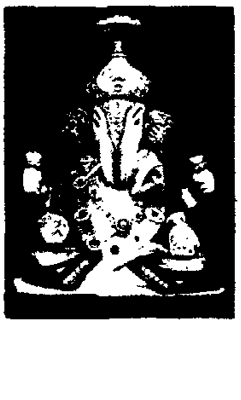

Affectionately Dedicated

To

My Beloved

Parents

Sau. Aai and Shri. Papa

... Mona

MUTATION BREEDING FOR DISEASE RESISTANCE IN ONION (*Allium cepa* L.)

By

Miss. MONALI ANANDRAO MORE
Reg. No. 03/094

A Thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST. AHMEDNAGAR
MAHARASHTRA STATE (INDIA)**

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

HORTICULTURE

**DEPARTMENT OF HORTICULTURE,
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST. AHMEDNAGAR, M.S., INDIA.**

2005

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2005

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

thereof has not been submitted by

me or other person to any other

University or Institute

for a Degree or

Diploma.

Place : MPKV, Rahuri

mpmore

Dated : 24 / 6 /2005 **(Monali Anandrao More)**

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CERTIFICATE

This is to certify that the thesis entitled, "**MUTATION BREEDING FOR DISEASE RESISTANCE IN ONION (*Allium cepa* L.)**", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **HORTICULTURE,** embodies the results of a *bona fide* research work carried out by **MISS. MONALI ANANDRAO MORE,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree, diploma or publication.

The assistance and help received during the course of this investigation have been acknowledged.

Place : MPKV, Rahuri,
Date : 24/ 6 /2005

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Date : 24 / 6 /2005

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ACKNOWLEDGEMENTS

I avail this golden opportunity to express my sincere and deep sense of gratitude towards Dr. R. S. Patil, Professor, Department of Horticulture, M.P.K.V., Rahuri as a Research Guide and Chairman of Advisory Committee, whose talented and versatile advice, scholastic guidance, profound interest in subject, constructive and inspiring discussion throughout the course of my post graduate study and friendly behaviour gave me this unique experience of planning, conducting and presenting the research.

I take genuine pleasure to express my deepest feeling of gratitude towards Dr. U. T. Desai, Head, Department of Horticulture; Dr. R. R. Perane, Assistant Seed Production Officer, BSP Vegetable Seed Technology, PGI, MPKV, Rahuri, the members of my advisory committee for their valuable suggestions, meticulous guidance, persistent endeavour and encouragement during the conduct of my research work.

I take this golden opportunity to express my sincere thanks to Dr. S. S. Kadam, Dean, Faculty of Agriculture; Dr. S. H. Shinde, Associate Dean, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri and Dr. D. M. Sawant, Associate Dean, College of Agriculture, Pune for permission and providing necessary facilities for the research work.

I also wish to express my appreciation to Dr. S. D. Warade, Dr. A. R. Karale, Dr. M. N. Bhalekar, Prof. S. N. Gohil, Dr. S. D. Masalkar, Dr. D. B. Pawar, Shri. S. B. Desale, Shri. U. S. Shinde, Shri. S. G. Shinde, Shri. S. G. Bhalekar, Shri. B. M. Ilhe and Shri. N. S. Gupta for their help and cooperation during conduct of my research.

I am thankful to Shri. B. B. Salve for tidy and meticulous typing and preparation of manuscript in descent form.

Friends are the real companions in one's life. I will be unable to excuse myself if I fail to appreciate the direct or indirect contribution of my beloved best friends Prabha, Mani, Shital, Bhagi, Sujata, Manisha, Chetan, Yogesh, Sandeep, Vijay and many other beloved friends for their excellent company, warmer affection, constant support and inspiration and valuable help.

I am also thankful to my friends and well wishers Pranali, Reshma, Swpanja, Anjala, Predeep, Vinod, Taimur, Hanumant, Deepak, Tushar, Machindra, Dulta and senior friends Bhagyashree and Hema.

I owe my sincere thanks to my continuous source of inspiration beloved elder sisters Sau. Akka, Sau. Tai, Sau. Shital, Sau. Ashu the 'Beacon' of my life and Jijaji Shri. Rajabhau, Shri. Bapu, Shri. Dada, Shri. Chandrashekhar for their love and support.

My special thanks to my beloved younger sister Shilpa and sweet little niece Saau Guari, Juee and Ritu whose joyful company always keeping spring in my life.

