CHAPTER 4

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 hetorosis 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,

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, Agrfound 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. Kurupppuarachchi (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,

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. M_1 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 MIClO 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 ^{0}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 (Havey, 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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