,498</td>
<td>46,234</td>
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<td>1,082,713</td>
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<td>641,286</td>
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<td>15,386</td>
<td>1,383,387</td>
<td>6,908</td>
</tr>
</tbody>
</table>

Source: SEPC, 2013.

Vethalan and Jaffna Local are the main cultivars, which are popular among cluster/red onion growers in Sri Lanka. Department of Agriculture has released the first ever cluster/red onion variety namely Thirunelvely Red (synonyms of
Present status and future prospects of onion cultivation in Sri Lanka

Thinnavely Red) for cultivation in the northern region in 2009, which matures at 70 days (DOA, 2009). Apart from those varieties and cultivars some other cultivars such as Vellarai in Jaffna district and Telulla Selection in Moneragala district are also being cultivated by farmers.

**Cultivating Season**

Big onion is mainly cultivated in the dry (*yala*) season during mid April to mid June and the crop is ready to harvest from end of July till early September in Matale and Anuradhapura districts, which are the major onion growing areas. Comparatively smaller extent is cultivated in late *maha* wet season (late December to early January). Recently, big onion cultivation has been expanded to Hambantota and Moneragala districts for off season production.

Red/cluster onion is grown both *maha* and *yala* seasons in the northern and eastern regions of Sri Lanka avoiding heavy rainy periods for planting and harvesting. In Kalpitiya area in the Puttalam district red onion is cultivated continuously except in February to avoid the possible frost damages. Red onion is grown in Telulla area of Moneragala and Ratnapura districts mainly in *yala* season.

Since the onion is harvested within a short period of time in the months of July to September, and due to perishable nature of the crop, long term storage is difficult to supply the monthly market demand. Therefore, Sri Lanka imports large quantities of big onion from the region to meet the off season demand. The Department of Agriculture in 2013, has identified few locations in the southern and northern provinces to produce off season big onions and red onions.

The mass onion production drive carried out in Hambatota area, in the DL5 Agro-ecological region, during 2013/14 *maha* was successful. Extension programs have used a novel approach in utilizing trained farmers to work hand in hand to disseminate knowledge and experience to new farmers to make this effort a success. Department of Agriculture strongly believes that the cultivation of onion in non-traditional areas in off seasons will provide the opportunity to scatter production to supply the monthly demand, thereby, reduce imports.
Establishment

At present, big onion is cultivated mainly from seeds while dry sets had been used by some farmers in early 1980's as a planting material to raise the crop. In this method, farmers have to raise dry sets in nursery beds using true seeds and subsequently, store them till the beginning of planting season. Red/cluster onion is normally established using mother bulbs. In 1999 Department of Agriculture introduced red onion cultivation using true seeds in view of reducing the cost of production (Sumanarathna et al., 2002). Nearly 1,500 kg/ha is of good quality mother bulbs are required when red/cluster onion is raised by bulbs. Only the cultivar Vethalan can be raised by seeds while Jaffna Local and all other cultivars can only be raised using mother bulbs. Based on the varietal spread, 55% of the cultivation is with Vethalan, while 45% covers Jaffna Local and other non bolting varieties and cultivars.

On average 5-6 kg/ha of good quality seeds are required as planting material for big onion or cluster/red onion (Sumanarathna et al., 2002). When onion is raised using true seeds, properly prepared sterilized seed beds are used for raising seedlings. The seedlings are usually ready for transplanting after 28-30 days. Incorporation of organic manure to the soil is vital for the success of the onion crop. Fernando et al. (2013; 2014) reported that application of Farm Yard Manure at the rate of 15 t/ha will reduce the fungal bulb rot disease incidence significantly. This will also increase the soil moisture retention and efficient use of inorganic fertilizers applied to soil. Onion seedlings or mother bulbs are usually planted on raised beds, which are normally 1m in width. The length of the bed varies according to the soil type and the method of irrigation used. During the dry season (yala) some parts of Jaffna, farmers use to plant red/cluster onion on sunken beds to conserve water. Seedlings are normally planted at 10 cm x 10 cm intervals on beds after proper fungicide drenching to control fungal bulb rot incidence during the early stage of the crop. It is reported that soaking of cluster/red onion bulbs one hour in Captan (50% wp) at the rate of 1 g/l is effective in controlling bulb rot incidence (Fernando et al., 2013; 2014).
Application of inorganic fertilizer as basal and top dressing to supply N, P and K requirement is vital for the growth and yield of onions. Department of Agriculture has recommended to apply N as Urea (195 kg/ha), P as Triple super Phosphate (100 kg/ha), K as Muriate of Potash (75 kg/ha) during the growth period. The prolong application of N fertilizer after 6 weeks will extend the vegetative period and increase the vulnerability of bulbs to higher storage losses. Control of weeds during the early growth of onion is important for better growth and subsequent yield. Most of the farmers who cultivate more than 250 m² practice chemical weed control using pre-emergence weedicides. Others practice hand weeding to keep the cultivation free from noxious weeds.

**Irrigation and Other Field Management Practices**

Surface irrigation using open canals or hose irrigation is commonly practiced in onion cultivations. However, there is an increasing trend in the use of micro irrigation practices such as sprinklers, drips and micro jets for cultivating onion in recent times to save water and to increase the productivity. A recent study revealed that micro sprinklers can be used with 60% overlapping for onion grown on Noncalcic Brown soils and 40% overlapping when grown on Reddish Brown Earth soil (Perera et al., 2014). When surface irrigation is practiced farmers irrigate once in 2-3 days based on the soil conditions and the season. In the dry season the farmers’ practice frequent irrigations to avoid stress to the plants. Sprinkling of water using sprinklers or through watering cans is necessary to control the tip burn caused by accumulation of dew in the early morning.

**Preparation for Harvest and Postharvest Handling**

All big onion varieties/cultivars grown in Sri Lanka mature around 90-110 days after establishment. When the crop is ready for harvest, irrigation should be stopped, and the plants should be allowed to fall the leaf and to form the neck between bulbs and leaves tight. Onion is perishable and liable to heavy post harvest losses in storage and handling if proper care is not taken. Maturity level at the harvest is one of the critical factors, which determines the shelflife. It is reported that harvesting at 50% leaf fall stage is necessary to obtain good quality (<50
g/bulb) smaller bulbs (Mettananda, 1991; 1993). Well maintained big onion crops will produce an average bulb yield of 20-25 t/ha.

Red/cluster onion variety Thirunelvely Red matures around 75 days while Jaffna Local matures in 75-90 days. Vethalan takes 110-120 days to mature depending on the soil fertility and weather conditions. Average yield of short age variety/cultivars is about 10-11 mt/ha while Vethalan can produce 15 mt/ha.

Cost and Benefit of Onion Cultivation

Onion is a lucrative cash crop generating substantial income for farmers. Figure 1 shows the fluctuation of average retail price of imported and local big and cluster/red onion in 2013. The profitability of big and red onion cultivations in 2012 yala season, is shown in Table 3.

Figure 1: Monthly retail prices of onion in year 2013.

Table 3: Cost and benefit of cultivation of big onion and red/cluster onion in 2012 Yala season.
**Present status and future prospects of onion cultivation in Sri Lanka**

<table>
<thead>
<tr>
<th>Item</th>
<th>Big onion (Matale)</th>
<th>Red onion (Puttalam)</th>
<th>Red onion (Trincomalee)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost (Rs./ha)</td>
<td>463,004</td>
<td>413,772</td>
<td>388,291</td>
</tr>
<tr>
<td>Gross income (Rs./ha)</td>
<td>1,175,080</td>
<td>923,295</td>
<td>630,717</td>
</tr>
<tr>
<td>Profit (Rs./ha)</td>
<td>712,076</td>
<td>509,524</td>
<td>242,426</td>
</tr>
<tr>
<td>Unit cost (Rs./kg)</td>
<td>22.42</td>
<td>50.00</td>
<td>35.15</td>
</tr>
<tr>
<td>Yield (kg/ha)</td>
<td>20,652</td>
<td>8,262</td>
<td>11,046</td>
</tr>
</tbody>
</table>

Source: SEPC, 2013

**True Seed Production**

Sri Lanka is expanding true seed production in onion to reach near self-sufficiency using many strategies. One of the strategies is to increase the productivity using cultivations with locally produce seeds. As the availability of lands to expand the cultivation of onion is limited this is considered as one of the best strategies. Table 4 indicates the quantities of true seeds imported during 2004-2011. It clearly shows the importance of expanding the local seed production to reduce the seed imports as well as to increase productivity.

During last few years Sri Lanka has launched production and productivity improvement programs to increase the production of food crops, which can be locally grown successfully. Big onion and red/cluster onion also has been identified as crops under this category. Therefore, special extension, research and development programmes were launched by the Department of Agriculture with the help of the Ministry of Agriculture to achieve these targets. Department of Agriculture and Provincial Agriculture Departments have taken numerous initiatives to encourage farmers and enhance the true seed production of onion. The following assistances have been provided to the farmers to promote onion seed production in Sri Lanka.

1. Storage facilities for small and medium scale farmers, who cultivate 120 and 1,200 kg of mother bulbs, respectively have been subsidized.
2. Vernalization process and coordination has been provided.
3. Newly designed plastic crates with improved ventilation were supplied to facilitate transport and prevent physical damages when mother bulbs were transported in gunny bags and wooden boxes.
4. Rain shelters were provided for selected enthusiastic farmers to encourage and increase the seed production.

5. Separation of seeds from dried umbels is laborious and time consuming, especially in medium to large scale seed production ventures. Therefore, arrangements have been made with Farm Mechanization Centre, Mahailuppallama to design and manufacture simple threshing machinery for seed separation.

Table 4: True seeds of red and big onion imported to Sri Lanka 2007-2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>Red onion</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Big onion</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Companies (Number)</td>
<td>Varieties (number)</td>
<td>Quantity (kg)</td>
<td>Companies (Number)</td>
<td>Varieties (Number)</td>
<td>Quantity (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>8</td>
<td>41,494</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>8</td>
<td>32,097</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>6</td>
<td>21,639</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>5</td>
<td>38,210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>2</td>
<td>8,968</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>4</td>
<td>23,113</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>2013</td>
<td>1</td>
<td>1</td>
<td>600</td>
<td>2</td>
<td>5</td>
<td>7,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>2</td>
<td>1</td>
<td>1,200</td>
<td>6</td>
<td>3</td>
<td>20,597</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: NPQS, 2014

Figure 2 shows the productivity increase achieved by the country in big onion using different strategies set by the onion crop development program. Except for the drop in 2010 and 2011, average productivity has shown increasing trend. Decrease in productivity during 2010 and 2011 was due to high disease incidence associated with extreme weather conditions.
Vernalization of mother bulbs is the primary operation in onion true seed production. This is practiced by placing mother bulbs which are already completed dormancy (nearly 2 months after harvest) in favourable environments for a period of 2-3 weeks to induce uniform flowering. Conventionally Rahangala in Nuwaraeliya district was identified as the place for vernalization of big onion and red/cluster onion mother bulbs. Therefore, actions are being taken to construct new facility to initiate vernalization process at Rahangala. Recent studies revealed that the same climatic conditions can be provided for vernalization of onion in Riverstern area of Matale district.

Once the vernalization process is completed mother bulbs can be treated with fungicides and plant in raised beds. Vernalized bulbs are low seed yielders due to few of flowers has been identified as a one of the key issues in seed production of big onion when compared to onion seed producing countries in the region. Ratio between bulb (kg): seed (kg) is 10:1 in Sri Lanka where as it is higher in other countries. In India, KNO$_3$ is used to reduce the ratio and improve the growth and yield of onion seed production. The Field Crops Research and Development Institute, Mahailluppallama has shown that dipping onion bulbs in 10% KNO$_3$ has given significant increase of about 15-25% seed yield. The ratio between bulb (kg):
seed (kg) has reduced from 10:1 to 7:8: (when compared to others; Deshabandu et al., 2014). This is being practiced by some farmers in the recent past.

As a farmer supporting service, mother bulbs to be cultivated in Maha (wet) season have been collected from farmers and transported to Rahangala at the third week of December where ambient temperature ranges from 7-14 °C to store for 2-3 weeks. After 2-3 weeks storage under cold temperature (vernalization) bulbs are redistributed among farmers for field planting in the first week of January. Crop is covered with 36” width 300 gauge clear polythene sheet arranged as an arch shape roof using wooden or bamboo sticks to protect it from intermitted rains and heavy dew during maha (wet) season and to protect from fungal diseases such as purple blotch and anthracnose. Before the initiation of inflorescences (umbels), fishing nylon net (6-7) is placed horizontally over the crop to support the flower stalks and avoid the lodging of developing flower stalks. Mature umbels with stalks are harvested at 3 months of age onwards several times and dried under shade for further maturation of seeds. These are then subjected to sun drying and threshed manually to separate seeds. Seeds normally produced during maha (wet) season are marketed from April for yala (dry) season bulb crop (Tables 5 and 6).

Red/cluster onion true seed production has been recently started in the districts of Jaffna, Hambantota and Ratnapura. This will be expanded to Ampara and Monergala areas soon. Department of Agriculture is targeting to popularize the use of true seeds in view of reducing the cost of production of red/cluster onion. Average annual cultivated area of red onion is 6,000-6,200 ha, of which 55% covers with cultivar Vethalan or bolting type red/cluster onions. Programmes are under way to raise 40% of the Vethalan type red/cluster onion cultivations using true seeds in future under crop leader program.

Conclusion

Both big onion and red onion are very important condiment crops in Sri Lankan agriculture and present strategies adopted by research and extension sectors of the department of Agriculture was able to increase the productivity and the production. Use of local seeds and improved management practice were some of the key factors
improvements in productivity. Identification of areas for off season cultivation will also be an important strategy to obtain steady supply of onion to meet the market demand.

Table 5: Big onion seed production in *maha* season in Matale district.

<table>
<thead>
<tr>
<th>Season</th>
<th>No. of farmers</th>
<th>Amount of mother bulbs planted (kg)</th>
<th>Seed yield (kg)</th>
<th>Selling price (Rs.)</th>
<th>Value (Rs. million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984/85</td>
<td>4</td>
<td>60</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992/93</td>
<td>45</td>
<td>1,800</td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995/96</td>
<td>118</td>
<td>3,636</td>
<td>202</td>
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<tr>
<td>2000/01</td>
<td>152</td>
<td>8,000</td>
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</tr>
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<td>2001/02</td>
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<td>2002/03</td>
<td>247</td>
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<tr>
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<tr>
<td>2004/05</td>
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<td>12,378</td>
<td>857</td>
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<tr>
<td>2005/06</td>
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<td>25,480</td>
<td>1,300</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>61,000</td>
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<td>9,500</td>
<td>43</td>
</tr>
<tr>
<td>2010/11</td>
<td>1,200</td>
<td>93,850</td>
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<td>12,000</td>
<td>42</td>
</tr>
<tr>
<td>2011/12</td>
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<td>12,000</td>
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<td>2012/13</td>
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<td>9,000</td>
<td>12,000</td>
<td>108</td>
</tr>
<tr>
<td>2013/14</td>
<td>1,700</td>
<td>117,910*</td>
<td>11,822</td>
<td>15,000</td>
<td>177.3</td>
</tr>
</tbody>
</table>

*Amount of vernalized (108,530 kg) and non vernalized mother bulbs in 2013/14 *maha.*
Table 6: Big onion seed production in yala season in Matale district.

<table>
<thead>
<tr>
<th>Season</th>
<th>Farmers (number)</th>
<th>Amount of mother bulbs planted (kg)</th>
<th>Seed yield (kg)</th>
<th>Seed selling price (Rs.)</th>
<th>Value (Rs. million)</th>
</tr>
</thead>
<tbody>
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<td>2001</td>
<td>7</td>
<td>113</td>
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<td>-</td>
</tr>
<tr>
<td>2002</td>
<td>11</td>
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<td>-</td>
</tr>
<tr>
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<td>15</td>
<td>1,955</td>
<td>66</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2004</td>
<td>30</td>
<td>2,000</td>
<td>65</td>
<td>-</td>
<td>-</td>
</tr>
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<td>2005</td>
<td>34</td>
<td>2,900</td>
<td>163</td>
<td>5,000</td>
<td>0.8</td>
</tr>
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<td>51</td>
<td>5,000</td>
<td>522</td>
<td>7,500</td>
<td>4.0</td>
</tr>
<tr>
<td>2007</td>
<td>60</td>
<td>9,043</td>
<td>925</td>
<td>7,500</td>
<td>7.0</td>
</tr>
<tr>
<td>2008</td>
<td>113</td>
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<td>8.2</td>
</tr>
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</tr>
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<td>9,500</td>
<td>28.5</td>
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<td>2011</td>
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<td>2,600</td>
<td>12,000</td>
<td>31.2</td>
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<tr>
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<td>350</td>
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<td>6,043</td>
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<td>2013</td>
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<td>55,000</td>
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</tr>
<tr>
<td>2014</td>
<td>355</td>
<td>56,000</td>
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CURRENT STATUS AND FUTURE CHALLENGES OF BIG ONION 
(ALLIUM CEPA L.) IMPROVEMENT IN SRI LANKA

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Abstract

Big onion (Allium cepa L.) is a main cash crop grown in the dry zone of Sri Lanka. Big onion was introduced to Sri Lanka in early 1960s. Seed production and first evaluation trial was reported in 1964. During 1960s to 1990s, a large number of introductions including both open pollinated and hybrids varieties have been evaluated for yield and quality of bulb, growth parameters, shelflife and ability of seed production. Some varieties with high yielding, high pungent with red skin were identified as suitable lines for local cultivation. However, only Poona red, Pusa Red, Rampure and Agrifound Light Red were popular among farmers. From these cultivars, Dambulla Red and Galewela Light Red were selected. In mid-1980, crop improvement programs were initiated to develop the Kalpitiya Selection. However, due to lower yield (15 t/ha) and small bulb size (average 45 g/bulb), variety Kalpitiya Selection was not popular among farmers. Subsequently, Dambulla Selection and MIBO 1 were identified and recommended for local cultivation by the Department of Agriculture in 2009 and 2014, respectively. Big onion variety Dambulla Selection was developed from population improvement of locally grown Pusa Red while MIBO 1 was developed by family selection from naturally out crossed population. These two varieties are being maintained by the Department of Agriculture with a systematic quality seed production program. Current crop improvement program comprise of germplasm collection, multiplication, evaluation, hybridization and selection, with mutation breeding to develop high yielding varieties with good keeping qualities which are having different maturity durations. Further, attempts are being made to develop hybrids to exploit heterosis to increase yield and other desirable traits using advanced breeding technologies.
Introduction

Big onion (Allium cepa L.) is a main cash crop grown in the dry zone of Sri Lanka, specially in Matale, Anuradhapura and Mahaweli H areas. The average cultivated extent and production in 2013 was 4,223 ha and 69,638 t, respectively. The total annual big onion requirement in 2013 was about 238,512 t of which only 29% was locally produced and the balance requirement was imported spending Rs. 9.179 million. The average big onion bulb yield in Sri Lanka was about 16 t/ha (AgStat, 2013). Seasonal production with gluts during the main season, inadequate availability of quality seeds, lack of high yielding varieties, poor shelflife of recommended varieties, pests and diseases and poor crop management practices are considered as major constraints in the big onion industry. Onion production is limited to the dry yala season results market glut from July to mid October. Therefore, part of the production should be stored at least up to 2-3 months to avoid price fluctuations. Onions which can be stored for a longer period exhibit combined high dry-matter content, high pungency and long dormancy period (Brice, 1997).