Lastly the words are small trophies to express my deepest sense of gratitude and indebtedness to my "living spring" of love and affection. "Path finder" of my educational carrier to my beloved parents Sau. Aai and Shri. Papa whose valuable blessings, scarification, support, encouragement and inspiration moulded my life and help to built up my educational carrier.

While travelling on this path of education many hands pushed me forth, learned hearts put me on the right track enlightened by their knowledge and experience. I ever rest thanks to all of them.

Place : Rahuri,
Date : 24 / 6 / 2005

(Monali A. More)

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LIST OF PLATES

LIST OF ABBREVIATIONS

cm	:	Centimeter(s)
Cv.	:	Cultivar
DAP	:	Days after planting
DAT	:	Days after transplanting
EI	:	Ethyleinamine
EMS	:	Ethyl methane sulphonate
et al.	:	And others (et alli)
g	:	Gramme(s)
i.e.	:	That is
kR	:	Kilo rad
NMU	:	Nitroso-methyl-urea
%	:	Per cent
PDI	:	Per cent disease intensity
TSS	:	Total soluble solids
Var.	:	Variety
Viz.	:	Namely

ABSTRACT

MUTATION BREEDING FOR DISEASE RESISTANCE IN ONION (*Allium cepa* L.)

By

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Research Guide	:	Dr. R. S. Patil
Department	:	Horticulture

The present investigation entitled, "Mutation breeding for disease resistance in onion (*Allium cepa* L.)" was undertaken with the objective to induce novel variability especially for disease resistance against purple blotch disease in white and red onions. Also effect of mutation was studied on plant growth, bulb development and seed parameters in three crops of two generations (i.e. M_3 bulb and seed crops and M_4 bulb crop).

Earlier mutation was induced by 10 kR gamma radiation in white and red onions during 2001 and in present study the M_3 bulb crop was evaluated in *kharif* 2003 under artificial epiphytotic conditions and 1625 and 1175 plant population of white and red onion, respectively were assessed with 500 plant population of control. Average performance and variability between control and mutated populations was measured by t and F tests, respectively. Eventhough an immunity against disease was not observed in M_3 bulb crop, genetic variability was induced for resistant to moderate resistant type of disease reaction and on the basis of disease resistance 58 and 40 seed bulbs (i.e. 3.56 and 3.40% selection pressure) of white and red onion were selected for growing M_3 seed crop. The M_3 seed bulbs showed significantly different disease reaction than the control M_0 seed bulbs as t and F tests were found significant.

For vigorous screening and to locate definite source of disease resistance, M_3 seed crop was also evaluated under artificial epiphytotic conditions during *rabi* 2003-04. At initial crop stage (45 DAP); per cent disease intensity (PDI) was significantly differed for

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variability and average performance between M_3 and control (M_0) populations. In white and red M_3 seed crops, considerable lower PDI (33.74 and 29.00, respectively) was recorded than their control populations (77.00 and 75.00, respectively). The seed parameters of M_3 generation were adversely affected due to combined effect of artificial inoculation and mutation. However, more abnormality (i.e. non-bolting) was noticed in white onion M_3 seed crop than red.

The M_4 bulb crop was raised with 20 and 40 M_4 genotypes of white and red onions, respectively and screened under natural field conditions during *Kharif*, 2004. The disease resistance against purple blotch disease was measured qualitatively with per cent disease intensity (PDI) and quantitatively with per cent number of disease affected leaves per plant. It was noticed that M_4 bulb crop recorded lower qualitative and quantitative values for disease reaction (PDI 19.50 and 23.50 and per cent number of affected leaves; 45.50 and 46.12 for white and red onion, respectively) than their control populations (PDI : 58.80 and 63.60 and per cent number of affected leaves 67.29 and 70.20 for white and red onions, respectively) at 90 DAT crop stage. More importantly for these two crucial disease characters, t and F tests were found significant indicating significant different disease reaction between two populations (M_4 and control). However, for most of the plant growth and bulb characters, non-significant variation was found between two populations displaying about to normal recovery of M_4 generation for most of horticultural traits. However, wide range variability was noticed in M_4 generation for important pathological and yield contributing characters and hence selection programme was suggested on the basis of population mean plus or minus its standard deviation values for advancing M_5 generation.

Thus, with mutation breeding, genetic variability was created for disease resistance against purple blotch. However, it should be refer for further detail investigation to identify certain source of disease resistance; especially in association with dark green waxy foliage. Nevertheless, modified mutation programme should be undertaken for improvement of other important characters of onion like higher TSS content, male sterility, etc. as in present investigation these characters could not induce novel variability for crop improvement.

Total Pages : 1 to 130

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Introduction

1. INTRODUCTION

Onion (*Allium cepa* L.) is a bulbous, biennial herb belongs to family *Alliaceae* and the genus *Allium*. It is an important bulb vegetable crop having importance at National and International levels. Commercially grown all over India. As a vegetable and spice, it is consumed throughout the year by almost all classes of people, on account of its medicinal and dietary value. It is an indispensable item in every kitchen as it adds flavour to various vegetable preparations, it is called as 'Queen of Kitchen' (Selvaraj, 1976). The young green leaves along with tender bulbs are eaten raw in salads while the mature bulbs are cooked or eaten raw as vegetable. They are used in soups, sauces, pickles and preparation of other products like onion powder and flake.

Onion is good source of vit. A, B and C, protein, phosphorus, calcium, ascorbic acid, etc. Medicinally, it has been observed that onion promotes appetite, useful against malaria, night blindness, for lowering blood pressure against bite of dogs (Perane, 2001). Its juice with honey is said to be beneficial against weakness of vision. It also suppresses the acidity. It is neither cold nor hot for digestive tract. It is used for hysterical fits for smelling. Onion have many uses as folk remedies and recent report suggest that onions play a vital part in preventing heart disease and other ailments (Augusti, 1976).

Onion is supposed to have its origin in the middle east Asian countries and introduced in India from Palestine. It is being extensively cultivated all over the world especially in India. Pakistan, China, Netherlands, Bangladesh, Australia. India contributes as much as 12 per cent to the world production. India is the second largest producer of onion with an area of 5.20 lakh ha and

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production of 65.7 lakh MT next only to China (FAO, 2003). India's recent export of onion in various forms is to the tune of Rs. 300 crores to the countries like Saudi *Arabia*, Singapore, Malaysia, UAE, Bangladesh, etc. (Anonymous, 2003).

In India, Maharashtra, Andhra Pradesh, Assam, Bihar, Gujarat, Punjab, Karnataka and Tamil Nadu, Orrisa, Uttar Pradesh are major onion growing states. At present, Maharashtra is a leading state in onion production having an area 1.03 lakh ha and production of 12-15 lakh MT (Anonymous, 2003) which is about 25% to the national production and 20% to the national area. In Maharashtra, Nasik district alone accounts to more than 30 per cent of state's production (Singhal, 2003). The onion is cultivated extensively in Nasik, Pune, Ahmednagar, Dhule, Jalgaon, Satara and Buldhana districts of Maharashtra.

In Maharashtra, onion grown throughout the year in *Kharif*, late *Kharif* (rangda), *rabi* and late *rabi* (Summer) seasons. Onion crop grows vigorously with soft and lustrous leaves. Also water percentage in leaves is high. Hence, many pests and diseases are attracted towards this crop. As the onion crop attracted by many diseases which cause loss in quality and quantity. The diseases such as downy mildew, smut, blast, neck rot, smudge, pink root, black mould of bulbs, damping off, cercospora leaf spot, wilt and especially purple blotch and a stem phyllium blight, etc. are reported on onion crop. *Kharif* cultivation is mainly responsible for lower yield due to unfavourable climatic conditions (such as cloudy atmosphere, heavy late rains, etc.) which causes congenial conditions for leaf blight diseases like purple blotch caused by *Alternaria porrii* and stem phyllium blight caused by *Stemphylium vesicarium* resulted in significant yield reduction. At present, no genetical source is available for disease resistance in onion.

In India, the purple blotch disease was first reported by Ajrekar in 1921. The purple blotch is one of the most wide spread and economically important disease of onion in Maharashtra. The disease is severe in almost all onion growing areas especially during *Kharif* season. The characteristic symptoms exhibited in the form of purple spot, yellowing and drying of leaves. Losses in yield vary from 25 to 100 per cent. Besides these visible form of symptoms the fungus produces toxic metabolites within the host (Suemitsu *et al.,* 1991) and affect the seed germination and seedling vigour (Gupta *et al.*, 1986).

The stem phyllium leaf blight which cause light yellow to brown water soaked lesions develop on leaves. It causes a losses as high as 80 to 90%. In India, it caused severe damage in 1973.

Many synthetic chemicals are used to control the disease, however, the indiscriminate use of chemical is hazardous to microbial population and living beings and it would also lead to a serious soil and water pollution. Onion bulbs are also used for direct consumption. Spraying of fungicide will cause residual effect. Hence, to find out alternative mean and to increase productivity; breeding for disease resistance is the top most priority in onion breeding.