Big onion was introduced to Sri Lanka and local seed production was started in early 1960s. Many exotic hybrids and open pollinated varieties have been tested over the past. Onion cultivars are classified into “short”, “intermediate” and “long” day length types. Short-day onions can initiate bulbs when day length exceeds 11-12 hours, which are suitable for cultivation at low latitudes. Rate of bulbing is proportional to both photoperiod and temperature (Brewester, 1994). High yielding, high pungent and red skin exotic varieties like Poona red, Pusa Red, Rampure, N53, Rough de Tana, Agrifound Light Red were recommended for local cultivation. Currently, none of these varieties are available in the market. However, cultivars Dambulla Red and Galewela Light Red which have been derived from these introductions as a result of long term self-seed production program by farmers are popular in major onion cultivated areas. In 2013, local seed production was about 31,000 kg. At present, many problems have been raised regarding the seeds produced by self-seed production program as long term use of seed materials without proper selection of mother bulbs and purity maintenance have deteriorated the parental stocks in farmers fields.
Department of Agriculture (DOA) had developed three big onion varieties; Kalpitiya Selection, Dambulla Selection and MIBO 1. Kalpitiya Selection was the first local big onion variety developed at the Agricultural Research Station, Kalpitiya during mid-1980s. This variety was not popular because of small bulb size (average 45 g/bulb) and low yield (15 t/ha) compared with commercial cultivar Poona Red. Hence, the seed production program of Kalpitiya Selection was not continued while a well-organized quality seed production program has been carried out for Dambulla Selection and MIBO 1.

The national crop improvement program comprise of germplasm collection, multiplication, evaluation and identification of suitable germplasm, hybridization and selection, mutation breeding, population improvement and evaluation of breeding lines for bulb yield, seed yield, studies on keeping quality and other desirable traits with a focus on developing high yielding (>45 t/ha) varieties with long shelflife of less than 25% loss in 4 month storage period and resistance/tolerance to biotic stresses. Further, programs have been initiated to develop short duration varieties (2 ½ months after transplanting, MATP) to match with extreme weather conditions and off-season (late maha) cultivation. In the future, hybrid onion development program will be initiated to exploit heterosis with advance breeding technologies.

Achievements of Crop Improvement Programs

Evaluation of exotic varieties

The first reported varietal evaluation was done by Regulathy (1964), which included Poona red and Bombay white varieties and reported that they performed well under local conditions during yala season. This research also focused on seed production in late maha season (Regulathy, 1965; Regulathy, 1966). Sivalingam (1966/67) reported that only Poona Red produced flowers and flowering was as low as 12% among evaluated exotic varieties for true seed production under local conditions. Viability and purity of locally produced seeds of Poona red was 89% and 78%, respectively. Out of 6 exotic varieties, California Early Red gave the highest yield followed by Poona Red (Sivalingam, 1967). Sixteen introductions and
locally produced Poona Red were evaluated and found that N 53, Pusa Red, Onion Lister seeds and locally produced Poona Red gave higher bulb yield (7-10 t/ac). The locally produced Poona Red showed better performance than imported Poona Red. Bellary Red and South Part Red Globe did not produce bulbs under local conditions (Kandiah, 1968). Brewester (1994) explained that long-day varieties growing at near equatorial latitudes does not produce bulb at all. Early Grano and Poona Red produced higher yield out of 8 varieties tested. However, the consumer preference to Early Grano was low as it was yellow skined (Kandiah, 1969). Regulathy (1973) evaluated 5 red skin, 4 yellow to white skin and one brown skin varieties. White, yellow and brown varieties produced higher yield than red varieties but consumer preference was low.

Based on above local seed production in Poona Red was continued from early 1960 at the Field Crops Research and Development Institute (FCRDI), Mahailluppallama. It was introduced to the farmers at Wanathawillu during early 1970s. Jayapathi (1984), Mettananda (1987) and Kuruppuarachchi (1992) reported Poona Red as recommended and commercially cultivated variety during early 1980s.

Mettananda, (1987) evaluated 3 red-pink varieties Bombay Red, Selection KE1 and Selection EI8 over cultivated variety Poona red and reported the highest yield from KI8. The yields of others were similar to that of Poona red. Out of 17 exotic big onion varieties, N 53, Bombay Red, Pusa Red (local), Niv, Arad and Tropicana (H) showed good storability and accounted for 16-19% loss after 3 month of storage period. Storage losses were higher with low TSS (%) and high thick neck bulb (%). Further, the same study evaluated Pusa Red, Ringors, Red Bombay, Nasic Red, N-53, Agrifound Dark Red for true seed production under local conditions and found that Ringors, Agrifound Dark Red, N 53 produced higher seed yield (314-441 kg/ha) and were highly suitable for true seed production under local conditions even without vernalization (Mettananda, 1991/92).

Mettananda (1991) found that the relationship between pungency and the TSS in bulbs as over 10% TSS had higher pungency. High TSS and high pungency combination give high storage ability of onion varieties (Foskett and Peterson,
Pathirana et al. 1950). Mettananda (1992) evaluated 16 pink-red skin and 7 yellow skin varieties for yield, bulb characters and quality characters. Eleven pink-red and 3 yellow varieties gave a yield of 12-20 t/ha. But all yellow-white varieties and some pink-purple varieties recorded low TSS%. Nasik Red, Agrifound Dark Red, Ringors, Poona Red, Agrifound Light Red, Pusa Red and Rampure were suitable for local cultivation in the dry zone of Sri Lanka. Out of 18 varieties, Pusa Red and Nasik Red gave comparatively better yield (10-11.5 t/ha) during late maha season with high TSS (8-10%) and low susceptibility to purple blotch in the early stage. Based on these information, exotic varieties, Pusa Red and Rampure have been recommended for local cultivation.

Edirimanna (1994) found that yield of Agrifound Light Red, Rough de Tana and Miltry onion were similar to the recommended varieties Pusa Red, Rampure and Kalpitiya Selection. But, the higher yield of Agrifound Light Red (25 t/ha) was observed from evaluation trials in farmers' fields at Dambulla, Moragolla and Dewahuwa than the check variety Rampure (21 t/ha). Mettananda and Fordham (1997) confirmed the suitability of Agrifound Light Red for cultivation under short day conditions (around 12 hours) by a rapid screening method. Agrifound Light Red has comparatively better shelflife (60% loss for 6 months storage period) whereas Rampure was not suitable for long term storage under ambient conditions (Mettananda, 2006).

Chithral (1996) evaluated 35 varieties/lines received from private seed companies from India, Israel, Netherland, Australia and Natural Resources Institute in United Kingdom. Two yellow skin hybrids, Grano F1 2000 and ARAD were high yielding (37-46 t/ha), early maturing (63-66 DATP), low pungent with good keeping qualities. Locally produced Pusa Red produced equal yield (42 t/ha) as promising hybrids and it was a high pungent with good keeping qualities. Subsequently, 24 introductions were evaluated in 3 evaluation trials during late maha under the thrust "development of technology for off-season cultivation, seed production and post-harvest handing of big onion” and found “Colosal PVP” as the suitable variety for off-season cultivation.
Among the 36 introductions including hybrids and OPV evaluated, PS 13,580 and Mercedes were high yielding hybrids (33-44.5 t/ha) which had 22-67% higher yield than Pusa Red (MI). But these hybrids had pale yellow skin and low pungency (Chithral, 1997). Edirimanna (1999) identified that Nasik Red, Rampure and Rough de Tana as high yielding, red skin and with high pungent varieties. Contrary results have been observed as very low bulb yield of Rampure due to higher bulb rot incidence (71%). Bombay red and Red king produced similar yield to Dambulla Selection (Pathirana et al., 2011).

During 1980s to 1990s, large numbers of varieties have been tested and among those varieties, Poona Red, Pusa Red and Agrifoud Light Red, Ramoure, Rough de Tana, N 53 have performed well under local conditions. Although, yellow-white skin varieties produced higher bulb yield, those varieties were not recommended due to lower consumer preference. Poona Red was introduced to farmers long before introducing Pusa Red. Based on the above review, it is very difficult to obtain a clear idea about the original variety involved in developing cultivar Dambulla Red. When onions have been cultivated for long periods, their bulb and inflorescence development must be closely adapted to the temperature and photoperiod that prevailed where they are grown (Brewester, 1994).

**Locally developed big onion varieties**

First emphasis on local varieties was given by Sivalingam (1966/67), and selected suitable seedling strains from Poona Red. Seeds were collected from individual plants and sown separately. However, seeds did not germinate. Kuruppuarachchi (1984/85) selected several families with flowering ability (individual plant progenies) from open pollinated field of commercially grown Poona Red, Ethiopian variety Adama Red, Pusa Red, Bellary and N53. From these experiments, mass selection was practiced to advance the generations and line named as Kalpitiya Selection (K1). It was tested in research fields at Mahailluppallam, Giradurukotte, Killinochchi and Kalpitiya during 1987 and 1988 and bulb yield of 15 t/ha and seed yield 400 kg/ha have been obtained. Chithral (1996) initiated a crop improvement program under the new thrust "development of high yielding (30 t/ha) pest resistant seed setting varieties of big onion with good
keeping qualities”. Mother bulbs (25 kg) of locally produced Pusa Red and Rampure were collected from farmers fields at Dambulla and Galewela and mass selection was practiced for both bulb and seed crops. The strain was named as Pusa Red MI. Further, improvement was done during 1997, where yield of Pusa Red MI selection was recorded as 22.8 t/ha, which was higher than 14 exotic varieties including Rampure and Agrifound Light Red (Edirimanna, 1999). Pusa Red MI showed better adaptability (Seneviratna and Pathirana, 2006; 2007; Pathirana and Jayasinghe, 2008) with 36 t/ha of higher yield (Pathirana and Jayasinghe, 2008). This variety was released as Dambulla Selection, which was the first officially released big onion variety in Sri Lanka (DOA, 2010).

As there was no clear phenotypical difference among Dambulla Selection, commercially grown cultivars and recommended exotic varieties, Samarasinghe et al. (2010) carried out a study using simple sequence repeat (SSR) markers to distinguish them. They extracted DNA from 3 local onion types (Galewela light Red, Dambulu Red P, and Dambulu Red R) and exotic varieties (Pusa Red, Agrifound Light Red, Pusa Red MI, and Rampure). Fingerprinting data were obtained and a dendrogram was developed after the statistical analyses of data. The genetic distances and relationships of seven accessions were identified from the clusters in the dendrogram. The authors identified 2 major groups. The first group contained Galewela Light Red, Dambulu Red P, Pusa Red, Agrifound Light Red and Pusa Red MI and the second group contained Dambulu Red R and Rampure. The variety Galewela Red and Rampure were reported to be the most genetically distant types with a genetic distance of 0.31. Agrifound Light Red, Dambulu Red P and Galewela Light Red showed a close relationship with a genetic distance of 0.04. The lowest genetic distance was observed between Dambulu Red R and Rampure. The authors observed that Pusa Red MI was genetically distant from the other local types and exotic varieties and identified all the big onion varieties and local types as different genotypes.

In maha 2008/09, seeds were collected separately from 6 plants of open pollinated population in farmers fields at Kalaththewa (Pathirana and Jayasinghe, 2009). Another 26 families were selected from variable populations collected from different sources considering early flowering without vernalization, bulb shape,
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colour and short duration of bulb crop. Stratified mass selection was practiced to improve each line. Based on high yield, short crop duration and better keeping qualities, MIBO 10-03 and MIBO 09E2 were selected for further evaluation (NCVT and VAT). Another 15 germplasm were received from AVRDC, Taiwan, but only AC980 and OC233-C-AST-BST-C-C produced true seeds under local conditions. (Pathirana et al., 2010; Pathirana and Jayasinghe, 2011; Pathirana and Jayasinghe, 2012). The most adaptable high yielding (38 t/ha) short duration (70-80 DATP) line MIBO 09E2 with better keeping qualities and low severity of thirps damage was conditionally released as MIBO 1 for local cultivation (DOA, 2015).

**Current Status of Crop Improvement Program**

Objectives of the current crop improvement program are to develop:

(i) high yielding (bulb yield >45t/ha and seed yield >900 kg/ha by 2020) and high pungent big onion varieties of 80-90 days maturity duration with good keeping qualities (weight loss < 25% in 4 months storage period);

(ii) short duration (<75 days after transplanting) varieties with acceptable yield for shorter seasons in different agro-ecologies (priority is also given to develop pink, red and bronze colour skin varieties followed by extra high yielding white-yellow skin varieties); and

(iii) varieties tolerant to pests; thrips, leaf and flower eating caterpillars and diseases such as Purple blotch, Anthracnose, and bulb rot.

Current big onion crop improvement program consists of germplasm collection, multiplication, evaluation and identification of suitable germplasm for hybridization and selection, family selection and generation advancement. Breeding lines are being evaluated, for seed and bulb yield, maturity duration, storability, pests and diseases resistance and field adaptability. A mutation breeding program was also initiated to study the mutagenic effect of gamma rays on big onion and to select mutated lines. M₁ populations are in the field.

As big onion is a recently introduced crop to Sri Lanka, land races are not locally available. Therefore, breeding program is mainly depending on exotic germplasm. As a germplasm widening events, 19 exotic varieties in 2014, and 10
exotic varieties in 2013 have been evaluated. In 2014 yala, 9 breeding lines have been developed from hybridization and selection program, and evaluated for yield and maturity. Short duration high yielding lines have been identified (Pathirana et al., 2014).

**Hybridization and Selection**

Chithral (1996) initiated a hybridization and selection program for big onion. In maha 1995/96, Agrifound Light Rd x Pusa Red x Kalpitiya Selection was allowed to pollinate naturally (cross pollination) and seeds were collected from Agrifound Light Red. Generation advancement was done during maha 1996/97, although the program was discontinued.

In maha 2010/11, 3 inter-specific crosses, namely Dambulla Selection x OC233-C-AST-BST-C-C, Dambulla Selection x AC 980, Bombay Red x Dambulla Selection were made following emasculation and hand pollination. Ten F$_2$ families were selected and advanced up to F$_5$. Yield evaluation trial was conducted during yala 2014. Another three crosses were made in maha 2011 and succeeded, but F$_1$ seed of one cross MICIO 09-01 (Multiplier onion) x Kohinoor 9 (common onion) was harvested and others were destroyed due to purple blotch disease. Eighteen big onion lines developed from family selection were evaluated for seed and bulb production. All lines gave similar seed yield irrespective of artificial vernalization under 10-13 °C. Two new big onion lines gave higher bulb yield (30-33 t/ha; Pathirana and Jayasinghe, 2011; 2012; Pathirana et al., 2013; Pathirana et al., 2014). In maha 2014/15, nine lines of F$_4$ families and one F$_2$ families will be advanced.

**Future Challenges**

Low productivity, seasonal production, poor keeping qualities, low yield of recommended varieties, diseases (purple blotch, anthracnose and bulb rot) and pests (thrips and leaf and flower eating caterpillars) are the constrains in onion sector in Sri Lanka. Development of suitable varieties to overcome these problems is a challenge. Considering these constrains, current breeding objectives have been formulated to develop high yielding varieties with longer shelf life at least by 2020.
In Sri Lanka, favourable climatic conditions for big onion cultivation prevail within very short period of the year (April to August). Short duration (2-2 ½ MATP) varieties with acceptable yield should be developed to overcome these extreme conditions and to cultivate during the off-season (late maha). Development of resistant or tolerant varieties for biotic stress is also needed.

Male-sterile cytoplasm is used worldwide for production of hybrid onion seeds. The source of cytoplasmic male sterility (S cytoplasm) was discovered by Jones and Clarke (1943). Development of CMS line and identification of maintainer line (restorer) and development of inbred lines are basic needs to develop onion hybrids in Sri Lanka. Marker-facilitated selection is a potential tool to indirectly select for quantitatively inherited traits in a practical plant-breeding program and it can reduce the number of test crosses required to select the maintainer line (Haevey, 2000). However, availability of adequate germplasm is the main obstacle to initiate this program. On the other hand, capacity building of breeders through training and exposure to strong breeding programs are very important to continue with the above long term objectives.

Conclusions

Big onion was introduced to Sri Lanka in early 1960s. Poona red was the first locally adaptable big onion variety. In 1970s to 1980s, locally produced Poona red was cultivated commercially. In 1980s, Pusa Red, Rampure, N53, Rough de Tana, Agrifound Light Red, Nasik Red were recommended for local cultivation. However, N53 and Nasik Red have shown high storage losses. Locally produced Poona Red, Pusa Red and Rampur produced higher yield compared with their imported varieties. Pusa Red MI (later released as Dambulla Selection) produced similar bulb yield (42 t/ha) to tested superior hybrids Grano F1 2000 and ARAD (37-46 t/ha).

Kalpitiya Selection was the first locally developed big onion variety in late 1980s. Due to low yield and small bulb size, this selection was not popular; hence, seed production was discontinued. Dambulla Selection and MIBO 1 were released.
in 2009 and 2014, respectively for local cultivation and seed production is presently continuing.

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Big onion crop improvement program in Sri Lanka


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CURRENT STATUS AND FUTURE CHALLENGES IN IMPROVEMENTS OF CLUSTER ONION IN SRI LANKA

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Abstract

Onion research in Sri Lanka began in early 1960s at the Field Crops Research and Development Institute (FCRDI), Mahailluppallama and Agriculture Research Station, Thirunelvely (synonymous Thinnavely). Variety selection and other agronomic studies were done earlier but a systematic breeding program on shallot onion was initiated in late 1990’s. Many land races were characterized and evaluated. Agronomic evaluation has resulted in differentiating three major types; Vethalam, Vallari and Jaffna Local. Among these types variation in genetic distance and the genetic diversity was reported. Confusion in nomenclature in red onion landraces was cleared. Series of field research studies and farmer field experiments with different maturity groups in different locations in Sri Lanka has resulted in releasing a new cluster onion shallot type, Thirunelvely Red for the Northern region in 2009. Thirunelvely Red is well adapted high yielding and early maturing variety. In addition, programs at Regional Agriculture Research and Development Centre (RARDC), Aralaganwila and Thirunelvely also identified three promising lines; ACC 66, TVM-1 and TMV-6. TVM-6 which were field tolerant to major fungal diseases. Since 1998, onion breeding program of RARDC, Aralaganwila focused mainly on cluster onion improvement with the aim of increasing quality and yield. In 1996, a hybridization program was initiated with reciprocal crosses between six parental combinations. A high bolting line was identified by FCRDI, Mahailluppallama. Finger printing studies also confirmed the variability among exotic and local collections. Presently, studies are being focused in achieving realizable potential yield of 18 mt/ha to increase the present national productivity of 11.2-15 mt/ha. Attempts are also being made to develop...
hybrids. Techniques for reducing the cost of planting materials and increasing stress tolerance are included in future breeding programs.