The crop improvement through traditional plant breeding methods is entirely dependent on naturally occurring variability in the germplasm. However, through mutation breeding novel and broad sense variability can be induced by artificial mutation. The method of creating new variation by irradiation has been new facet of present agricultural science. Eventhough, artificially induced variability has less heritable values; the selection effect can be improved dramatically to identify new genotype with desirable characters (Swaminathan, 1968). Mutation breeding is an efficient method of modifying genotypes for certain attributes. The major advantages of mutation breeding are basic genotype of the variety is usually slightly changed, while the improved characters are added. Secondly the time required to breed the improved variety can be shorter. Mutation breeding has been useful in introducing traits like resistance to certain diseases (Sigurbjornsson and Micke, 1969).

For the present research studies, onion cultivars Phule Safed and Baswant-780 were employed for induction of variability for desirable characters through mutation breeding. The M_3 and M_4 generations were screened mainly for disease resistance and TSS content. The cv. Baswant-780 is the leading dark red onion cultivar for *Kharif* season while cv. Phule Safed is a white onion cultivar, due to high TSS content (12-13.5%), it is suitable for onion processing. Nevertheless, due to photothermoinsensitivity Phule Safed can be grown throughout the year in Maharashtra.

For purple blotch disease at present no source of resistance is available in onion germplasm (*Allium cepa*) and similarly Indian onion genotypes are short day varieties having low TSS content (8-11%). Therefore, in past no noticeable success was achieved for improvement of these two traits through traditional plant breeding methods. Hence, alternative to conventional breeding methods, mutation breeding in onion was employed to create inexhaustible variation with greater frequency than that occurring in nature. Keeping this view in mind, mutation breeding was undertaken in present study and M_3 and M_4 generations were evaluated with following objectives.

1. To screen M_3 bulb and seed crops and M_4 bulb crop against purple blotch blight under artificial epiphytotic conditions.
2. To evaluate horticultural traits i.e. plant growth and bulb characteristics of mutated onion plants.
3. To screen plant population for high TSS (16-18%) content.

Review of Literature

2. REVIEW OF LITERATURE

Since Darwin, it is realised that mutations are the foundation of natural evolution which are nothing but sudden heritable change in the genetic constitution of an organism. Mutation breeding research has contributed much to improve or modify genotypes for certain attributes. Induction of plant traits like earliness, short stature, it is also useful to introduce trait like resistance to certain diseases (Sigurbjornsson and Micke, 1969). The available literature on various aspects of the mutation is reviewed hereunder.

2.1 Importance of induced mutation

As early as 1901 de-Vries suggested the idea of inducing mutation in cultivated species. Muller (1927) was the first to induce mutation in Drosophila with the help of x-rays. Since the mutation have been used in various crop plants to improve different characteristics.

Spontaneous mutation occurred naturally but mutation may be artificially induced by physical or chemical mutagenes. Induced mutations result in inexhaustible variability in all living organism and is the ultimate source for supplementing the conventional plant breeding methods. Thus, induced mutation makes the breeders free from depending on nature for generating variability in plant genotypes (Sigurbjornsson and Micke, 1972). The induced mutation may result in creating novel variation, which is completely free from earlier existing DNA recombinations. Hence, use of mutations proved valuable for plant breeding, especially when whole of germplasm is exhausted or when a particular gene for desirable improvement is known but can not be expressed or exploited due to geographical, biologically unfavourable linkages (Mutum, 1993).

2.2 Mutagenes used for induced mutations

Induced mutations are oftenly used in different plant breeding methods (Gual, 1963).

Mutation breeding has been employed to create desired variability in crop plants and for this purpose a wide range of physical and chemical mutagenes have been used (Heslot, 1967).

Physical mutagens

Radiation-induced variability due to use of X or gamma rays (2 kR – 80 kR) were used more efficiently in mutation breeding with high probability of altering and improving any morphological character (Kumar, 1972; Rajput, 1974; Senthikumar and Natrajan, 1997and Kirtane, 2002).

Chemical mutagens

The chemical mutagenes such as Ethyl Methane Sulphonate (EMS), Diethyl Sulphate (DES), Ethium Bromide (EB), Colchicin (Col), Sodium Azide (SA), Nitroso Methyl Urea (NMU), Ethylene Imine (EI), Epichlorhydrin (ECH) were used to induce mutation either individually or in combination with gamma rays (Kataria and Singh, 1990; Rao *et al.*, 1991; Singh *et al.*, 1997; Mehta *et al.*, 1999; Kirtane, 2002).

2.3 Application of induced mutation in crop improvement

Mutation breeding involved to induce novel variability caused by induced mutation is not essentially different from the variability caused by the spontaneous mutation during evolution. M_2, M_3 and M_4 generations are important for crop improvement for induction of mutation. Because the induced mutations like spontaneous ones are nearly always recessive and deleterious in their effects on the genotypes and it necessitated testing of large second generation (M_2) populations and requires efficient screening techniques for detecting the desirable mutants (Kirtane, 2002).

The useful of the mutation is determined not only by its ability to induce the high number of mutations but its ability to induce mutations free from the associated harmful changes. In crop improvement wider gene pool provides better opportunities to exercise selection for desirable genotype. Intensive breeding and selection practiced in past half century resulted in the development of several varieties (Kirtane, 2002).

2.4 Induced mutations in vegetable crops

The use of induced mutations for the improvement of vegetable crops was initiated since 1960's. At present more than 67 mutant varieties of vegetable crops belonging to 24 different species have been released worldwide for cultivation (Kirtane, 2002). The important characters like yield, earliness, disease resistance, quality, etc. were improved through induced mutation.

Several reports on induction of viable mutations on vegetable crops such as tomato (Contant *et al.*,1971), brinjal (Zeerak, 1991), *Solanum khasianum* (Bhattacharyya *et al.*, 1996), okra (Senthilkumar and Natrajan, 1997; Singh *et al.*, 2000), chilli (Mehata *et al.*, 1999), cowpea (Mohansundaram *et al.*, 1997), feba bean (Ritakumari, 1996); mungbeans

(Rajput, 1974; Singh *et al.*, 1997), garlic (Choudhari, 1978) and fenugreek (Datta and Luxmi, 1992) were reported.

2.5 Induced mutations in onion

Onion is the most important vegetable crop in India because of fairly large area, production, consumption and export purpose. As onion is biennial and highly cross pollinated, photo-thermo sensitivity for year round bulb cultivation and also for seed crop, storage, variability in bulb crop, etc. Thus, process of genetic improvement of onion crop is quite slow and difficult.

The research work on the induced mutation in onion is very scanty. This may be due to the breeding system and availability of genetic variability (Kirtane, 2002).

2.5.1 Mutagenes used in onion

Various physical and chemical mutagenes were used for induction of mutation individually and in combination. The effectiveness and efficiency of mutagenes were also studied.

Pawar (2003) used induced mutation in onion cv. Phule Safed by 10, 20, 30, 40 kR gamma rays irradiation and observed that lower doses of irradiation were more effective.

Kataria and Singh (1989) studied mutation in onion with use of gamma rays and EMS, NMU and EI. The range of former physical mutagen of gamma rays was 7.5 to 15 kR while chemical mutagens were used within range of 0.01 to 0.2%.

Kirtane (2002) used gamma rays and sodium azide for induction of mutation in onion var. N-2-4-1. The mutagens were used within range of 2-12 kR and 0.1 to 0.7%, respectively, individually as well as in combination.

2.5.2 Effect of concentration of mutagens in onion

Pawar (2003) reported that the 10 kR gamma irradiation was the most suitable for irradiation dose for onion crop as satisfactory seedling growth and bulb development was achieved in M_1 bulb crop. Particularly higher doses of irradiation (20-40 kR) proved more lethal on M_1 bulb crop.

Kirtane (2002) studied effect of physical and chemical mutagenes on mutation effectiveness and efficiency for onion cv. N-2-4-1. In her studies, she reported that 0.1% Sodium Azide (SA) was the most effective treatment (7.02) followed by combination of 0.5% SA and 6 kR gamma rays (4.08) while individual gamma rays, a dose of 8 kR was most effective while 4 kR was the least effective.

Positive correlation coefficients of all the biological parameters like seed germination, plant survival, plant height, etc. with doses of mutagens were found to be highly significant for mutation rates or sensitivity (Kataria and Singh, 1989a). The lowest doses of gamma rays EMS and EI occasionally produced stimulus effect on plant height and bulb weight, while higher doses were found to be more lethal and caused 50 per cent reduction in germination, seedling height and seed setting in onion (Kataria and Singh, 1989a).

Although increasing doses of mutagen increased the mutation rate but effectiveness of mutagens was impaired due to relatively more detrimental effects of higher doses of mutagens (Kataria and Singh, 1989b).

They further reported that gamma rays irradiation was more effective than the chemical mutagenes (EMS, NMU and EI). In this context, it was observed that gamma rays at 10 and 12.5 kR recorded the highest mutagenic effectiveness in onion cvs. White Warangal (6.29) followed by Pusa Red (5.93) and Pusa Ratnar (5.78). Furthermore, they reported that physical and chemical mutagenes were more effective in white onion cultivar than the red onion cultivars.