Introduction

Onion is the most important species of Allium group belonging to family Alliaceae. The monocot genus Allium is a large genus with more than 500 species. Out of these, only seven species are in cultivation. However, Allium cepa L. and Allium sativum (Garlic) are the two major cultivated species grown all over the world. Onion (A. cepa) is a biennial but is usually grown as an annual crop. The varieties belonging to multiplier onion and shallot subgroups are classified as “small onions”. These two subgroups are most important in Aggregatum group of A. cepa in Sri Lanka (Sumanaratne et al., 2002; 2005). China, India, USA, Russia and Spain are the leading producers of onion. In terms of area, India ranks first in the world with over 480,000 ha but the highest producer is China.

Onion is believed to be brought by ancient traders from Tamil Nadu, especially to the Northern Sri Lanka and later spread to other parts of the country (Arasakesry and Jehanathan, 2005). Red Onion is grown over an area of over 3,000 ha in Sri Lanka with a production of over 64,000 mt in 2013 (DCS, 2014). Both shallots and multipliers are being widely cultivated in Sri Lanka. Until recently local landraces are being cultivated as a cash crop and maintained by storing bulbs under natural conditions. Studies by Sivalingum and Kandiah (1967) on shallot type flowering strain was reported where seedlings were transplanted from lines with around 80% flowering and seed yield of about 114 kg/ac (FCRDI, 1967-2014). It was reported that in 1969 cluster onion varieties from Thailand, Philliphines, and also Vethalam were evaluated at Mahailluppallama. In 1970 and 80s’ further research have been conducted on red onion using both land races and introductions (FCRDI, 1967-2014).

However, information on systematic crop improvement research on red onion in Sri Lanka was not available until recently. Therefore, this paper highlights the present status and future challenges of crop improvement research carried on red onion by the Regional Agriculture Research and Development Centre (RARDC),
Crop Improvement of Onion in Northern Region of Sri Lanka

Germplasm collection, characterization and evaluation.

In the past red onion landrace have been evolved without systematic or sustained plant breeding efforts. Studies on selection of red onion lines were initiated at the Agriculture Research Station (ARS), Thirunelvelly in late 1960’s using germplasm available in the region. At the same time, studies on red onion were also conducted at FCRDI, Mahailluppallama (FCRDI, 1967-2014). Thereafter, work on red onion was also started at the RARDC, Aralaganwila in mid-1990’s (RARDC, 1995-2014). Studies were reinitiated in 2002 at the ARS, Thirunelvelly to expand the genepool, create diversity and to subject them to possible selection and hybridization program (ARS, 2002-2003). Sixteen onion germplasm lines collected from Jaffna district have been evaluated for their agronomic traits to identify genetic variability adapted to various soil types and climatic condition (Singh, 2000). Morsy (2011) suggested that range in size, colour, pungency and taste depending upon the variety of onion. Traditionally, three major landraces, Jaffna Local, Vallari and Vethalam have been grown in the Northern region (Arsakesary and Jehanathan, 2005). However, many landraces cultivated in the region were found to be mixtures and are grown in different parts with different names which had caused confusions in the nomenclature of red onion. Therefore, knowledge on materials available in the Northern region along with their descriptors became imperative for further advancement of this crop (ARS, 2002-2003). Therefore, a purification program was initiated in these landraces simultaneously and completed in maha 2003/04.

Characterization and evaluation has grouped these 16 landraces into six major types viz; Vethalam, Murivethalam, Vadali Vethalam, Kalvethalam, Vallari and Jaffna Local. First five types could be classified as multipliers while the last one belongs to shallot type. Vetahlam might have been introduced through Vetharniyam and this south Indian name of Vetharniyam town has been in use as the name of this landrace. In the past these Tamil names were given based on their
unique characteristics, i.e. Murivethalam (Murri=fallen or broken) leaves were fallen abruptly on maturity; Kal vethalm (Kal=stone) bulbs appears like a small round stone which is heavier to its size; Vaddali Vethalam looked like young palmyra in the field; Vallari is meaningless however it might have attained this name due to its town of origin; Sinna vengayam (Sinna=small) is relatively small in size. These landraces showed significant differences in bulb characteristics and days to maturity between and within the groups. Major types had significant difference among these characters. The difference in bulb weight between Vethalam types may be attributed to their flowering behaviour. Vallari and Jaffna Local produces lighter bulbs than the rest. Bulbs of Vallari were heavier than that of Jaffna Local (Arsakesary et al., 2005). In general, bulb weights were more in maha season than in the yala season.

A molecular study carried out with 10 promising landraces using six primers amplified 31 bands out of which 14 have been polymorphic. Vethalam (JVM 302) can be identified with the single band in contrast to the rest of the accessions with two bands cam in primer OPD 15. Results depicts that all selected 10 accessions of 16 tested under field condition are genetically diverse. This diversity revealed that farmer field collections grouped with their traditional names based on their characteristics could be identified as different landraces. According to the dendrogram five distinct clusters can be identified. In addition, landraces have shown a remarkable difference between the groups and notable difference among the group (Arsakesary et al., 2005). Though six types in two major groups have been found, traditionally in Northern region only five major clusters have been observed on these red onion landraces by using molecular markers. Further evaluations of purified stock of landraces are continuing.

**Release of Thirunelvley Red – a new cluster onion variety for the Northern region**

After series of fields’ research and farmer field experiments, the first high yielding, short duration cluster onion line has been released in 2009 as Thirunelvley Red for cultivation in the Northern region. It was the first cluster onion variety developed through a systematic breeding approach in Sri Lanka (DOA, 2009). This variety is confirmed as a mutation from variety Vethalam (Arsakesary et al., 2005).
Major cultivars in multiplier onion

Agronomic evaluation, characterization, RAPD analysis and the farmers’ knowledge helped to separate these germplasm into three major groups as mentioned earlier. However, multipliers fetched different identities in later studies as they differed in their maturity, bulb shape, bulb weight, bulb skin colour, pungency and storability (ARS, 2004). These true variations in agronomic traits among these cultivars have also been confirmed by molecular studies (Arasakesary et al., 2005).

Rapid exploitation of hybrid vigour through naturally out crossed onion population

Even though reports indicate a true seed onion cultivation at FCRDI in 1970’s, red onion is usually being cultivated through seed bulbs while few plants recorded flowering and seed setting in maha season. Seeds of these plants have been further tested and MH3, MH4, MH5 and MH 6 have found to be flowering during yala season even without vernalization (ARS, 2003-2006). Among them MH 4 (accession 4; ACC 4) which had 100% flowering was promoted for further studies on true seed cultivation in Northern region. Bulbs of ACC 4 which need no vernalization even in yala seasons have been distributed among the farmers in Northern region.

High yielding multiplier onion line - TVM-1

National coordinated trials have been conducted using 60 days and more than 70 days maturity groups of both shallot and multipliers and TVM-1 performed well in all locations. Variety Adaptability Trials (VAT) in different agro ecological zones also confirmed that TVM-1 was a higher yielder. This line will be further tested in farmer’s fields (ARS, 2007-2013).
Cluster onion crop improvement program in Sri Lanka

A multiplier with high flowering and filed tolerant to major fungal diseases

Filed screening studies for diseases at ARS, Thirunelvelly revealed that TVM-6, though relatively lower yield has performed well against bulb rot, anthracnose and purple blotch under field condition (ARS, 2013; ARS, 2013-2014). In separate studies conducted at RARDC, Killinochchi, TVM-4 has produced more flowers and set more seeds and their flower stalks were not affected by anthracnose in late *maha* indicating the resistance (Araskesary *et al.*, 2014). Further evaluation of disease resistance is continuing.

Recent studies on agronomic characterization and molecular separation of onion landraces in Jaffna district.

Twenty six germplasm lines collected from farmers’ fields in Jaffna district (Map 1) (Arsakesary *et al.*, 2014) were characterized for plant height, leaf width, bulb shape, size, maturity group, TSS, leaf colour, bulb colour and yield potential. This study identified three major types of germplasm with three different maturity durations and yield potential. Further, confirmation of these germplasm lines were done by developing finger prints using appropriate molecular techniques at the FCRDI.

Onion Improvement Program at RARDC, Aralaganwila

Since 1998, RARDC, Aralaganwila focused mainly on cluster onion improvement program with the aim of increasing quality and yield of red onion (RARDC, 1995-2014). In 1995, among 6 different cultivars, Vethalam and Agrifound Rose have been identified as better bolting cultivars (RARDC, 1995-2014). In 1996, hybridization program with reciprocal crosses have been started between Vethalam and Agrifound Rose (RARDC, 1995-2014). Further, reciprocal crosses between Vethalam x Kalpitiya Selection, Jaffna Local x Agrifound Rose, Vallari ACC 3 x Agrifound Rose, Vallari ACC 5 x Agrifound Rose and Rambawa White x Vethalam have also been conducted for hybridization (RARDC, 1995-2014). *Yala* season has been identified as the most suitable for true seeds production from these cultivars (RARDC, 1995-2014). Investigation on varietal performance
and regional suitability of available germplasm commenced from 2000/2001 maha season. Vethalam, Vallarai and ACC 5 were significantly higher yielders compared to Jaffna Local and Agrifound Rose.

Preliminary Evaluation of inter varietal crosses continued and better performing lines (Vethalam x Kalpitiya Selection, Vethalam x Agrifound Rose, Rambawa White x Agrifound Rose and one exotic line) were selected for the major yield trial (RARDC, 1995-2014). Jaffna Local and Thelulla selection (ACC 7) were identified as the early maturing cultivars but their yields were lower than others lines tested.

Twenty two accessions including 8 local collections, 4 exotic lines (Indian and Thailand), 6 inter-varietal crosses and 4 lines from Plant Genetic Resource Centre were characterized in 2003/04 maha. Characterization continued in subsequent seasons (RARDC, 1995-2014) and selected lines were tested under PYT and MYT. Six lines of shallot sub group with the check line of Jaffna Local and 8 lines of multiplier group with the check lines of Vethalam and Agrifound Rose were tested under NCVT in 2005 yala. By using morphological traits, isozymes and randomly amplified polymorphic DNA markers, confirmed the hybridity of onion
Cluster onion crop improvement program in Sri Lanka

crosses and estimated genetic diversity of the available germplasm (42 accessions). Selected crosses carry a wide genetic base, as the parents are genetically wide apart. Therefore, vegetative propagation of these hybrids or advancing generation for further selection was continued. Ten lines of multiplier with Vethalam and 7 lines of shallot with Jaffna Local were tested in 4 locations from 2005 yala (RARDC, 1995-2014). Based on these and Variety Adaptability Trial (VAT) results, ACC 18 was identified as better performing exotic shallot line. Thus, further characterization and DUST test are being carried out at RARDC, Aralaganwila.

**Current Status of Onion Research at RARDC, Aralaganwila**

Onion improvement program continued and a high quality bulb rot tolerant line, ACC 16, bolting line, ACC 66 and high yielding TVM 1 and ACC 66 were selected and advanced to VAT at Kalpitiya, Moneragala, Jaffna and Aralaganwila. The local germplasm from main growing areas (Jaffna, Kalpitiya, Thellulla and Kollonna) and from the local market were collected for increasing the diversity. Characterization of 53 lines and selection is continued (Plate 1). Selection for bolting type onion from available germplasm is also being done using 22 lines under MYT. Evaluation of high quality cluster onion with high pungency (9) is also continuing under MYT. To identify lines for environmental variations, tolerant lines to biotic and abiotic stresses with short to medium duration are being tested with Jaffna Local and variety Thirunelvely Red under NCVT in 4 locations (Plate 2). Hybridization program (Plate 3) is continuing using artificial emasculation while investigation of Cytoplasm Male Sterile (CMS) lines using staining method and development of Male sterility using different concentrations (0.2-0.8%) of Gibberalic Acid are being tested with the aim of developing hybrids.

**Cluster Onion Improvement Program at FCRDI, Mahailluppallama**

In 1967, studies on shallot type flowering stains reported that seedlings were developed and transplanted from lines with around 80% flowering and seed yield of about 114 kg/ac (FCRDI, 1967-2014). In 1969 cluster onion varieties from Thailand, Philliphines and also Vethalam types were evaluated. Thailand varieties matured within 80 days after planting (DAP) whereas Vethalam took 85 days to
Plate 1: Variation in germplasm available at RARDC, Aralaganwila.
mature. Philippine variety recorded lower yield but matured in 70 DAP. Thailand varieties produced large size sets and Local Red and Vethalam recorded more storage losses (FCRDI, 1967-2014).

Plate 2: Testing of short age lines under NCVT (left) and selected flowering lines tested under MYT (right).

Plate 3: Multiplication of F₁ generation and hybridization through emasculation.

After a long gap, cluster onion research at FCRDI, Mahailluppallama was reinitiated and 7 seed setting cluster onion lines in yala 2009 and 2010 were evaluated. Those lines were evaluated with Vethalam during yala 2011 and two lines gave higher yields over Vethalam. Evaluation of cluster onion line MICLO.09-01 for true seed production was carried out in maha 2012/13 and yala 2013 at FCRDI. MICLO 09-01 reached to 50% flowering within 69-70 DAP irrespective of vernalization. Flowering of Vethalam depended on vernalization and 50% flowering completed within 52DAP which was 26 days earlier than other lines. It was concluded that MICLO 09-01 produced higher true seed yield than Vethalam.
Mother sets of both MICLO 09-01 and Vethalam should be vernalized to get higher true seed yield during *yala* season but it is not necessary to vernalize during *maha* season. Population improvement of cluster onion lines MICLO 09-01 was continued. Generation advancement of white cluster onion line, “MICLO 09-white” selected from same initial population of MICLO-09-01 in 2009 was maintained vegetatively during past 2 years. Red coloured cluster onion accession K-4 which was collected from PGRC had better flowering and generation advancement of those lines are in progress since *yala* 2012.

**Germlasm evaluation of cluster onion**

There is a need to develop high yielding, seed setting cluster onion varieties to increase the average yield to reach national targets. Seventeen cluster onion accessions were therefore evaluated during *yala* 2013 at FCRDI. MICLO-10-02, MICLO-10-03, MICLO-10-04, MICLO-10-06, ACC-09 and NO-05-01 were selected for further evaluation. The following germplasm are being maintained at FCRDI for future research (Table 1).

**Table 1: The germplasm maintain at FCRDI for future research.**

<table>
<thead>
<tr>
<th>Accession</th>
<th>Line No</th>
<th>Remarks</th>
</tr>
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<tbody>
<tr>
<td>ACC 02</td>
<td>C -2011-03-41</td>
<td>MICLO-09-01 White</td>
</tr>
<tr>
<td>ACC 09</td>
<td>C -2011-03-42</td>
<td>Moragollagama Selection</td>
</tr>
<tr>
<td>ACC 10</td>
<td>C -2011-03-48</td>
<td>Thirunelvely Red</td>
</tr>
<tr>
<td>ACC 21</td>
<td>C -2011-03-59</td>
<td>Vethalam</td>
</tr>
<tr>
<td>ACC 26</td>
<td>No.1</td>
<td>Rambawa White</td>
</tr>
<tr>
<td>K-4</td>
<td>No. 5</td>
<td></td>
</tr>
<tr>
<td>K-9</td>
<td>No.-05-01</td>
<td></td>
</tr>
<tr>
<td>K-10</td>
<td>MICLO-11-04</td>
<td></td>
</tr>
</tbody>
</table>

**Future Directions of Cluster Onion Research in Sri Lanka**

Shallot onion production which is about 75,000 mt at present should be increased to 120,000 mt to meet the national demand. This could be achieved by either increasing the area under cultivation, which is very limited or by increasing
the productivity. The present average realizable potential of 15 mt should be increased to 18 mt to increase the national productivity of 11.2 to 13 mt.

Cluster onion improvement program is mainly focused on developing high yielding cluster onion lines. Further onion cultivation is threatened by diseases than pests which can be easily controlled with recommended chemicals. However, fungal diseases are major constraint in both shallot and multipliers. Tip burning in shallot types is also a problem especially in the dry season. Therefore, lines which are tolerant to major diseases are needed.

Identifying dual purpose short duration high yielding red onion lines are in progress using both conventional and other breeding techniques. Attempts are also being made to develop hybrids. Further, to overcome biotic stresses, lines tolerant to water stress and short duration are needed. Techniques for reducing the cost of planting materials and increasing the keeping quality are also essential. Confusion in the nomenclature is being cleared by germplasm evaluation, characterization and molecular studies in two different stages.

Onion seed costs more than 60 % of the total cultivation expenditure. Seed bulb production often fails due to bulb rot, anthracnose and nematode attack. Currently the true seed cultivation technique is in progress for which the seeds are imported. Farmers often complain that the imported lines are not uniform and less suitable to local conditions and lower storability. Many farmers are also involved in bulb seed production which is the main source of income for the farmers in the Northern region (Plate 4). Developing a dual purpose variety which can produce about 600-800 true seed and 7-10 seed bulbs per plant with longer storability is needed. Research on cluster onion at ARS, Thirunelvely, RARDC, Kilinochchi and Aralaganwila and FCRDI, Mahailluppalama will be further strengthened to achieve the above objectives.
Plate 4: True seeds production of red onion variety in farmers’ field (above) and variety selection of bolting types in the research station (below).

References


Cluster onion crop improvement program in Sri Lanka


INTEGRATED DISEASE MANAGEMENT OF ONION IN SRI LANKA

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2 Field Crops Research and Development Institute, Mahailluppallama, Sri Lanka
3 Regional Research and Development Centre, Aralaganwila, Sri Lanka

Abstract

The importance of onion in Sri Lankan diet needs no over emphasis. National agriculture policy has also emphasised on improvement of onion. In spite of the rapid expansion of onion cultivation, considerable losses are reported to occur throughout the production process. Onion diseases account for a major share of total yield losses. Among important diseases in Sri Lanka, bulb rot (fungal bulb rot and bacterial bulb rot), leaf twister disease (anthracnose) and purple blotch continue to cause significant damage to both seed and bulb onion crops throughout the onion growing areas in Sri Lanka. The Department of Agriculture, Sri Lanka have carried out many investigations to find out effective management practices to control these diseases. Used alone, an individual management practice may not reduce the level of disease to an economic threshold level, hence the additive effect of several practices are experimented. Integrated disease management practices are being implemented for the management of onion disease in Sri Lanka.