2.5.3 Sensitivity of onion cultivars to mutagens

Kataria and Singh (1989a) studied sensitivity of three onion cultivars to physical (gamma rays), chemical (EMS, NMU and EI) mutagens. They noticed that relative mutagen sensitivity of three onion cultivars was different and also dependent on individual character. The white onion cultivar was the most sensitive for characters seed germination and plant survival than the other two red onion cultivars.

2.5.4 Effect of induced mutations on bulb crop

2.5.4.1 Plant height and number of leaves

Pawar (2003) reported that irradiation resulted in dwarf plant growth as seen from range (26-75 cm) at M_2 generation. It was noticed that variability was created for number of leaves in M_2 generation by 10 kR irradiation treatment. The wide range was observed in M_2 generation.

Kirtane (2002) noticed stimulatory as well as inhibitory effect of mutagenes on plant height. Lower to moderate doses of mutagenes (i.e. upto 0.5% SA and 10 kR gamma rays) resulted in stimulatory effect (72.21 to 78.49 cm) while higher doses of mutagens (i.e. 0.7% SA and 12 kR gamma rays) showed inhibitory effect (71.43 cm) on plant height.

Majority of gamma rays treatments showed increase in number of leaves per plant. The highest increase (10.11) was recorded in 6 kR dose.

2.5.4.2 Bulb development (Bulb diameter, bulb colour, bulb weight, bulb shape index, neck thickness)

Pawar (2003) reported that 10 kR irradiated created significant variability for character equatorial bulb diameter. At M_1 generation, the adverse effect of irradiation was noticed on equatorial and polar bulb diameter. Similarly, in M_2 generation irradiation with 10 kR created significant variability for bulb diameter but in M_2 generation certain improvement was noticed for bulb diameter; as wide range (0.8-7.6 cm for equatorial diameter and 0.9-6.03 cm for polar diameter) was observed in M_2 generation for bulb diameter.

Kirtane (2002) observed beneficial effect of 0.5% SA and adverse effect of 12 kR gamma rays on equatorial diameter. The highest equatorial bulb diameter (7.48 cm) was noticed in 0.3% SA followed by 7.07 cm by treatment 0.1% SA + 2 kR and 6.49 cm by 8 kR. However, for polar diameter, linear improvement was noticed with higher doses of gamma rays. The highest polar diameter (5.14 cm) was observed in 12 kR treatment.

Pawar (2003) reported that irradiation showed adverse effect on bulb weight in M_2 generation as lower mean bulb weight (50.51 g) but wide range (i.e. 1.04-218.7 g) was recorded in M_2 bulb crop. Thus 10 kR irradiation created significant variability for bulb weight in M_2 generation.

Kataria and Singh (1989) reported stimulatory effect of lower doses of gamma rays (7.5 kR) on bulb weight of onion.

Kirtane (2002) recorded increase in average bulb weight of onion with increasing doses of gamma radiations upto 10 kR dose treatment and the highest increase in bulb weight (81.04 g) recorded was in 10 kR.

Kirtane (2002) reported increase in neck thickness at 12 kR dose treatment and reduction in neck thickness in 2 to 10 kR treatments, highest reduction was at 6 kR treatment.

Pawar (2003) noticed that bulb shape index for M_2 and M_0 i.e. control population almost similar (1.16 and 1.06, respectively).

Similarly, the neck thickness was also almost similar for M_2 and M_0 population.

2.5.4.3 Total soluble solids (TSS) content

Pawar (2003) reported that irradiated population has wide range of TSS (9.2-15.4%) in M_1 generation. While the M_2 generation could not create further higher expected variability for high TSS content i.e. within range of 16-18% TSS.

Kataria and Singh (1990) evaluated the mean range of total soluble solids in M_2 generation of varieties Pusa Red, Pusa Ratna and White Warangal after treating the seeds with gamma rays, NMU and EI. Treatment of Pusa Red with 0.1 per cent NMU produced a significant increase in TSS from 12.12 in untreated control to 14.01 per cent in treated ones.

Kirtane (2002) also observed the highest TSS content in onion (cv. N-2-4-1) by combination of 8 kR gamma rays + 0.3% SA (16.73% TSS) followed by 10 kR gamma rays (15.20% TSS).

2.5.4.4 Bulb maturity

The maturity period was decreased or increased due to the mutagenic treatment of Sodium Azide or gamma radiation alone and in combination (Kirtane, 2002).

An early maturity (92 days) was noticed in 0.5% SA or 8 kR + 0.3% SA treatments while late maturity (126 days) was observed in 8 kR, 0.5% SA + 2 or 4 kR, 6 kR + 0.1 or 0.3% SA treatments in comparison to 114 days maturity of control (var. N-2-4-1) treatment.

2.5.5 Effect of induced mutation on seed crop of onion

2.5.5.1 Number of umbels per plant

Pawar (2003) noticed that lower number of umbels /plant was recorded in irradiated M_1 seed crop (3.02) than the control population (5.20). The M_1 generation showed reduction in number of umbels as a result of artificial mutation.

2.5.5.2 Seed coat colour

Pawar (2003) reported that normal black seed coat colour was observed in all M_1 plants.

2.5.5.3 Seed weight per plant

Pawar (2003) reported that the much less seed (1.61) was observed in M_1 generation than the control population (9.55).

2.5.5.4 Number of seeds per plant

Pawar (2003) reported that the irradiation resulted in severe reduction in number of seed per plant in M_1 generation (373.71) than the control population (2397.3).

50 per cent reduction in seed setting was observed at 12.5 kR and 15 kR doses of gamma radiations (Kataria and Singh, 1989a)

The effect of gamma radiations revealed that only 4 kR dose treatment had shifted the mean value of seed yield towards the positive direction, all other treatments had shifted the mean value towards negative direction (Kirtane, 2002).

An adverse effect on seed yield was recorded by higher doses of mutagenes (0.5 to 0.7% SA or 6-12 kR gamma radiation). Either lower doses of gamma radiation (4 kR) or lower combination treatments (2 kR + 0.1 to 0.3% SA) were only found effective to increase seed yield.

2.6.1 Screening for purple blotch disease resistance in onion

The purple blotch disease caused by *Alternaria porrii* caused severe yield losses which vary from 25-100%. At present no source of resistance is available in onion germplasm for purple blotch disease and absolute immunity was not reported in any onion cultivar.

Sidhu and Kaur (2001) screened onion germplasm for purple blotch disease however, no immunity was observed. Furthermore, they reported resistance with low MDI viz., Early Stocken Yellow, Early Stocken Red and PBR-5. In the seed crop no variety was recorded as immune or resistant only two varieties i.e. PBR-5 and PBR-1 were moderately resistant.

Gupta and Pathak (1988) screened 21 indigenous and exotic cultivars under multilocational trial in two years under artificial inoculations. All the exotic lines except two cvs. from the Sudan, were highly resistant to *Alternaria porri* while all indigenous lines were susceptible to purple blotch disease.

Sugha *et al.* (1992) reported 94 onion genotypes for resistance to purple blotch under artificial epiphytotic conditions during *rabi* season. IC 39178, IC 49371 were resistant and ADR Red Globe, IC 33617, IC 43130, IC 48001 and IC 48045 were moderately resistant.

Sharma (1997) reported, 86 onion genotypes grown in Himachal Pradesh, India were investigated for resistance to purple blotch. The lines IC 48059, IC 48179, IC 39887, IC 48025 and ALR showed resistance and another 10 lines were moderately resistant.

Michail and Salem (1981) reported that Taliani Red variety was resistant to *Alternaria porri.*

Silverira *et al.* (1971) tested ten commercial varieties in Brazil and reported that the varieties Roxa Barreiro, Monte Alegare, Baia Piriforme, do Ro Grande and Baia Piriforme Piracicaba were resistant to *Alternaria porri.*

Pandotra (1965) tested different onion varieties and showed that variety 53-5 was a potential source of field resistance to purple blotch disease.

Thirumalchar and Mishra (1953) reported that the onion purple blotch caused a severe scorching to some onion varieties from Bihar but indigenous red varieties remained unaffected.

MaRae (1924) reported that the Goa and Nandore varieties were considerably resistant to *Alternaria* spp.

2.6.2 Disease resistance in onion for purple blotch disease through mutation

Pawar (2003) noticed genetic source of resistance for purple blotch disease in M_2 generation, as 38 i.e. 7.6% M_2 plants showed resistance to purple blotch under artificial epiphytotic conditions. M_2 generation of 10 kR irradiation provided better chances for onion crop improvement with special regard to resistance against purple blotch disease.

2.7 Screening for resistance in onion for stem-phylium leaf blight disease

Pathak *et al.* (2001) reported that five welsh onion (i.e. *Allium fistulosum*) and 106 onion cvs. (*Allium cepa*) were screened under field and laboratory conditions. All the *Allium fistulosum* lines were resistant or moderately resistant to stem phylium leaf blight further crosses made between *A. fistulosum* and *Allium cepa* lines. All the F_1 hybrids were resistant or moderately resistant to stemphylium leaf blight disease but were bunching type (i.e. non-bulbous type).