Introduction

Two general types of onion have been traditionally known to Sri Lankan consumers, called red onion (shallots) and big onion. They are distinguished by size rather than colour of bulbs. Red onion produces small bulbs whereas, big onion produces larger bulbs. In spite of the rapid expansion of red onion and big onion cultivations, considerable losses occur throughout the production process and onion diseases account for a major share of the total yield loss. Seed production in onion in Sri Lanka requires two different seasons viz., one season for bulb production (bulb crop) and another season for seed production (seed crop). The big onion and red onion are affected by many diseases at different crop growth stages and they
account for considerable losses in bulb and seed yield. Apart from reduction in crop yield, the diseases also cause harmful effects during harvesting, post harvesting, storage and marketing stages, causing significant losses in quality, which lead to heavy economic losses. The disease alters the cropping pattern and also consistent use of chemicals to control plant diseases not only poses a threat to the environment and mankind but also help in building up of resistance in pathogens. Among more important diseases in Sri Lanka, bulb rot (fungal bulb rot and bacterial bulb rot), leaf twister disease (anthracnose) and purple blotch contribute to cause significant damage in both seed and bulb onion crops throughout the onion growing areas in the country (Plates 1-3).

This article reviews the information on onion diseases recorded since 1970. The primary objective of this article is to summarize the coordinated and collaborative research program that was intended to improve the disease management strategies; outreach implementation and to overcome or minimize damage due to diseases of onion.

**Damping Off**

Early studies on onion diseases were mainly focused on management of nursery diseases. Two types of diseases *i.e.* pre emergence and post emergence seedling deaths (Plate 1) have been reported (Wimalajeewa and Wijewardana, 1971; Priyantha, 2014). Soil treatments with benlate, captan and cerasan have shown significant control of nursery diseases. Covering of nurseries during night with cadjan leaves was also found to be effective in controlling nursery diseases (Wimalajeewa and Wijewardana, 1971). However, the Integrated Disease Management (IDM) practices are recommended for the management of nursery diseases which comprises of soil solarization, seed treatment, cultural practices and fungicide treatment (Priyantha, 2014). Soil solarization of nursery beds has been found to be very effective in reducing damping off in onion. To minimize the risk of infection from soil borne diseases, nursery beds have been sterilized by burning straw and paddy husk on beds.

Sterilization of nursery beds help to destroy the pathogens in the upper layers of soil. Crop rotation in nursery beds for 2-3 year periods is recommended
Priyantha et al.

for raising healthy seedlings. Seed treatment with fungicides like captan, thiram, thiophanate methyl+thiram reduces the both phases of the disease i.e. pre-emergence and post emergence. Infected soils in the nursery beds can be drenched with fungicides like captan, thiram, thiophanatemethyl+thiram during the nursery stage for better control of disease.

Plate 1: Pre and post emerging seedling death of onion.

Leaf Twister Disease – Anthracnose (Colletotrichum gloeosporioides and Fusarium oxysporum)

Leaf twister disease has been reported at various crop growth stages of onion from different parts of the island. The disease is locally named “disco” by farmers (Plate 2). The disease was first reported in shallots (red onion) from the Trincomalee district in 1970’s, and from Puttalam district in 1987 (Anon, 1992). Similar symptoms were reported in big onion from Matale district in 1996 (Weerarathne, 1996; 1997). It was subsequently reported from Kalpitiya area in red onion (Rajapaksha et al., 2001). During the maha 1995/96, a severe outbreak of the disease was observed.

Initially, the possible causes of disease symptoms were suspected as nematodes. However, Nugaliyadda and Ekanayake (1986) reported that parasitic nematodes were not associated with infected plants. Fungus named as Fusarium oxysporum was isolated from infected shallot plants. Thrips, mites, nematodes and other fungi could also cause similar symptoms (Kuruppu, 1992). Mithrasena (1994) isolated the fungus Colletotrichum spp. from infected samples collected from Ratnapura and suggested that it could be due to a soil borne pathogen. Both
Colletotrichum gloeosporioides and Fusarium oxysporum f. sp. cepae were isolated from the infected plants collected at Kalpitiya (Wijesinghe, 1994). It was subsequently reported in big onion cultivation and causal organism was identified as Colletotrichum gloeosporioides (Penz). Sacc. the perfect stage of Gomerella cingulata (Stonem) (Weerarathne, 1996; 1997). In 2002, Rajapaksha et al. (2001) also reported that leaf burning of red onion known as “acid disease” also caused by a fungus, C. gloeosporioides. According to the latest report, the causal agent of leaf twister disease of shallot in Kolonna area has been identified as C. gloeosporioides and F. oxysporum. Colletotrichum gloeosporioides causes twisting of above ground parts and F. oxysporum causes bulb rot. The both fungi were involved in the development of typical leaf twisted disease symptoms observed in Kolonna area. Morphological characters of C. gloeosporioides and F. oxysporum pathogens are given in Table 1.

Plate 2: Leaf twister disease symptoms (left) and decayed flower head on bulb crop (right).

It was reported that C. gloeosporioides quickly differentiates on leaf surfaces of onion varieties, Rampur and Pusa Red. Small, about 2-3 mm size brown lesions initiated on inoculated sites of leaves within 6 days under induced moisture conditions (Rajapaksha et al., 2001; Priyantha et al., 2002). Understanding the mode of anthracnose development in different varieties under different conditions could be used as a guide to identify suitable control measures for anthracnose disease of onion.
Table 1: Characters of *Colletotrichum gloeosporioides* and *Fusarium oxysporum* collected from leaf twister disease affected shallot plants.

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>C. gloeosporioides</em></th>
<th><em>F. oxysporum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Colony colour</td>
<td>Gray, turn gray-black when older</td>
<td>White, turn brown-purple when older</td>
</tr>
<tr>
<td>Reverse colony colour</td>
<td>Black</td>
<td>Purple</td>
</tr>
<tr>
<td>Acervuli</td>
<td>Conidia produced in black acervuli as conidia masses, individually smaller size</td>
<td>Setae absent, conidia produced openly within hyphae and exposed to the air</td>
</tr>
<tr>
<td>Setae</td>
<td>Brown</td>
<td>Absent</td>
</tr>
<tr>
<td>Conidia</td>
<td>Straight rounded ends, unicellular</td>
<td>Two types; Macro conidia- Sickle shaped and pointed at ends, 3-5 cells, larger. Micro conidia- Abundant, cylindrical, 1-2 cells, smaller.</td>
</tr>
</tbody>
</table>


Leaf twister disease can be recognized by typical symptoms on the host plant. Symptoms observed in the seed crop and bulb crop vary while the disease spread sporadically in the field. In the bulb crop, appearance of leaf curling, twisting, chlorosis and abnormal elongation of the pseudo stem could be observed. White sunken oval lesions appear mainly in lower leaves. However, a few lesions could also be observed in some young leaves. These lesions enlarge with time and spread all over the leaf. Black, minute, slightly raised acervuli (fruiting bodies) with pink masses of conidia could be seen scattered on the surface of lesions (Plate 2, left). Affected leaves wither and became detached. Bulbs produced from these plants were small and eventually rotted. Most of the affected bulbs rotted before harvesting while the others rotted during storage (Weeraratna, 1996; 1997).

Seed crop did not show symptoms of leaf curling, twisting, chlorosis or abnormal elongation of the pseudo stem. Lesions on seed crop consisting of dense black acervuli with pink masses of conidia were observed on flower stalks. These lesions increased in size and several lesions coalesced to form large infected areas on flower stalks. When the lesions reached the base of the flower head, young
flowers decayed prematurely (Plate 2, right). At early flowering stage, flower stalks collapsed at the lesions and as a result the upper portion of the flower stem drooped and dried up prematurely with no seeds produced in the flower. Rajapaksha et al. (2002) described certain other characteristic symptoms like leaf burning.

Transmission studies showed that typical disease symptoms could be observed on seedlings raised on infected soil and on autoclaved soil incorporated with crop debris within 7-10 days and within 4-5 days after planting, respectively. But no symptoms were observed in seedlings raised on autoclaved and uninfected soil (Weerarathne, 1996; 1997). This suggests that the disease can be transmitted through soil and crop debris and the fungus could be inactivated by autoclaving. The same author further demonstrated that disease could also be transmitted through water and infected seeds. The inoculum sources were identified as infected planting materials and soil for both *C. gloeosporioides* and *F. oxysporum* pathogens (Rajapaksha et al., 2001).

Environmental factors influence the occurrence of leaf twister disease. High relative humidity (RH nearly 100%) and moderate temperature changing from 20 to 31 °C with rainfall (5-31 mm) appeared to be very conductive for the infection and development of leaf twister disease (Weerarathne, 1996; 1997). Such environmental conditions are found during later part of *maha* season (January-February). It occurs rarely during the *yala* season (dry period). The results revealed that the disease may appear in the field at any stage of growth depending on the weather conditions and presence of inoculum.

Variety screening studies using locally available cultivars and exotic germplasm against leaf twister disease have been carried out in collaboration with plant breeders (Weerarathne, 1996). It was reported that all locally available big onion cultivars were susceptible to leaf twister disease whilst exotic varieties Red Grano, Hybrid Rojo and Primero showed resistance under field conditions. However, all available shallot cultivars were susceptible to leaf twister disease (Rajapaksha et al., 2001).
Use of fungicide is a common practice for management of diseases in crop cultivation. Field studies conducted by Rajapaksha et al. (2001) reported that application of homai (thiophanate methyl 50% + thiram 30% WP) as soil and bulb treatment and alternate spraying of thiophanate methyl 70% wp and chlorothalonil 70% WP or bulb treatment and spraying or spraying only with respective fungicides resulted a reduction in leaf twister disease incidence and an increase in bulb yield in the field. However, foliar spray was less effective in controlling leaf twister disease under severe epidemic and favourable weather conditions (Weeraratne and Yapa, 1999). Rajapaksha et al. (2002) reported that seed treatment with thiophanate methyl 80% + thiram 30% and solarization of soil for two weeks prior to planting significantly reduced the incidence of the disease and enhanced yield of onion.

Thiophanate methyl is a widely used fungicide for onion anthracnose control in Sri Lanka. In recent years, losses due to anthracnose in onion have been severe despite the use of thiophanate methyl (Priyantha et al., 2011). Although the chemical fungicides effectively suppress and control the disease, continuous use of systemic fungicides can reduce their effectiveness due to the development of resistance. C. gloeosporioides isolates collected from Matale district showed to have developed resistance against thiophanate methyl (Priyantha et al., 2011). The occurrence of thiophanate methyl resistant isolate in Matale district may be due to frequent cultivation of onion and widespread use of thiophanate methyl in the district. No other reports, except from Matale, on the failure of thiophanate methyl fungicides for controlling the disease have been reported. Hence, thiophanate methyl still provides excellent control of anthracnose in onion in other parts of Sri Lanka. Effective alternative fungicides for the control of anthracnose have also been identified as trifloxystrobin + tebuconazole 75 wg, pyraclostrobin + metiram 60 wg and fluzinam 500 g/l sc. (Priyantha et al., 2010).

Accordingly, it can be stated that used alone, an individual management practice may not reduce the level of disease to an acceptable level, whereas the additive effect of several practices will be desirable. Therefore, the following integrated disease management practices are being implemented for the management of leaf twister disease of onion in Sri Lanka. Among the regulatory measures, use of healthy bulbs and seeds and removal of infected bulbs from the
storage has been recommended. In epidemic areas, farmers are advised to collect infected materials and either burn or bury deep to minimize the initial inoculum content. Such practices reduce the initial inoculum and reduce spread to new areas. Fungicides thiophanate methyl 70% WP (20 g/10 l water) and thiophanate methyl + thiram 80% WP (18 g/10 l water) have been recommended to treat bulbs and seedlings and seed treatment with fungicides like thiram, captan, thiophanate methyl + thiram have been recommended. Some other fungicides have also been found effective against onion leaf twister disease, such as chlorothalonil, mancozeb, fluzinam, thiophanate methyl and pyraclostrobin + metiram.

**Purple Blotch (*Alternaria porri*)**

Purple blotch disease caused by *Alternaria porri* (Ellis) Cif. is one of the most important diseases of onions (Wickramaarachi *et al.*, 2004). Development and spread of the disease is highly correlated with warm weather and humid conditions. The fungus can cause a reduction in yield from 90-100% in the low country dry zone during wet seasons if the disease is left uncontrolled. Major constraints in onion seed production in *maha* season are crop damage due to high rainfall and severe development of purple blotch. Hence, the production of onion is limited to *yala* season due to purple blotch disease. Proper management of this disease is the key determinant factor in true seed production during wet (*maha*) season (Sumanarathne, 2000). Big onion and shallot cannot be grown from October to January due to high incidence of this disease (Wijewardana, 1972).

Purple blotch disease is mainly a leaf disease and spreads to flower stalks. The initial symptoms are small, water-soaked lesions with white centres that appear usually on older leaves. As the disease progresses, the lesions enlarge and become purplish with light yellow concentric rings on margins (Plate 3, left). As the severity increases, leaves turn yellow brown, lose erectness and wilt. Lesions may also form on seed stalks and floral parts (Plate 3, right). In severe cases the seed stalks may be girdled, destroying the stalks before seeds get matured (Priyantha, 2014).
Persistent rains and heavy dew are factors that favour the development of purple blotch disease during *maha* season. Wind borne conidia from previous crop debris initiate infection, which is favoured by high temperatures and humid conditions. Prolonged leaf wetness increases the probability of further infection. Continuous rain over 6 hours, high RH (70-90%) and air temperature of about 20-33 °C are favourable environmental conditions for purple blotch (Priyantha, 2014). Twelve big onion varieties have been screened to determine resistance and the genetic base of purple blotch resistance in Sri Lanka. The results showed that all varieties available were not resistant to purple blotch disease (Wickramaarachchi et al., 2004) also reported that complete control of disease even with fungicides is difficult to achieve in Aralaganwila area (DL 26) during the wet season. Studies conducted by Priyantha et al. (2010) on the efficacy of foliar fungicides reported that trifloxystrobin + tebuconazole 75 wg, pyraclostrobin + metiram 60 wg and fluzinam 500 g/l sc were effective in controlling purple blotch in onion.
Spraying of sulphur develops a thin sulphur coat on the leaf surface, which could act as a protective barrier against pathogen infection (Edirimanna and Rajapaksha, 2003). They suggested further that significantly higher seed yields could be obtained with this treatment although sulphur was not a recommended fungicide for purple blotch disease. Covering of onion seed crop with white polythene at night and during rainy periods can be used as a cultural practice to minimize crop damage due to rain and dew formation and to obtain higher seed yield. Spraying water on onion leaves in the morning to wash-off the dew drops from the plants is practiced by many farmers. On the contrary, Edidimanna and Rajapaksha (2003) reported that removal of dew drops by spraying water early in the morning did not reduce the severity of purple blotch disease.

Based on the research, IDM package has been suggested for the management of purple blotch disease in onion in Sri Lanka. Since the fungus cannot survive if buried deep in the soil, deep ploughing the debris can be used as one of the sanitary precautions. The field should be well drained to prevent further spread of the disease. The most important precaution is the use of disease free seeds and bulbs. Seed and bulb treatment with fungicides like thiram, captan, thiophanate methyl + thiram are also recommended to reduce seed borne inoculums. Covering of the seed crop with white polythene at night during rainy periods is recommended as a cultural practice to minimize crop damage. Spraying of fungicides like chlorothalonil, tebuconazole, mancozeb, fluzinam and pyraclostrobin + metiram are recommended to spray as soon as first lesion is noticed or before the seed stalk is attacked.

**Bulb Rot**

Bulb rot in onion was first reported in 1986 and causal organism was identified as *Sclerotium* spp. and *Fusarium* spp. (Soyza *et al.*, 1986). Fungal bulb rot caused by *Fusarium* spp., *Sclerotium* spp., *Pythium* spp. and bacterial bulb rot caused by *Ralstonis* spp., *Erwinia* spp. are ranked first among the diseases of economic importance (Priyantha, 2014). Both pathogen groups are widely distributed in the soil of major onion growing areas. Although there are no
published data on the actual yield loss of onion due to bulb rot, heavy losses up to 10-75% have been experienced by farmers. In severe cases, entire crop may be lost.

**Fungal bulb rot (Sclerotium spp.)**

Leaves of plants infected with fungal bulb rot show yellowing, leaf dieback, and wilting. Leaf decay begins at the base with older leaves collapsing first (Plate 4, left). A semi-watery decay of the bulb scales results. Roots also rot and the plant can be easily pulled from the ground. Fluffy white growth is associated with the fungal mycelium, which develops around the base of the bulb. If damage is caused by *Sclerotium* spp. as the disease progresses, the mycelium becomes more compacted, less conspicuous, with numerous small spherical black bodies (sclerotia - resting bodies of the pathogen) forming a mycelia mat. Plants can become infected at any stage of growth (Plate 4, right).

**Bacterial bulb rot (Erwinia spp.)**

Soft rot starts in the field when the crop is maturing (Plate 5). When infected bulbs are pressed, bacterial exudates ooze out. The slimy decay is accompanied by a foul sulphurous smell (Priyantha, 2014). The bacterial bulb rot can be caused by *Erwinia* spp. and *Pseudomonas* spp. The primary inoculum of these bacteria comes from soil. Presently there are no commercially acceptable onion varieties with known resistance to bulb rot. Crop rotation offers some promise for soil borne disease management. However, onion production is location specific and very intensive. Diverting a land, which is being used for onion production for any length of period, is practically impossible and justifiable. Thus, crop rotation is not an acceptable management alternative for onion disease management.
Plate 4. Fungal bulb rot symptoms (left) and numerous sclerotia on infected bulb (right).

Plate 5: Symptoms of bacterial bulb rot caused by *Erwinia* spp. and *Pseudomonas* spp.

Amending soil with organic matter increases natural suppressiveness against soil borne pathogens. Soil amendments of ipil-ipil and gliricidia reduced the sclerotia formation while soy straw enhanced the sclerotia formation (De Soyza *et al.*, 1988). Cow dung application (15-20 t/ha) was effective for the fungal bulb rot management of cluster onion in DL2b agro ecological region (Fernando *et al.*, 2013). Priyantha *et al.* (2013) reported that effective control of bulb rot in big onion can be achieved using the following combined approaches of pathogen exclusion and removal:

1. Use of disease free planting materials for cultivation as they are the initial source of disease infestation.
2. Dipping of bulbs / seedlings before planting in an aqueous solution of thiram + thiophanate methyl (20 g / 10 l water).
3. The bulb rot causing pathogens may survive in the soil for extended periods of time often coming from debris from past infected plants or spores living in soil. These pathogens therefore,can easily spread with the movement of disease plants, soil or surface water. In onion growing areas water is pumped to flood irrigate the plots. Water is delivered from plot to plot once the initial plot is filled with water. Pathogens move easily with water. If pathogen contaminated irrigation water is used to irrigate fields, contamination in adjoining fileds may take place. Controlling water logging and limiting
surface water movement from plot to plot by deepening the furrows between beds and using drainage channels have been recommended (Figure 1).

4. Field population of resting spores can be reduced by collection and removal of infected bulbs. Farmers are advised to remove infected plants with soil at 10 days interval.

5. Drenching infected plants and adjoining plants during the growing season with an aqueous solution of thiram + thiophanate methyl ($5 \text{ g} / 5 \text{ l water} / \text{ m}^2$). Thiophanate methyl + thiram foliar application has been proved ineffective in reducing severity of bulb rot while drenching and spot application result in more effective control.

Figure 1: Field layout of irrigation in onion.

Storage Losses

Bulb rot caused by fungi is one of the major causes for storage losses and contributes to about 10-20% of the total storage losses. Mettananda and Edirimanna (1998;1999) reported low rotting losses in Rahangala, Bandarawela and Seethaeliya areas in the up country wet zone where the minimum environmental temperature ranged between 15-20 °C. The activity of one of the major storage fungi *Aspergillus niger* was lower when the storage temperature was below 17 °C. Storage losses due to rotting could be reduced by selecting low temperature (< 15 °C) locations for big onion storage.

Small bulbs had lower rotting loss when compared to large bulbs during the storage. On average, there was about 8% less rotting loss in small bulbs compared to the large bulbs (Mettananda, 2011). Bulb rotting is caused by a number of micro...
organisms. Among them fungi are the major causal organisms responsible for storage losses. The field survey revealed that five fungal genera are associated with rotting of big onion bulbs (Rajapaksha and Edirimanne, 2002). Among them, major causal agents are *Fusarium* spp., *C. gloeosporioides* and *Sclerotium* spp. *Alternaria* spp. and *Aspergillus* spp. grew on surface of onion bulbs but those pathogens were not responsible for rotting. Application of carbendazim 50% wp, two weeks before harvesting reduced the storage losses of big onion up to 40% due to fungal pathogens (Rajapaksha and Edirimanne, 2002).

**Seed Associated Diseases**

Micro flora associated with onion seed was studied by Rajapaksha (1998) in locally produced onion seed lots collected from different location in Sri Lanka. Among them *C. gloeosporioides*, *Alternaria porri*, *Aspergillus* spp. and *Penicillium* spp. were identified as most commonly associated fungal pathogens with onion seeds. Onion seeds are imported to Sri Lanka by the private sector and cultivated by many farmers. These varieties are marketed in the country without screening for their susceptibility to local diseases. Thus, the possibility for a disease outbreak cannot be excluded. Exotic big onion variety Nashik Red seeds and local variety Rampur has been tested for major diseases and agar plate test revealed the presence of *Aspergillus flavus*, *Aspergillus niger* and *Rhizopus* spp. (Priyantha et al., 2010; 2011). The exotic onion variety Nashik Red seeds sample was free from seed borne pathogens. Many seed associated fungi are reported to live on the surface of the seeds as contaminant micro-organisms. The fungi *C. gloeosporioides* and *Alternaria porri* can attack any aerial parts of the onion plant, including seeds, suggested their seed borne nature and systemic transmission from seeds to seedlings (Weeraratna, 1996; 1997; Priyantha, 2014).

**Future Strategies**

Future strategies for the management of onion diseases should be an integrated effort of the plant breeders, plant pathologists and agronomists. Breeding for disease resistance has to be considered a priority. Effective integrated disease
management practices should be developed for all diseases and it is an urgent need to minimize the use of fungicides.

References


INTEGRATED PEST MANAGEMENT OF ONION IN SRI LANKA

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Abstract

Onion is one of the most important condiment crops grown in Sri Lanka. The onion crop is attacked by many pests at different crop growth stages causing considerable losses in yield. Thrips and onion caterpillars were identified as major pests and onion maggot and root eating ant as minor pests of the onion crop. Bulb mites, tuber moth and flower chafer beetles are new pests recently reported in Sri Lanka. The consistent use of insecticides to control the pests not only poses a severe threat to environment, human being and natural enemies but also build up resistance in pests. Therefore, integrated pest management practices were identified to manage the major pests. Research activities should be conducted to develop pest management strategies for the new pests reported in Sri Lanka. Biology and ecology of important pests associated with onion crop along with current management strategies based on chemical, biological, and cultural control as well as host plant resistance and future directions in onion pest management are summarized.

Introduction

Onion is one of the most important condiment crops grown in Sri Lanka. Two main types of onions, big onion (Allium cepa, variety cepa) and shallot or multiplier onion (Allium cepa, variety aggregatum) are cultivated in Sri Lanka. In 2013 the production of big onion and shallot were 69,638 t and 55,608 t, respectively. The annual cultivated extent of both types of onion was about 8,829 ha in 2013 (Agstat, 2014). It is generally used as a vegetable, spice or for medicinal purposes.

The onion is attacked by many pests at different growth stages causing considerable losses in yield (Table 1). In addition, these pests also reduce the quality of bulbs after harvest, during processing and marketing. This paper reviews the
important pests affecting onion along with their management practices and future research and development needs.

Table 1: Pests of onion reported in Sri Lanka.

<table>
<thead>
<tr>
<th>Major pests</th>
<th>Minor pests</th>
<th>New pests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrips:</td>
<td>Onion maggot:</td>
<td>Bulb mite:</td>
</tr>
<tr>
<td>Thrips tabaci Lindeman (Thysanoptera: Thripidae)</td>
<td>Delia antique (Meiger) (Diptera: Anthromyiidae)</td>
<td>Rhizoglyphus spp. (Acarina: Acaridae)</td>
</tr>
<tr>
<td>Onion caterpillars:</td>
<td>Root eating ant:</td>
<td>Tuber moth:</td>
</tr>
<tr>
<td>Spodoptera litura (Fabricius), S. exigua (Hubner) (Lepidoptera: Noctuidae)</td>
<td>Dorylus orientalis(Hymenoptera:Formicidae)</td>
<td>Phtorimaea operculella (Lepidoptera: Gelechiidae)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flower chafer beetle:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxycetonia versicolor (Coleoptera: Scarabaeidae)</td>
</tr>
</tbody>
</table>

Thrips: **Thrips tabaci** Lindeman (Thysanoptera: Thripidae)

Onion thrip, is identified as a pest of national importance in Sri Lanka. It is the most common and serious insect pest of onion. High populations of thrips can reduce both yield and keeping quality of onions. The yield loss due to thrips damage has been estimated to be 20-40% (Anon, 2002).

Thrips are tiny slender insects, best seen with a hand lens or microscope. They are about 1.3 mm long (Plate 1). Adults have 2-pairs of wings that are fringed with long hairs. Thrips species vary in colour from pale yellow to light brown. Eggs are white to yellow, kidney-bean shaped, microscopic. Eggs hatch in 5-10 days. Larval instars I and II (0.5-1.0 mm) are active feeding stages. The immature stages have the same general body shape as adults but are usually lighter in colour and wingless. They require 10-14 days to develop. The instars III (pre-pupa) and IV (pupa) (1.0-1.2 mm) are inactive, non-feeding stages. They are pale yellow to
brown. They are found in the soil, at the base of the onion plant neck or underneath bulb scales. This stage lasts 5-10 days. Complete generation requires 2-4 weeks during warmer conditions. Five to eight generations may occur each year (Wijeratne, 2006).

Onion thrips have a wide host range, including cereals and broad leaved crops. They thrive in hot, dry conditions and are more damaging when these climatic conditions prevail for most of the production season. Thrips damage can initiate at any stage of the crop. Immature and adult thrips prefer to feed on newly emerged leaves at the centre of the onion neck. Both adult and larvae feed on foliage causing white to silver patches and streaks. When foliage is severely damaged, the entire field appears silvery (Plate 2). Thrips are most damaging when they feed during the early bulbing stage of plant development (Gunewardena et al., 2013a).

Population dynamics studies have shown that peak population of thrips occurs from July to August and associated with low relative humidity, high temperature and high wind velocity (Anon, 1991). Therefore, correct time of planting (early May) is very important to minimize the damage. Use of recommended fertilizer at correct rate and time of application is very important. Onion crops should be fertilized with adequate, but not excessive amount of
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nitrogen fertilizer. In 2010 and 2011, goat manure, poultry manure and cow dung were tested against pests of onion and the low thrips incidence was observed in all the organic manure applied plots (Anon, 2011).

Mulches placed on plant beds (gliricidia leaves, neem leaves, paddy straw) have reduced thrips populations and improve onion growth. The thrips incidence was low in neem leaves treated plots (Anon, 2011). Selections of quality seeds, use of appropriate nursery management techniques, removal of plant residues after harvest were identified as other important practices to reduce the thrips population. Sticky traps can be used to reduce thrips by mass trapping them in the nursery or field. Sprinkler and drip irrigation can suppress thrips population levels (Gunewardena et al., 2013a).

There is no known true resistance in onions to thrips. However, some onion varieties can tolerate thrips damage with a little yield loss. Varieties with tolerance to thrips require a few insecticide applications. Gunewardena et al. (2013a) evaluated 19 big onion lines along with the recommended variety, Dambulla Selection under insecticide free conditions. Thrips damage was low in the variety MIBO 1 (Anon, 2013). Varietal evaluation studies conducted at Thirunelvely in 2013 and 2014 revealed that all the shallot onion lines/varieties tested (Vethalam type - TVM 4, TVM 6, ARL 10, OHR, OH 8, True seeds, and small onion type - TVS 3, TVS 6, Jaffna Local and Thirunelvely Red) were susceptible to thrips (Anon, 2013a). Onion cultivars that have open neck growth and dark glossy leaves are less attractive to thrips. In 2008, exotic onion variety, Nashik Red was evaluated for pest incidences and found that it was severely damaged by thrips (Anon, 2008). Several species of predators (Anthocorid bugs, Pirate bugs Orius spp., Ground beetles, Lacewings, Spiders) that are associated with onion thrips have been identified (Anon, 1991).

Insecticides have been the primary approach for the management of thrips (Table 2). Farmers apply insecticides at weekly intervals to control thrips. In 1980’s organophosphate and carbamate group insecticides (Fenthion 50EC and Carbaryl 85% WP) were recommended for the control of thrips (Anon, 1982). The availability of series of new groups of insecticides and field reports indicated that
the earlier recommended insecticides were not effective in controlling thrips. This necessitated the testing of new insecticides for the control of thrips in onion. In 2002, different insecticides were screened and Thiacloprid 24SC, Imidacloprid 20SC, Fipronil 5SC and Prothiofos 50EC were recommended against thrips (Anon, 2002).

Table 2: Recommended and pipeline insecticides for control of onion thrips.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Year of registration</th>
<th>Mode of action group</th>
<th>Estimated EIQ*values based on recommended dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenthion 50EC</td>
<td>Prior to 1990</td>
<td>1B-AChE inhibitors</td>
<td>-</td>
</tr>
<tr>
<td>Carbaryl 85%WP</td>
<td>Prior to 1990</td>
<td>1A-AChE inhibitors</td>
<td>2.9 8.0 25.3</td>
</tr>
<tr>
<td>Thiacloprid 24SC</td>
<td>2002</td>
<td>4A-nAChR agonists</td>
<td>1.2 1.3 5.2</td>
</tr>
<tr>
<td>Imidacloprid 20SC</td>
<td>2002</td>
<td>4A-nAChR agonists</td>
<td>0.7 0.5 6.4</td>
</tr>
<tr>
<td>Fipronil 5SC</td>
<td>2002</td>
<td>2B-GABA-gated Chloride channel antagonists</td>
<td>0.2 1.0 3.3</td>
</tr>
<tr>
<td>Prothiofos 50EC</td>
<td>2002</td>
<td>1B-AChE inhibitors</td>
<td>-</td>
</tr>
<tr>
<td>Sulfoxaflor 24SC</td>
<td>Pipeline</td>
<td>4C-nAChR agonists</td>
<td>0.2 0.6 2.1</td>
</tr>
<tr>
<td>Pymetrozine 50%WG</td>
<td>Pipeline</td>
<td>9B-Selective homopteran feeding blockers</td>
<td>1.4 0.9 2.0</td>
</tr>
</tbody>
</table>

*EIQ = Environmental Impact Quotient.

Onion Caterpillars: *Spodoptera litura* (Fabricius), *S. exigua* (Hubner) (Lepidoptera: Noctuidae)

*Spodoptera litura* adults are stout-bodied moths, 1.4-1.8 cm long and with a wingspan of about 3 cm. Forewings are dark-brown with distinctive grey-black markings. Hind wings are white with dark veins (Plate 3). Adult lifespan is 5 to 16 days. Eggs are almost spherical, slightly flattened, and about 0.5 mm in diameter. They are whitish yellow. Eggs hatch after 2 to 5 days, depending on temperature.
Six larval instars occur. Newly hatched larvae are hairless and blackish-green with distinct band on the first abdominal segment. The mature larva is dull greyish and blackish green. Caterpillars have dark and light longitudinal bands and two dark, semi-circular spots on their back. Fully-grown caterpillars are about 40 mm in length (Plate 4). Larval stage of *S. litura* lasts 14 to 22 days. Mature caterpillars burrow into the soil to pupate. The pupae are brown and after pupation turning darker brown and finally almost black. They are 10 to 14 mm long. Pupal phase takes 7 to 15 days. The life cycle can be completed in about 5 weeks (Wijeratne, 2006).

*Spodoptera exigua* adult moths are moderately sized, the wing span measuring 25 to 30 mm. The forewings are mottled gray and brown and normally with an irregular banding pattern and a light coloured bean-shaped spot (Plate 5). The hind wings are a more uniform grey or white. Eggs are laid in clusters of 50 to 150 eggs/mass. Eggs are usually deposited on the lower surface of the leaf. Eggs hatch in 5-7 days. Larval period has six instars. The larvae are pale green or yellow (Plate 6). Mature larvae is about 37-50 cm. Larval development takes 10-12 days. Pupation occurs in the soil. The pupa is light brown and 15 to 20 mm in length. Duration of the pupal stage is 6-7 days during warm weather conditions (Wijeratne, 2006).

*Spodoptera litura* larvae bore into tubular leaves and feed concealed inside (Plate 7). Young larvae feed gregariously and skeletonize foliage. As they mature, larvae become solitary and make large irregular holes in foliage. *S. exigua* larvae
feed on both foliage and bulbs (Gunewardena et al., 2013a). In 1977, *S. exigua* outbreak was reported in Jaffna district and synthetic pyrethroids were recommended for the control. In 1979, light trap studies conducted at Thirunelvely showed that synthetic pyrethroids recommended for the control of onion caterpillar was not effective in reducing the damage (Anon, 1979). Therefore, different control measures were introduced to address the problem. Collection and destruction of egg masses and larvae, destruction of crop debris, flooding the field after harvesting, use of recommended fertilizers at correct rate and time of application were the recommended management practices for the control of onion caterpillars (Anon, 1979).

In 2006, onion caterpillar, (*S. exigua*) was reported as a serious pest in onion for the first time in the history in Matale district. Crop damage caused by this pest has been around 60-75%. In certain localities 100% crop loss has also been observed. Despite repeated application of recommended insecticides, including pyrethroids failed to provide an effective control of the pest. Therefore, new insecticides having different mode of action were tested and two insecticides, Metaflumizone 24 SC and Emamectin benzoate 5%SG were recommended (Table 3). Three applications of these insecticides in 7-10 day interval were sufficient to keep the damage below 10% (Gunewardena et al., 2008).

Very little attention has been paid in the past to biological control studies. In 1979, an attempt was made to investigate the possibilities of bio control of the *S. exigua*. A hymenopterous parasite, *Telenomus remus* was imported and tested at Thirunelvely. However, the parasite could not be recovered from the field (Anon, 1979). In 1984, nuclear polyhedrosis virus was used as bio control agent at Thirunelvely (Anon, 1984). In addition, different predators such as ants, pirate bugs, lacewing and lady bird beetles were identified to be associated with onion caterpillars (Anon, 1991).
Onion Maggot: *Delia antique* (Meiger) (Diptera: Anthromyiidae)

Onion maggot is a minor pest of onion. Adults are slender, grey, large-winged, 6 mm long and resemble houseflies. It has large legs and narrower abdomen (Plate 8). Eggs hatch into maggots 2-3 days after being laid. There are three cream-coloured larval stages. The full grown maggot larvae is pearly white, 8mm long and legless (Plate 9). Larval stages complete within 2-4 weeks depending on the temperature. The pupa is chestnut brown and 8mm long. First and second generation pupae remain in soil for 2-4 weeks before adult emergence. Cool, wet weather favours the development of onion maggots, while hot, dry weather is detrimental to the survival of this pest.

Onion maggot larvae feed on the below-ground tissues of seedlings (Plate 10). The damage done at first larval stage is more severe as this occurs when the plants are young. The larvae can kill small seedlings, which first wilt and then
become flaccid. Therefore, poor plant stands may indicate an onion maggot attack. Later generations may infest developing bulbs resulting in distorted growth accompanied by rotted tissue. Culled onions left piled on the ground are an important source of insect infestation. In addition, feeding and burrowing by the maggot may introduce and spread fungal and bacterial pathogens. Destruction of crop debris and removal of culls from the field is extremely important in controlling the onion maggot.

Table 3: Recommended insecticides for onion caterpillars.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Year of registration</th>
<th>Mode of action group</th>
<th>Estimated EIQ values based on recommended dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbofuran 3% G</td>
<td>1979</td>
<td>1A-AChE inhibitors</td>
<td>Consumer 9.1 Worker 32.1 Ecology 40.1</td>
</tr>
<tr>
<td>Deltamethrin 2.5EC</td>
<td>1979</td>
<td>3A-Sodium channel modulators</td>
<td>Consumer 0.0 Worker 0.1 Ecology 0.4</td>
</tr>
<tr>
<td>Esfenvalerate 7.5EC</td>
<td>1979</td>
<td>3A-Sodium channel modulators</td>
<td>Consumer 0.0 Worker 0.1 Ecology 0.9</td>
</tr>
<tr>
<td>Cyfluthrin 5E C</td>
<td>1979</td>
<td>3A-Sodium channel modulators</td>
<td>Consumer 0.1 Worker 0.1 Ecology 2.3</td>
</tr>
<tr>
<td>Permethrin 25EC</td>
<td>1979</td>
<td>3A-Sodium channel modulators</td>
<td>Consumer 0.1 Worker 0.3 Ecology 1.9</td>
</tr>
<tr>
<td>Fenvelerate 20EC</td>
<td>1979</td>
<td>3A-Sodium channel modulators</td>
<td>Consumer 0.2 Worker 0.5 Ecology 7.4</td>
</tr>
<tr>
<td>Diazinon 50 EC</td>
<td>1982</td>
<td>1B-AChE inhibitors</td>
<td>Consumer 2.1 Worker 5.9 Ecology 10.5</td>
</tr>
<tr>
<td>Chlorfluazuro n5EC</td>
<td>1982</td>
<td>15- Growth regulators</td>
<td>Consumer 0.1 Worker 0.3 Ecology 1.4</td>
</tr>
<tr>
<td>Metaflumizone 24SC</td>
<td>2008</td>
<td>22B-Voltage dependent sodium channel blockers</td>
<td>Consumer 0.6 Worker 1.3 Ecology 8.2</td>
</tr>
<tr>
<td>Emamectin benzoate 5SG</td>
<td>2008</td>
<td>6- Chloride channel activators</td>
<td>Consumer 0.0 Worker 0.1 Ecology 0.5</td>
</tr>
</tbody>
</table>
Root Eating Ants: *Dorylus orientalis* (Hymenoptera: Formicidae)

Adults are reddish brown ants. Head is nearly rectangular with a flat posterior margin (Plate 11). They live as colonies. At the early stage of the plant growth, ants damage roots and underground parts of the onion plants. They make burrows in soil. Under dry weather conditions, red ants cause considerable damage to onion roots (Dharmasena, 1993). Before establishing the crop, exposing soil to direct sunlight and destroying crop debris will help to reduce the population of ants. When a crop is damaged by ants, Diazinon 50EC can be applied to soil to reduce the ant damage (Anon, 2009).

Bulb Mite: *Rhizoglyphus* spp. (Acarina: Acaridae)

Bulb mite is a new pest reported in onion crop. They are 0.5-1mm long and shiny creamy white. Adults have four pairs of legs (Plate 12). They can infest bulbs in storage or in the field. Bulb mites can survive on decaying vegetation in the field until complete decomposition. Mites can be seen only under microscope (Gunewardena *et al.*, 2013b). Bulb mites attack roots and basal plate of onion plants. They reduce plant stands, make stunted plant growth and promote bulb rot during storage (Plates 13 and 14). The damage caused by bulb mites to the outer tissues helps the rotting organisms (fungi, bacteria) to penetrate into the bulbs (Plate 15). Crop rotation, soaking bulbs in miticides before planting, fallowing of fields, flood irrigation and use of mites free bulbs for planting help to reduce mite infestation (Gunewardena *et al.*, 2013b).
**Tuber Moth: Phtorimaea oper culella (Lepidoptera: Gelechiidae)**

Tuber moth was identified as a new pest of onion. The wing span is 10-12 mm. Fore wings are yellowish grey sprinkled with little black spots and the hind wings are grey (Plate 16). Eggs are oval, smooth and milky white. Larva is 10-12 mm long. It is rosy white with brown-black head. Pupa is narrow, 12 mm long and whitish. Larvae damage onion bulbs during storage (Plate 17). The damaged bulbs can be infected with fungi and bacteria and become rotten (Gunewardena et al., 2013b). Destruction of infested bulbs is an important preventive method (Anon, 1990). Nugaliyadda et al. (2014) developed pheromone based method for the management of tuber moth. The yellow delta traps containing phero-lure found to be effective in attracting male moths.

**Flower Chafer Beetle: Oxycetoniaversicolor (Coleoptera: Scarabaeidae)**

Flower chafer beetle is a new pest. It is brown with white markings on the elytra. Beetle is about 1 cm long (Plate 18). It damages onion flowers. Heavy infestation of flower beetles may cause considerable damage to onion crops. Hand picking of beetles can be done to control the problem (Gunewardena et al., 2013b).

**Future Directions for Onion Pest Management**

Pests are considered as one of the main constraints to increase the productivity of onion. Pesticides are used as the first line of defence by farmers for managing the pests. Recognizing the drawbacks associated with chemical pesticides, such as environmental pollution, human health hazards, pests becoming resistant to pesticides, secondary pest outbreaks etc., it is important to develop integrated pest management strategies to control onion pests. Research efforts should be undertaken to investigate the potential for biological control methods, especially for onion caterpillars. Information on the natural enemies available should be collected. Pheromones based control methods should be developed. Effect of secondary plants on onion pest management should be studied. Strong monitoring strategies should be designed to identify major pests.
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In addition, more emphasis should be given to develop better pesticide application technology especially for thrips control as the insecticides hardly reach the target pests living at the base of plants. Economic thresholds, at which insecticides are needed, should be identified. The impact of recommended
insecticides for pest resistance especially, for thrips should be determined. Farmers should be educated and trained to build up their knowledge and skills on pest management. Group approach through farmer training classes, demonstrations, field days as well as mass media is useful in disseminating this information.

**Conclusions and Recommendations**

Pest problems in onion cultivation in Sri Lanka have been identified and recorded. Identified methods for the management of these pests should be documented for farmer adoption. Biology, ecology and behaviour of the pests should be studied to develop better understanding of pests and threshold levels for control. Priority should be given to identify biological control agents of major pests, and plant resistance to widen management options. A need has arisen to develop improved pesticide application/delivery system to enhance the effectiveness and efficiency of pesticides in controlling pests and to minimize the pesticide loading to the environment through drifts and other means.

There is a need to continually update the recommended management methods utilizing information generated. Demonstration plots/fields should be established to educate farmers on the best pest and crop management practices at village level and also to monitor pest infestation levels. This is in view of increasing trends for onion production in the country and enormous economic benefits that farmers could obtain from the crop.

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PROCEDURE FOR QUALITY CONTROL OF ONION SEED AND BULB PRODUCTION IN SRI LANKA

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Abstract

Local production of onion (Allium cepa L.) is insufficient to achieve self-sufficiency. Unavailability of good quality seeds of recommended big onion varieties is a major constraint for increasing the productivity. The requirement of quality true seed of big onion and sets of red onion were 27,450 kg and 6,908 mt, respectively in 2013. In 2014, Government has spent about Rs. 103 million to import 20,597 kg onion seeds. Due to the demand for onion seeds and export restrictions in India, the quality of imported big onion true seeds is not up to the standard. Therefore, seed quality control through seed certification has become a prime requirement in the country. Seed certification on onion has been implemented after the release of red onion variety Thirunelvely Red and big onion varieties Dambulla Selection and MIBO 1 by Department of Agriculture. Registering under seed certification service and obtaining its service throughout the production period and use of farmer’s own quality assurance system after registering under Seed Act by establishing the seed crop using basic seeds are two methods that can be adopted by farmers for the quality assurance of onion seeds.

Introduction

Red onion and big onion are the most important bulbous crops grown in Sri Lanka and essential food item consumed mainly as spice due to their flavour and pungency. The annual requirement of big onion in Sri Lanka is around 309,000 mt assuming annual per capita consumption of about 10 kg whereas annual requirement of red onion is around 70,000 mt. However, local production is insufficient to achieve the self-sufficiency of big onion (SEPC, 2013). The average
big onion extent, production and seed requirement during 2000 to 2013 have been recorded as 4,460 ha, 67,004 mt, 28,990 kg, respectively and the production accounts for 31% of the national requirement. The highest extent of 6,988 ha and production of 92,167 mt has been recorded in 2007. Similarly, the average red onion extent, production and seed requirement during the same period have been reported as 4,680 ha, 52,715 mt and 7,019 mt, respectively where the highest extent of 6,228 ha and production of 72,339 mt have been recorded in 2006 and 2010, respectively.

The use of quality seed helps in achieving higher productivity and also plays a primary role to derive the full potential of all inputs such as fertilizer, agro-chemicals and irrigation water. In general, it is estimated that the direct contribution of quality seed alone to the total production is about 15-20% and it can be further raised up to 45% with efficient management of other inputs (Poonia, 2013).

Unavailability of good quality seeds of recommended big onion varieties is a major constraint for increasing its productivity (Mettananda, 2006; Hewavitharane et al., 2010). Seed material (seed sets or true seeds) must be available during the cropping period and they should be of high vigour and free from seed borne diseases (Sumanarathne et al., 2002). During 2013, based on seed rate of 6.5 kg/ha of true big onion seeds and sets at 1.5 mt/ha of red onion, the requirement of quality true seed and sets were 27,450 kg and 6,908 mt, respectively. Red onion seed (sets) requirement has been met mainly from local production and big onion seed requirement by farmers own seed or imported seeds (Table 1). However, the quality of the imported big onion true seeds is not up to the standard as they reach the country through illegal routes due to export restrictions in India (Edirimanna, 2003). Thus, setting of quality control system for onion seeds and bulbs is a prime requirement for achieving self-sufficiency.

Onion Seed Production and Importation

Local big onion seed production began in early 1980’s by few farmers in Matale district in the Central province. Later, during both maha and yala seasons, the cultivation expanded as it became a very profitable business as seeds fetch around Rs. 12,000-15,000/kg. Matale district is the major big onion seed producer in the country (Tables 2 and 3).
Table 1: Big onion and red onion true seed imports - 2007 to 2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>Red onion</th>
<th>Big onion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Companies (Number)</td>
<td>Varieties (Number)</td>
</tr>
<tr>
<td>2007</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
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<tr>
<td>2010</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2012</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: SEPC, 2013

Other districts such as Anuradhapura, Polonnaruwa, Kurunegala, Kandy, Mahawali areas, a few private sector organizations, government seed farms under Seed and Planting Materials Development Centre (SPMDC), Agrarian Service Department are also involved in producing substantial amount of big onion seeds. The rest of the big onion seed requirement is met by importing seeds from India. A decreasing trend of importation of big onion seed was observed during 2007 to 2014 (Table 1). The red onion true seed importation started by importing 600 kg from India in 2013 which doubled in 2014. The balance planting material requirement of red onion was met from local bulb (setts) production and small amount of true seed produced locally. Big onion seed crops established by SPMDC were certified by Seed Certification Service (SCS; SEPC, 2013) and while own certification was done for seed crops managed by private sector. The other seed producers can be categorized as informal or own seed producers without registering under the Seed Act of Sri Lanka.

Table 2: Big onion seed production in maha season in Matale district.
Seed Quality Control

The farmers must be provided with an assurance on good quality seed and planting material to obtain a high yield. Considering the quality, the most important parameters are genetic, physical, physiological and seed health attributes, which ultimately determine the value of seeds and planting materials. Seed certification is a legally sanctioned system for quality control of seed and planting materials production and distribution (SCS, 1985).

Table 3: Big onion seed production in yala season in Matale district.

<table>
<thead>
<tr>
<th>Season</th>
<th>No. of farmers</th>
<th>Amount of mother bulbs planted (kg)</th>
<th>Seed yield (kg)</th>
<th>Selling price (Rs.)</th>
<th>Value (Rs. million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984/85</td>
<td>4</td>
<td>60</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992/93</td>
<td>45</td>
<td>1,800</td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995/96</td>
<td>118</td>
<td>3,636</td>
<td>202</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000/01</td>
<td>152</td>
<td>8,000</td>
<td>345</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001/02</td>
<td>257</td>
<td>9,301</td>
<td>370</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002/03</td>
<td>247</td>
<td>10,478</td>
<td>430</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003/04</td>
<td>207</td>
<td>10,000</td>
<td>553</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004/05</td>
<td>205</td>
<td>12,378</td>
<td>857</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005/06</td>
<td>379</td>
<td>25,480</td>
<td>1,300</td>
<td>5,000</td>
<td>6.5</td>
</tr>
<tr>
<td>2006/07</td>
<td>500</td>
<td>30,000</td>
<td>1,725</td>
<td>7,500</td>
<td>13</td>
</tr>
<tr>
<td>2007/08</td>
<td>671</td>
<td>48,468</td>
<td>1,132</td>
<td>7,500</td>
<td>8.5</td>
</tr>
<tr>
<td>2008/09</td>
<td>750</td>
<td>55,000</td>
<td>4,183</td>
<td>9,000</td>
<td>38</td>
</tr>
<tr>
<td>2009/10</td>
<td>1,000</td>
<td>61,000</td>
<td>4,500</td>
<td>9,500</td>
<td>43</td>
</tr>
<tr>
<td>2010/11</td>
<td>1,200</td>
<td>93,850</td>
<td>3,500</td>
<td>12,000</td>
<td>42</td>
</tr>
<tr>
<td>2011/12</td>
<td>1,500</td>
<td>120,000</td>
<td>11,600</td>
<td>12,000</td>
<td>139.2</td>
</tr>
<tr>
<td>2012/13</td>
<td>1,500</td>
<td>125,000</td>
<td>9,000</td>
<td>12,000</td>
<td>108</td>
</tr>
<tr>
<td>2013/14</td>
<td>1,700</td>
<td>117,910*</td>
<td>11,822</td>
<td>15,000</td>
<td>177.3</td>
</tr>
</tbody>
</table>

*Amount of vernalized (108,530 kg) and non vernalized mother bulbs in 2013/14 maha
### History of Seed Testing in Sri Lanka

In 1956, seed paddy was tested for varietal purity and germination. In 1958, generation system of seed multiplication began after the release of rice variety H4. This led to the launching of systematically designed seed paddy program with the help of government seed farms and private seed growers. As a result, in 1958, the government improved its seed testing facilities with the assistance from the international co-operative administration of USA by establishing a seed testing laboratory at the Royal Botanical Gardens, Peradeniya. In 1968, seed testing was expanded to include vegetables and other field crops (OFC) seeds. In 1970, a new seed laboratory was established with modern facilities at Gannoruwa with the help of Australian Methodist Church. This process led to gain membership of International Seed Testing Association (ISTA) in 1974.

In 1977, a seed laboratory at MahaIluppallama was established and independent Seed Certification Service (SCS) was commenced in 1978 under
assistance from the Government of the Netherlands. Subsequently, two more seed laboratories were established at Alutharama and Bataatha in 2000 to fulfil growing demand for seed testing services both from the government and the private sector. All seed laboratories in Sri Lanka follow the rules of the ISTA. In 1985, the Peradeniya seed laboratory became an ISTA accredited laboratory with the right to issue international orange certificates after achieving the international recognition of seed testing activities (DOA, 2013b). This facility is not available at present.

SCS was organized into six major sub sections covering, field inspectorate (seed grower registration, seed crop inspections and seed farmer training, post-harvest supervision, sampling of seed for lab testing and post control testing, labelling and sealing of seed lots, inspection and sampling of imported seeds, implementation of Seed Act activities, follow up on complains regarding seeds and planting materials etc.), seed testing (varietal purity, physical purity, moisture content, germination, seed health testing etc.), variety and post control (characterization of DOA varieties, testing of promising varieties for Distinctness, Uniformity and Stability [DUS test] prior to release, post control testing [grow out], and trueness to label testing), fruit plant registration, seed research (established in 2012 to test seed samples for the presence of seed borne pathogens and find-out solutions for seed and planting material related problems) and Seed Act (established in 2008 to implement Seed Act No. 22 of 2003 which stipulated that seed should confirm to a minimum level of genetic and physical purity and compulsory labelling with required information) to carry out its duties more efficiently and effectively.

Formal seed certification for seed paddy was begun in 1980. Later, these services were expanded to OFC in 1983, vegetable in 1984, seed potato in 1987 and other planting materials in 1990. The legal status of the SCS is covered under Seed Act No. 22 of 2003. Altogether, 32 units (24 SCS regional units, four seed testing laboratories and four post control units) are operated under SCS and scattered throughout the country and is under the Seed Certification and Plant Protection Centre, Department of Agriculture. Initiation of a regional office at Mulathivu, seed testing laboratory at Paranthan and two post control fields at Bataata and Karadiyanaru are planned (DOA, 2013a).
**Onion Varieties**

Until release of Thirunelvely Red in 2009 for the Northern region of the island by the Department of Agriculture, there were no locally released varieties of red onion (DOA, 2009a). However, there are several popular cultivars such as Vethalan, Jaffna Local, Thellula Selection used in Sri Lanka (DOA, 2013b). Vethalan and Jaffna Local varieties are widely grown and an additional advantage of Vethalan is that it produces flowers and sets seeds after vernalization under local conditions, thus true seed production of red onion is feasible in Sri Lanka (DOA, 2014).

There are several introductions (eg. Pusa Red, Rampur, Bomby Red, Agrifound Light Red, Nasik Red) and cultivars selected from introductions by big onion farmers eg. Dambulla Red and Galewela Light Red from Pusa Red and Agrifound Light Red which are popular among farmers. Locally developed big onion varieties, Kalpitiya Selection, Dambulla Selection (DOA, 2009a) and MIBO 1 (DOA, 2014) were released in 1992, 2009 and 2014, respectively. Even before the releases of varieties, some farmers have been producing true seeds using introduced cultivars in Dambulla area (MASL, 2009). Later, the onion true seed production became popular and private sector companies and producers entered into this profitable business.

**Certification of Onion Seed**

In 2009, seed certification procedure for onion was developed and implemented for DOA recommended varieties, mainly in the Government seed farms. For certification procedure, one of the two methods can be adopted. The first method is registering under SCS and obtaining SCS service throughout the production process. The second method is using own quality assurance system after registering under Seed Act by establishing the seed crop using basic seeds.

Farmer demand for locally produced true seeds of onion is very high and the demand is expected to grow rapidly. However, farmers are following their own seed certification procedure with a help from extension staff of DOA to produce their own seeds. Onion is a biannual, predominantly cross-fertilizing, in which a strong inbreeding depression is present (Masayoshi and Chris, 2002). Therefore, a practical and appropriate quality control system is a necessity.
Certification Methodology for Onion

The main objective of the seed certification of onion is to ensure the acceptable standards of genetic, physical, physiological attributes and seed health.

Eligibility Requirement for Onion Seed Certification

*General requirement of the variety*

Full certification can be done only for the varieties released by the DOA. Presently, one variety of red onion (Thirunelvely Red) and two varieties of big onion (MI BO 01 and Dambulla Selection) are eligible for full certification. However, some exemptions are given for farmer varieties for testing seed in seed laboratories of DOA as listed below.

- Producer should purchase certified basic mother bulbs or true seeds from authorized sources (from SPMDC in the DOA).
- Producer shall make a request within 2 weeks of planting for registration. Origin of the material used for planting shall be confirmed by providing seed labels.

*Methods of seed production and seed classes*

Onion is biennial crop and takes two full seasons for producing seeds. Bulbs are formed during first year and flower and fruiting take place in the second year. There are two methods of true seed production: (i) seed to seed and (ii) bulb to seed methods. However, in Sri Lanka, only bulb to seed method is used for seed production. Production cycle and seed classes of onion are given blow.

- Mother bulbs are obtained from planting of true seeds and the next generation true seeds are obtained from the planting of these mother bulbs or *vice versa*.
- There are five seed classes (Nucleus, Breeder or Pre basic, Basic, Standard and Commercial) of setts or true seed for red onion planting materials in the seed multiplication process.

1. Nucleus seed is produced by the breeder and it is genetically pure seed.
2. Breeder seed (pre-basic seed) is produced by the breeder from breeder bulbs produced from Nucleus seeds and certified by the SCS. Tag with pink colour design in white background is affixed by the SCS.

3. Basic seed is produced at the government seed farms of the SPMDC by using basic bulbs produced from breeder seeds under the supervision of SCS. Tag with brown colour design in white background is affixed by the SCS.

4. Standard seed is produced at the government seed farms or by contract growers of the SPMDC or private sector by using standard bulbs produced from basic seeds under the supervision of SCS. Tag with yellow colour design in white background is affixed by the SCS or label approved under Seed Act by the private producers.

5. Commercial seed is produced mainly with contract growers of the SPMDC or private sector by using certified bulbs produced from standard seeds under the supervision of SCS or producers own certification. Tag with light green colour design in white background is affixed by the SCS while label approved under Seed Act is affixed by the private producers.

**Land requirement and isolation**

Land to be used for onion seed or bulb production should free from volunteer plants. There should be a minimum extent of 100 m$^2$ while maintaining required isolation distance as specified in Table 4.

<table>
<thead>
<tr>
<th>Table 4: Minimum isolation distance (m) required for onion seed production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother bulb production stage - bulb crop (m)</strong></td>
</tr>
<tr>
<td>Breeder</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

**Field Inspections**

Usually seed quality inspections are done in several stages as indicated below.

a) **Seeding to mother bulb production**

- First inspection at seedling stage
- Second inspection at bulb initiation
- Third inspection at bulb maturity
Minimum of two inspections shall be done and rouging of off-types *viz.* those having different shapes, colours, maturity durations of plants, leaves and bulbs.

**b) Final inspection at harvesting stage**

Minimum of two inspections shall be done with rouging of off-types. Leaves and bulbs of those having different shapes, colours, maturity durations should be removed. Rough estimate of bulb yield should be mentioned in the final report. Awareness should be given to the producers on post-harvest activities on mother bulb harvesting and storage such as stopping irrigation two weeks before harvesting and harvesting should be done at proper stage.

After harvesting and selecting mother bulbs according to the criteria given in Table 5, SCS officer shall complete a lot inspection report (including the weight of the bulbs) before sending bulbs for vernalization.

**Table 5: Standards for mother bulbs.**

<table>
<thead>
<tr>
<th>Bulb part</th>
<th>Character for big onion</th>
<th>Character for red onion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>Slender and sealed</td>
<td>Slender and sealed</td>
</tr>
<tr>
<td>Diameter of the widest part of the bulb (cm)</td>
<td>4.0 to 5.0</td>
<td>Medium and large size bulbs</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>60 to 80</td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td>Well matured, single centre</td>
<td>Well matured</td>
</tr>
</tbody>
</table>

**Bulb to Seed (Production of True Seeds from Mother Bulbs)**

Producer shall make a request for registration within 2 weeks of planting.

1. Registration – Following requirements shall be fulfilled for registration and a fee of Rs. 400/= shall be paid.
   a. Requirements for registration
      i. Origin of the material used for planting shall be confirmed by providing lot inspection report.
      ii. Minimum extent should be 100 m²
      iii. Bulb requirement
(i) Big onion 80.0 kg/100 m²
(ii) Red onion 17.5 kg/100 m²
b. Isolation distance should be maintained as indicated in Table 4
c. Should have a good plant population
d. Free from pests and diseases

2 Field inspection
At least three field inspections should be made and off types present in the crop is removed to maintain the approved standard (Table 6)
   a. 1st inspection should be done at seedling stage (vegetative stage)
   b. 2nd inspection should be done at flowering stage
   c. Final inspection should be done at maturity stage. At this stage, suitable inflorescences shall be selected for seed collection.

Table 6: Allowable off type for onion seed production.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Breeder</th>
<th>Basic</th>
<th>Standard</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulb not confirming to</td>
<td>0.10</td>
<td>0.20</td>
<td>0.20</td>
<td>0.30</td>
</tr>
<tr>
<td>varietal characters</td>
<td>(by number)</td>
<td>(by number)</td>
<td>(by number)</td>
<td>(by number)</td>
</tr>
<tr>
<td>Off-types</td>
<td>0.10</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

3 Harvesting shall be done when 10-15% of the capsules on individual heads expose the black seed.

4 Post harvesting activities
   a. Until seed separation, inflorescences shall be kept horizontally as a bunch
   b. Inflorescences shall be dried in sunlight for few days
   c. Seeds shall be separated manually or by machines.
   d. Inert matter shall be separated using a slow speed fan
   e. Seed shall be packed and stored in a refrigerator or cool and dry place

5 Sampling
   a. Processed seed lot shall be inspected for its suitability for sampling.
   b. Labelling and sealing the lot shall be done before sampling.
   c. Representative seed sample from the sealed seed lot shall be taken.
   d. The sample taken shall be submitted to the seed laboratory for testing. Seed testing standards are given in Table 7.
Quality control in onion sees and bulb production

Table 7: Seed standards for onion seed.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Breeder</th>
<th>Basic</th>
<th>Standard</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure seed (minimum) (physical) (%)</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Genetic purity (minimum) (%)</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Inert matter (maximum) (%)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Germination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. onion (%)</td>
<td>80</td>
<td>80</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>R. onion (%)</td>
<td>80</td>
<td>80</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Weed seed (maximum/kg)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Noxious weed seeds (number/kg)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. onion (%)</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>non moisture proof containers</td>
<td>R. onion (%)</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Moisture proof containers (%)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Self Quality Assurance System after Registering Under the Seed Act.

Under this procedure, producer shall register under the Seed Act with the DOA. The producer shall follow standards and procedures stipulated by the DOA for onion seed production and certification. The producer shall take responsibility for the quality parameters shown in the seed packet. Presently, only a small extent of onion has been certified by the seed certification service (Table 8). Hence, it is necessary to increase the certified extent to produce quality seeds to achieve higher productivity and increase the basic seed production. In red onion, about 2.53 ha of commercial seed class requested for seed certification in 2013.

Conclusions

Unavailability of good quality true seeds or setts of recommended varieties in adequate quantities is considered as the main constraint for increasing production.

Table 8: Extent of certified big onion seed production - 2012 to 2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>Class</th>
<th>Registered extent (ha)</th>
<th>Inspected extent (ha)</th>
<th>Actual extent (ha)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Commercial</td>
<td>0.6073</td>
<td>0.6073</td>
<td>0.6073</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Basic</td>
<td>0.4251</td>
<td>0.4251</td>
<td>0.4251</td>
<td>-</td>
</tr>
<tr>
<td>2013</td>
<td>Commercial</td>
<td>0.6478</td>
<td>0.6478</td>
<td>0.6478</td>
<td>44</td>
</tr>
</tbody>
</table>
of big onion and red onion in Sri Lanka. Presently, few varieties have been released by the DOA for general cultivation. Certified quality seed or planting materials of such varieties with high physical purity assures farmers against the introduction of seed borne diseases, weeds or other crop seeds which could reduce productivity and lower seed quality. In order to achieve this objective, the onion seed producers should maintain the quality standard either by obtaining service from SCS or their own certification system. This will lead to achieve continuous supply of quality seed or propagating materials of recommended onion varieties for farmers. It also helps to avoid unnecessary losses in yields from planting seed or planting materials of unknown origin or contaminated varieties.

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Quality control in onion seeds and bulb production


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ONION BREEDING AND SEED PRODUCTION IN KOREA

by Cheol-woo, Kim

ABSTRACT

□ Status of onion cultivation in Korea
○ Korea ranked Top 10 in the world in production of onions -1,411,650 metric ton, 2012 FAO.
○ In dry-bulb onion yield per hectare, Korea ranked the first(672,476kg, 1990-2009, USDA)
○ National cultivation area : '14 Year 23,908ha
○ Onion seed market : 29.4 billion $ (import 1.80million-Most varieties of Japan)

□ Cultivars of Korea
○ Early maturation type 12%, mid-late maturation type 88%
○ Chief production area in Korea
  - Early maturation type (2,542ha)
    : Jeonnam 61%>Jeju 35%> kwangju 3%> kyeongnam 1%
  - Mid-late maturation type(19,552ha)
    : Jeonnam 52%> kyeongnam 22%> Kyungpoog 14%> Jeonbuk 7%

□ Researches for development of onion cultivars
○ Traditional methods : The Use of cytoplasmic Male Sterility for Hybrid Seed Production
○ Using molecular marker : development pcr marker distinguished cytoplasm and geno type related male sterile and maintainer
○ Research of inter-specific hybrid : to breed pest and disease resistance line
Contents

01 Introduction – Status of onion industry in Korea
02 Breeding procedure of hybrid seed production
03 Research of breed efficiency enhancement
   • Development of molecular marker and use
   • Development inbreed line using of Doubled haploid
04 Research of Inter-specific hybrid
05 Seed production in south korea
Onion breeding and seed production in Korea

Onion seed market in Korea

- onion seed market in Korea is ranked three, followed by peppers, radisheses
- Onion seed market is a 29.4 billion $

SALES OF ONION SEED (100 million, US $)

Onion seed production in 2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic</th>
<th>Abroad</th>
<th>Total(kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield(kg)</td>
<td>ratio(%)</td>
<td>Yield(kg)</td>
</tr>
<tr>
<td>1995</td>
<td>20,747</td>
<td>68.5</td>
<td>9,526</td>
</tr>
<tr>
<td>2000</td>
<td>23,014</td>
<td>40.5</td>
<td>33,788</td>
</tr>
<tr>
<td>2004</td>
<td>3,208</td>
<td>11.1</td>
<td>25,671</td>
</tr>
<tr>
<td>2006</td>
<td>6,855</td>
<td>20.0</td>
<td>27,355</td>
</tr>
<tr>
<td>2007</td>
<td>9,197</td>
<td>19.9</td>
<td>36,994</td>
</tr>
<tr>
<td>2008</td>
<td>9,234</td>
<td>34.0</td>
<td>29,174</td>
</tr>
<tr>
<td>2009</td>
<td>7,473</td>
<td>18.9</td>
<td>6,846</td>
</tr>
<tr>
<td>2010</td>
<td>9,183</td>
<td>50.1</td>
<td>9,174</td>
</tr>
<tr>
<td>2011</td>
<td>8,768</td>
<td>19.3</td>
<td>36,655</td>
</tr>
<tr>
<td>2012</td>
<td>14,616</td>
<td>26.5</td>
<td>40,485</td>
</tr>
</tbody>
</table>
Cheol-woo, Kim

- Onion cultivation area according to ecotype

- South Korea’s annual acreage and quantity of onion
Onion breeding and seed production in Korea

South Korea's annual acreage and quantity of onion, 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Cultivation Area (ha)</th>
<th>Yield / ha (Kg)</th>
<th>Total production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>15,314</td>
<td>6,093</td>
<td>933,095</td>
</tr>
<tr>
<td>2003</td>
<td>12,352</td>
<td>6,033</td>
<td>745,203</td>
</tr>
<tr>
<td>2004</td>
<td>15,563</td>
<td>6,090</td>
<td>947,797</td>
</tr>
<tr>
<td>2005</td>
<td>16,737</td>
<td>6,114</td>
<td>1,023,331</td>
</tr>
<tr>
<td>2006</td>
<td>15,315</td>
<td>5,809</td>
<td>889,619</td>
</tr>
<tr>
<td>2007</td>
<td>17,751</td>
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<td>2014</td>
<td>23,908</td>
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○ The two types are grown in accordance with temperature distribution in Korea

○ Early maturation type 12%, mid-late maturation type 88%
○ Chief production area in Korea
  - Early maturation type (2,542ha)
    : Jeonnam 61% > Jeju 35% > kwangju 3% > kyeongnam 1%
  - Mid-late maturation type (19,552ha)
    : Jeonnam 52% > kyeongnam 22% > Kyungpoog 14% > Jeonbuk 7%
Onion consumption amount

Health food
- World average per capita consumption: 6.2kg
- Libya: 30.3kg
- Korea: 25.5kg
- USA: 9.5kg

Uses of onion in South Korea
Onion breeding and seed production in Korea

**Onion life in South Korea**

- Harvest: April ~ June
- Over winter: March
- Transplanting: Late Oct.~ Mid Nov.
- Sowing and nursery: Early ~ late Sep.

**Onion Seed Production procedure in South Korea**

- **Seedling**: late Aug.~Mid Sep.
- **Planting**: late Oct.~Mid Nov.
- **Harvesting**: early April~mid June
- **Mother bolting planting**: late Aug.~early Oct.
- **Seed production**: mid-July
onions (*Allium cepa* L.)

- Major vegetable crop
- Biennial crop
- Cross-pollinated crop
- Vernalization and specific photoperiod requirement for flowering
- Severe inbreeding depression

### Goal Setting

- How to cultivate the breed type: fixed species (OP), hybrid
- Daylength response
  - Early variety daylength = 11.5 hours
  - Mid–late variety daylength more than 14 hours
- Uniformity
- By use
- Disaster Resistant
- Local adaptability
The Use of Cytoplasmic Male Sterility for Hybrid Seed Production

Cytoplasmic male sterility (CMS)

- Controlled by mitochondrial genes
- Maternally inherited
- Used for hybrid production in many crops
  - Onion, carrot, cabbage
  - Corn, sorghum, pearl millet, sunflower, sugar beets

Male sterile (A-line) Mintainer (B-line)
Cheol-woo, Kim

Use backcross breeding method

- Make selection in maintainer
  - Also self or sib-mate
- Plant seed from self or sib-mating
- Make selection in maintainer
  - Self or sib mate
- Continue

Male-sterile line will look more like maintainer lines.
Search for maintainer lines

Unknown plant X Male-sterile (Smsms)

- All sterile progeny (Smsms) then Nmsms
- 50% fertile : 50% sterile then SMsms or NMsms
- 100% fertile then SMsMs or NMsMs

Simple hybrid with cms and restoration

**Male sterile (A-line)**

\[ S, \text{msms} \]

\[ \text{N1} \times \text{Male sterile (A-line)} \]

\[ S, \text{msms} \]

\[ \text{N1} \times \text{N2} \]

\[ \text{Pollen parent (C-line)} \]

\[ N, \text{MsMs} \]

\[ F_1 \text{ hybrid} \]

\[ S, \text{Msms} \]
Research of breed efficiency enhancement
Development of Shortening generation
breeding Tools

- Development of molecular marker
- Development inbreed line using of Doubled haploid
Development of molecular marker for distinguishing 3 onion mitotypes

A

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<tr>
<th>Normal</th>
<th>CMS-T</th>
<th>CMS-S</th>
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Development of molecular marker distinguishing maintainer

F2 population

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<td>11 12 13 14 15</td>
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[jnurf17] [jnurf10] [jnurf06] [jnurf20] [jnurf05]
**Male sterile type investigation for 116 varieties grown in the domestic**

- Imported varieties from Japan
- Domestic varieties

- Graph showing the distribution of male sterile types:
  - Imported varieties: S 24%, T 35%
  - Domestic varieties: S 15%, T 48%

- Development of molecular marker distinguishing 3 cytoplasm and genotype

- Maintainer selection: 4~8 years (traditional method) → 1 Month

- Diagram illustrating the process of maintaining and identifying male sterile types.

- Images showing the results of molecular marker analysis for different cytoplasms and genotypes.
Development inbreed line using of Doubled haploid (DH line)

Haploid grown through the ovary of onion flower

Development of DH line breed procedure
Doubled haploid line induced from immature ovary

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04. Research of Inter-specific hybrid

Gene pool concept in cultivated Allium species based on hybridization (Shigyo, 2007)

A. sativum (Garlic)
A. ampeloprasum (Leek)
A. chinense (Rakkyo)

A. cepa (onion)
A. ascalonicum (shallot)
A. vavilovii
Introgression through interspecific hybrid

*Allium cepa* (common onion) x *A. ascalonicum* (shallot)

- to improve storability, functional ingredients
Onion breeding and seed production in Korea

**BC₁F₁**

**BC₄F₁**

*Allium cepa* (common onion) × *A. fistulosum* (bunching onion)

: to introduce disease resistance (leaf blight, pink root, downey mildew etc)
05. Seed Production in Korea
The procedure of pollination and seed production

Artificial rearing of pollinator vector (blow fly, Lucilia illustris)

- Sand plastic box
- Cattle lung
- Attract fly
- Spawning
Life cycle of blow fly
Lucilia illustris Utilization for onion pollination

Seed fruition

Selfing

Ventilation methods of plastic greenhouse
Seed production in farm

<table>
<thead>
<tr>
<th>Ventilation method</th>
<th>Flowering Period</th>
<th>No. of flower stalk (%)</th>
<th>Fertility (%)</th>
<th>Seed harvested (ℓ/10a)</th>
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<td>120.0c</td>
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<td>Opening skylight/100㎡</td>
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<td>5.2</td>
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DMRT (5%)
Thank you
INTEGRATED PEST MANAGEMENT FOR GOOD QUALITY ONION PRODUCTION IN KOREA

by Jongtae Lee

Presentation structure

1. Bulb onion production in Korea
2. Diseases and pest insects
3. Integrated pest management strategies in Korea
1 Bulb onion production in Korea

Introduction of Korea and agriculture

General
Land size: 10 million ha (22 mil. ha including N.K.)
Population: 50 million (75 mil. Including N.K. 2010)

Agricultural sector (2013)
Agricultural land: 1.71 million ha (17.1% of land)
- Paddy 56%, upland 44%
Cultivated area per farm household: 1.50ha
Population: 2.8 million (5.64%)
Fifty seven percent of total bulb onion area is grown in this part, in upland soil.

Thirty three percent of total bulb onion area is grown in this part, in paddy soil.

Main bulb onion production areas
In Korea, bulb onion has the fourth biggest area among vegetables, following hot pepper, Chinese cabbage and garlic.

- Cultivation area: 23,911 ha (southern part)
- Production: 1.59 million tons per year
- Average bulb yield: 66.5 ton ha$^{-1}$
- Cultivars: short-day (7%) to intermediate-day (93%)
- Storage: half of harvested onions, until 4 to 10 months

Korean bulb onion performs the highest yield all over the world, which is due to extremely intensive practices, including plastic mulch, high plant density, and frequent chemical sprays, etc.
Temperature change during onion growth ('72~'03)

Habcheon county: southeastern part of Korea

Average temperature: 10.0°C (early Sept. ~ early Jun.), yearly average temp.: 13.0°C

Maximum temp. 22.8°C (early September); minimum temp. -0.8°C (late January)

Korean climate is affected by north pacific ocean in summer, with 'monsoon season' (late June to early August) and typhoon, and is affected by continental high pressure in winter, with dry and cold weather.

Rainfall during onion growth ('72~'03)

Total rainfall: 582mm (early Sept. ~ early Jun.), yearly rainfall: 1,276 mm

Maximum rainfall 60mm (mid September); minimum rainfall 4.3mm (late December)

Habcheon county: southeastern part of Korea
Onion seedling

- Sowing (Early to mid September)
- Seedling management (September to October)
- Soil solarization of seedling bed (August)
- Seedling lifting (Late October to early November)

Transplanting and overwintering in paddy soil

- Field preparation and plastic mulching (Late October)
- Transplanting (Early November)
- Flood irrigation (Early November)
- Overwintering (December and January)
Integrated pest management of onion in Korea

Vegetative stage in paddy soil

- Initial growth (February)
- Leaf enlargement (Early April)
- Maximum vegetative stage (Late April)
- Initial growth (March)

Bulb development

- Initial bulbing stage (Early May)
- Mid bulbing stage (Late May)
- Tops-down stage (Early June)
- Late bulbing stage (Mid June)
Harvest

Leaf cutting and plastic film removal (Mid June)
Bulb lifting (Mid June)
Putting bulbs in 20kg mesh bag (Mid June)
Transporting onion bags

Storage

Short storage (July)
Cold storage at 0°C (August to April)
Grading and packaging
Grading and packaging
Mechanization get underway.

Sowing in plug trays in a nursery

Sowing in seedling box

Mechanization get underway.

Sowing in soil bed with a seeder

Direct Sowing
Mechanization get underway.

Transplanter (Dongyang, Korea company)

Transplanter (Kuboda, Japan company)

Mechanization get underway.

Bulb lifter

Bulb harvester
2 Diseases and pest insects

Fungal foliar diseases

1. Downy mildew

- Pathogen: *Peronospora destructor*
- Symptoms
  - Pale, elongated patches on leaves forming gray or purple downy hair of sporing bodies
  - Chlorosis and collapse of leaves and flower stalks
- Infection sources: plant debris, crop overlap, systemically infected bulbs and sets, infected transplants
- Conditions for spore production
  - Temp.: 3-25°C
  - Relative humidity: 100%
  - Spores form at night and release with RH drop in day, 9-16 days latent period between infection and spore production
- Conditions for infection: optimum 10-12°C, free water on leaf for 2-4 hours (fog, rain or irrigated water)
- Fungicides: dithiocarbamates, copper, chlorothalonyl, metalaxyl, etc. (alternate different fungicides to avoid pathogen resistance)
- Resistance: cultivar differences, resistance from *A. roylei* being transferred to onion
- Cultural control: avoid crop overlap, hygiene, rotation > 4 years, to minimize RH round leaves, use wide spacing, orient row parallel to prevailing wind and use moderate N
2. Stemphylium leaf blight and stalk rot

- **Pathogen**: *Stemphylium vesarium*
- **Symptoms**
  - Small, white to brown watery leaf spots elongating to spindle-shaped patches with dark brown or black centres where conidia form
- **Infection sources**: ascospores from infected debris, conidia form debris in spring and from infected plants as epidemic develops
- **Conditions for spore production**
  - Temp.: 10-21°C, >14 h for ascospores, rainfall and 15-32°C for conidia
- **Conditions for infection**: >8 hours leaf wetness at 10-25°C, more infection with longer wetness and higher temp. (up to 20°C), tissue damage by other pathogens (downy mildew)
- **Fungicides**: dithiocarbamates, iprodione, mancozeb, chlorotharonyl (vary fungicides to avoid resistant pathogens)
- **Cultural control**: rotation > 3 years, hygiene, to minimize leaf wetness by wide spacing, orient row parallel to prevailing wind and use moderate N
- **Special features**: symptoms difficult to distinguish from purple blotch, often occurs with the latter as a disease complex, causes collapse of flower stalks

3. Purple blotch

- **Pathogen**: *Altaernaria porri*
- **Symptoms**
  - 2-3mm watery lesions on leaves and flower stalks which elongate and bleach, with purple or brown centres, rot of infected bulbs
- **Infection sources**: debris, infected bulbs
- **Conditions for spore production**
  - Optimum temp.: 25°C, little at < 13°C
  - light and RH > 90%, spore release with RH drop
- **Conditions for infection**: 25°C, free water on leaf for 6 hours, older and damaged leaves more susceptible (e.g. by thrips)
- **Fungicides**: as for *Stemphylium* leaf blight
- **Cultural control**: as for *Stemphylium* leaf blight
- **Special features**: often in disease complex with *Stemphylium* leaf blight
**Fungal foliar diseases**

**4. Leaf fleck, leaf spot, collar rot**
- **Pathogen:** *Botrytis cinerea*
- **Symptoms**
  - Small leaf spot, rot round pseudostem with grey mould on it
- **Infection sources:** debris, nearby crops, sclerotia in soil
- **Conditions for spore production**
  - It can occur at low temp. (5°C)
- **Conditions for infection:** plants stressed by cold (collar rot)
- **Fungicides:** dithiocarbamates, benimidazoles
- **Cultural control:** avoid crop overlap, hygiene

**Fungal foliar diseases**

**5. Leaf blight or blast**
- **Pathogen:** *Botrytis squamosa*
- **Symptoms**
  - Small, round to ellipsoid white lesions with pale halo, leaf die-back from tip, sporing on dead leaves
- **Infection sources:** sclerotia in debris and soil which form conidia, nearby crops
- **Conditions for spore production**
  - Temp.: 14-20°C
  - Free water for 12 hours, spore release with RH change
- **Conditions for infection**
  - Temp.: 16-28°C
  - Free water on leaf for > 6 hours, old and senescent leaves susceptible
- **Fungicides:** as for leaf fleck
- **Resistance:** cultivar differences, resistance from *A. roylei* being transferred to onion
- **Cultural control:** avoid crop overlap, hygiene, promote air movement and leaf drying by wide spacing, rotation
1. Damping off

- **Pathogen**: *Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp., and *R. solani*
- **Symptoms**
  - Pre-emergence: the fungus kills radicle and plumule of seed before emergence from soil
  - Post-emergence: The pathogen attacks the collar region of seedlings on the surface of soil. The collar portion rots and ultimately the seedlings collapse and die.
- **Conditions for infection**
  - Temp.: wide range (generally, high temp and high humidity)
- **Control**: fumigation, solarization, avoidance by timing, crop rotation, fungicide

2. *Fusarium* basal rot

- **Pathogen**: *Fusarium oxysporum*
- **Symptoms and features**
  - The pathogen can cause disease at all stages of onion growth, from seedling to stored bulb.
  - The fungus can penetrate the base plate of alliums and cause a brown discoloration and rot, so that the shoot easily detaches from base.
  - Infection can be increased by damage from pests.
- **Conditions for infection**
  - Optimum temp.: 27-30°C
  - Temp. range: ≥15°C
- **Control**: resistant cultivars, crop rotation, fumigation, solarization, avoidance by timing
Fungal diseases infecting from the soil

3. White rot

- **Pathogen**: *Sclerotium cepivorum*
- **Symptoms and features**
  - The fungus penetrates the root epidermis and invades the root cortical tissue.
  - Plants infected with white rot may have a cottony white or grey mass of fungal mycelium on the stem base.
  - Mycelium can infect adjacent plants and spread of the disease is facilitated by the high plant density. It is easily transferred from infected field to other fields by machines or equipments.
  - Field infections can go unnoticed at first, but can reduce yields to uneconomic level in 4 years of successive onion crops.
  - Once established, infected land is usually abandoned for onion production because of the persistence of sclerotia in soil.
- **Conditions for infection**
  - Optimum temp.: 14-18°C
  - Temp. range: 9-24°C for sclerotial germination; 5-29°C for mycelial growth.
- **Control**: fumigation, solarization, fungicide, avoidance by timing.

Fungal diseases infecting from the soil

4. Pink rot

- **Pathogen**: *Pyrenochaeta terrestris*
- **Symptoms and features**
  - Infected plants have characteristic pink-hued roots which become darker red with time.
  - Infected roots ultimately collapse and die.
- **Conditions for infection**
  - Optimum temp.: 24-28°C
  - Temp. range: ≥ 16°C
- **Control**: resistant cultivars, fumigation, solarization, fungicide, avoidance by timing.
Fungal diseases infecting from the soil

5. Disease control

• Prevention of spread
  - All soil-borne diseases can be spread by anything that moves infected soil from place to place.
  - The movement of contaminated soil from disease-infested land on boots, implements, etc. must be prevented
  - Infected plant debris should be confined and the disease propagules destroyed by high-temperature composting or other means.

• Cultural control
  - 5 or 6-year gap between allium crop: pink root
  - 3 or more-year gap: Fusarium basal rot

• Resistant cultivars
  - Pink root or Fusarium basal rot resistant cultivars available.

• Destruction of propagules
  - Crop rotation
  - Fumigants: methyl bromide, chloropicrin or dichloropropene (the use of fumigants is becoming increasingly unacceptable on environmental grounds)
  - Composting of crop residue: more than 7 days over 50°C for destroying white rot sclerotia

• Fungicides
  - It can be effective to apply at seed sowing, set planting or seeding transplanting.
  - Broad-spectrum dithiocarbamate protectant fungicide: thiaram
  - Systemic and curative fungicides: thiobendazole, carboxin, tebuconazole
  - However, problems of loss of fungicidal activity through the build-up of resistance and of enhanced degradation in soil is increasing.

• Biological control
  - Fungal antagonists: Bacillus subtilis, Trichoderma harzanium, Sporidesmium sclerotivrum
  - The control efficiency is erratic and unpredictable under field conditions

⇒Improved control can be achieved by combination of biological control agents, disease-suppressive composts, fungicidal seed treatment and crop rotation as well.
# Fungal diseases of stored bulbs

## 1. Neck rot
- **Pathogen**: Botrytis aclada, B. allii, B. byssoidea
- **Symptoms**
  - Bulb decay starting at bulb neck
  - Forming black sclerotia on bulb surface
- **Infection sources**: spores from senescent leaves and from sclerotia, infected seed
- **Conditions for infection**
  - Optimum temp.: 22-23°C
  - Temp. range: 5-25°C
- **Special features**
  - The symptoms usually develop 2-3 months after harvest.
  - The pathogens produce spores on dead leaf tissue and can invade the tip of ageing leaves. It is latent in live green leaves, causing no disease. By sequentially invading successive leaves, the pathogens enters those leaves which swell at the base to form the outer fleshy scales of the bulb.
  - There is no evidence of spread from bulb to bulb in store.
- **Control**
  - Use of uninfected seeds, disinfection of seed by systemic benzimidazole fungicide
  - The pathogens cannot infect dry, senescent leaf tissue, so that in dry climate, onions field-dried with the foliage intact are not at risk.

## 2. Black mould
- **Pathogen**: Aspergillus niger
- **Symptoms**
  - Black, sooty mould and between outer bulb scales, particularly along vein
- **Infection sources**: debris in soil, infected seed
- **Conditions for infection**
  - Optimum temp.: 28-34°C (> 80% humidity)
  - Temp. range: 10-40°C
- **Special features**
  - In tropical regions where onions are frequently stored above 30, the fungus commonly blemishes stored bulbs
  - The fungus invades via the neck, often via injured tissue when tops fall or are cut near maturity.
- **Control**
  - Use of uninfected seeds
  - Good curing after harvest, careful bulb handling and storage of unwounded bulbs
Fungal diseases of stored bulbs

3. Blue mould

- **Pathogen**: *Penicillium* spp.
- **Symptoms**
  - Soft, watery lesions later covered with blue mould
- **Infection sources**: debris in soil
- **Conditions for infection**
  - Optimum temp.: 21-25°C (> 80% humidity)
  - Temp. range: 15-32°C
- **Special features**
  - Invasion of bulbs is usually through tissue damaged by bruises, wounds, sunscald or freezing
- **Control**
  - Good curing after harvest, careful bulb handling and storage of unwounded bulbs

Bacterial diseases

1. Bacterial streak or bulb rot

- **Pathogen**: *Pseudomonas viridiflava*
- **Symptoms**
  - Dark, water-soaked streak on leaves spreading to leaf base and into bulb
  - Causing total foliar collapse in severe cases
  - Milder infections causing pale yellow turning to red-brown rotten centre bulb scales after harvest
- **Special features**
  - It survives as surface dweller on many weeds
  - It can be very destructive to nitrogen-rich succulent onions
**Bacterial diseases**

2. Bacterial soft rot

- **Pathogen**: *Erwinia* sp.
- **Symptoms**
  - Soft yellow to brown rot starting in bulb centre releasing fetid-smelling, viscous, watery fluid
- **Special features**
  - It is short-lived in soil but persists in rhizosphere.
  - It survives in intestine of onion fly larvae and adults.

---

3. Sour skin or bacterial canker

- **Pathogen**: *Burkholderia cepacia*
- **Symptoms**
  - Macerated, sour-smelling, mushy bulb scales
  - Grainy yellow ooze under infected scales
  - Spread within scales, rather than between
- **Special features**
  - It can persist in soil.
4. Slippery skin or other soft rots
- **Pathogen**: *Burkholderia gladioli pv. alliicola*
- **Symptoms**
  - Rotten inner scales spreading to the whole bulb
  - The infected core can slip out of the top of the onion bulb when squeezed
- **Special features**
  - It infects via wet neck wounds when onion topped at harvest.
  - Bulb rot is promoted by high-temperature drying (30°C).
  - It can be spread by planting infected onion sets.

5. Centre rot
- **Pathogen**: *Pantoea ananatis*
- **Symptoms**
  - Water-soaked, white-bleached centre leaves surrounded by brown tissue
  - Macerated, foul-smelling bulb interior
  - Also infects seed stalks
- **Special features**
  - It survives as surface dweller on many weeds.
  - It is transmitted by thrips and seed-borne.
Bacterial diseases

6. General characteristics of bacterial diseases

• Symptoms and infection
  - Infected tissue becomes macerated and water-soaked through the destruction of plant cell wall
  - Wounds necessary for infection (wind, pest, hail, cultivation operations, topping at harvest etc.)

• Control measures
  - Ensure seed and sets are pathogen free.
  - Maintaining good crop hygiene by removing or burying diseased debris.
  - Utilizing crop rotations of non-host crops with a minimum of 1 year between Allium crops
  - Separating vulnerable crops both in time and space so that there is not a continuous ‘infection cycle’ from one Allium crop to another.
  - Avoiding excessive nitrogen fertilizer, which can result in luxuriant foliage that is easily damaged by wind and cultivation traffic and which tends to maintain a wet microclimate in the crops
  - Minimizing damage to plants from cultivation and by having good pest control

Pest insects

1. Onion thrips

• Symptoms and infection
  - Most severe in the warmer onion production areas.
  - Pierce leaf cells and feed on the sap released, between the young leaf blades at the top of the neck.
  - Damage is most severe when plants are water-stressed in hot, dry weather.
  - Thrips-vectorized iris yellow spot virus (IYSV) is a potentially devastating disease of onion bulb and seed crops.

• Control
  - Insecticides: when more than 50% plant sampled contained thrips, to avoid insecticide resistant problem
  - Sprinkler irrigation can directly wash many thrips off onion leaves.
**Pest insects**

2. Onion fly or maggot

- **Symptoms and infection**
  - The most severe damage is caused by the maggots burrowing into the base of seedlings, causing wilting and collapse.
  - When seedling die, the maggots migrate to neighboring plants and may destroy successive plants in a row.
  - In many onion-growing regions there are three generations per year of the onion fly.
  - Maggots of the second and third generations burrow into the bases of large plants and developing bulbs and thereby predispose them to rotting by secondary infections of fungi and bacteria.

- **Control**
  - Use of good decomposed compost
  - Removal of onion plant debris or previous crop residue

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3. Integrated pest management strategies in Korea
Disease incidence

- **Pathogen**
  - Presence of pathogen
  - Pathogenicity
  - Adaptability
  - Dispersal efficiency
  - Survival efficiency
  - Reproductive fitness
- **Host**
  - Susceptibility
  - Growth stage and form
  - Population density and structure
  - General health
- **Environment**
  - Temperature
  - Rainfall and dew
  - Leaf wetness period
  - Soil properties
  - Wind
  - Herbicide damage

Integrated management practices

- **Pathogen**
  - Crop rotation
  - Pathogen-free seed
  - Control volunteers
  - Weed control
  - Fungicides
  - Biological control

- **Host**
  - Crop selection
  - Resistant cultivars
  - Adapted cultivars
    - maturity
  - High quality seed
  - Proper fertility

- **Environment**
  - Tillage
  - Reduced tillage
  - No tillage
  - Proper fertility
  - Planting date
  - Stand density
  - Seeding rate
  - Row spacing
Solarization in seeding bed

**Methods**
- Covering material: transparent plastic film
- 20 to 40 days before sowing
- Before mulching, compost at 30 ton/ha plus lime 2 ton/ha are applied and bed preparation performed.
- Intact seal of plastic film

**Effects**
- Reduction in disease incidence
  - Damping off 93.5%, pink root 98.0%
- Reduction in weed incidence: 88%
- No incidence of maggots

Onion production followed by rice harvest

**Methods**
- Flooding during summer season

**Effects**
- No soil borne disease incidences
- Reduction in foliar diseases
- Reduction in weed incidence
**High ridge and deep furrow**

- **Methods**
  - Approximately 20 cm deep at ridge preparation
  - 2~3 times furrow cultivation in spring

- **Effects**
  - Good drainage
  - Decrease in field humidity
  - No excessive soil moisture stress
  → Good root growth
  → Decrease in fungal and bacterial diseases

**Narrow ridge and wide distance between rows**

- **Methods**
  - Ridge width 100-110 cm and furrow width 30-40 cm
  - 16-20 cm between rows and 13 cm plant distance

- **Effects**
  - Good aeration
  - Good drainage
  - Decrease in field humidity
  - No excessive soil moisture stress
  → Good root growth
  → Decrease in fungal and bacterial diseases
Thank you
감사합니다
KOPIA ACTIVITIES ON ONION IN SRI LANKA

Multiplication of onion bulbs at Field Crops Research and Development Institute, Mahailluppallama under the KOPIA program
KOPIA activities on onion in Sri Lanka

Identification of elite lines received through KOPIA and other programs
Production of breeder seeds at the Field Crop Research and Development Institute, Mahailluppallama

Evaluation of breeding line at the Field Crop Research and Development Institute, Mahailluppallama
KOPIA activities on onion in Sri Lanka

Bulb multiplication in farmers fields

Storage of onion bulbs for distribution among farmers
KOPIA activities on onion in Sri Lanka

Seed production units in farmer’s fields