Materials & Methods

3. MATERIAL AND METHODS

The present investigation entitled, "Mutation breeding for disease resistance in onion (*Allium cepa* L.)" was carried out during the years 2003 and 2004 at Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri.

3.1 Material

Earlier the mutation in red and white onions was induced by physical mutagen i.e. with 10 kR radiation of gamma rays in the year 2001 and disease resistance was reported in M_1 and M_2 generation at this Agricultural University (Pawar, 2003). For present experimental study the M_3 seed bulbs of white onion (cv. Phule Safed) and red onion (cv. Baswant-780) were obtained from Onion Storage Scheme, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri.

3.2 Programme of Research Work

I. In *kharif* 2003

The M_3 bulb crop grown by Onion Storage Scheme was screened for resistance against purple blotch disease in artificial epiphytotic conditions and selection pressure was applied on seed bulbs to raise M_3 seed crop.

II. In *Rabi* 2003-04

The M_3 seed crop of white and red onions were grown in isolation and screened against leaf blight disease at NARP, Ganeshkhind, Pune, while control seed plots (i.e. non-irradiated) of red and white onions were assessed at Mahatma Phule Krishi Vidyapeeth, Rahuri.

III. In *kharif* 2004

The M_4 bulb crop were screened against purple blotch at Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri.

3.3 Assessment of M_3 generation Bulb crop

While screening M_3 bulb crop against purple blotch disease, observations were recorded on per cent disease intensity (PDI) and selected seed bulbs were evaluated for bulb weight, bulb diameter and TSS content.

3.4 Assessment of M_3 generation seed crop

During first fortnight of December, 2003, the selected 40 and 58 M_3 seed bulbs respectively of red and white onions were planted in isolation and mixed inoculum of purple blotch and stemphylium blight was spread at prebolting stage i.e. 30 days after planting (DAP). The observations were recorded on PDI at 45 DAP crop stage. Similarly observations were noted on number of umbels, number of seeds and seed weight per plant.

3.5 Assessment of M_4 generation bulb crop

For advancing M_4 bulb crop during *kharif* 2004 at MPKV, Rahuri, out of 58 white onion genotypes, the M_4 seed of only 20 genotypes were selected on the basis of disease resistance and viable seed development. While M_4 seed of 40 genotypes of red onions were selected for raising of bulb crop. A plant progeny of 25 plants was evaluated of each M_4 line. Thus, irradiated plant population of 20 M_4 lines of white onion constituted of 500 plants and similarly, irradiated plant population of M_4 lines of red onion constituted of 1000 plants. These irradiated M_4 generation was compared with 500 plant population of M_0 generation i.e. control, where for recording ancillary observations, randomly plants were selected (10-25). However, whole plant population of control plots (500) was screened against disease resistance. The bulb crop was evaluated under natural field conditions and artificial inoculum of purple blotch disease was not sprayed as congenial condition was observed after 60 DAT crop stage and control plants showed more than fifty per cent PDI. The PDI for purple blotch was recorded at 60 and 90 DAT crop stages. The plant and bulb characteristics of M_4 bulb crop were noted down.

3.6 Observations recorded

M_3 bulb crop, M_3 seed crop and M_4 bulb crop were assessed for disease resistance and other horticultural traits.

3.6.1 Observations for M_3 generation bulb crop

3.6.1.1 Disease reaction of purple blotch disease

The bulb crop were screened against purple blotch disease in artificial epiphytotic condition. The per cent disease intensity were recorded by 0-9 scale i.e. six grading system.

3.6.1.2 Bulb weight (g)

The bulb weight of selected 58 white and 40 red seed bulbs were recoded in grams.

3.6.1.3 Bulb diameter (cm)

The equatorial as well as polar diameter of selected 58 white and 40 red seed bulbs were recoded by vernier calliper.

3.6.1.4 TSS (%)

The total soluble solid content of these selected (58 white and 40 red) seed bulbs were recorded using hand refractometer.

3.6.2 Observations for M_3 seed crop

3.6.2.1 Disease reaction for leaf blight disease

The per cent disease intensity of these seed bulbs of white and red onion were recorded at 45 DAP stage i.e. 15 days after artificial inoculation.

3.6.2.2 Number of umbels per bulb

Number of umbels per bulb were recorded at full bloom stage i.e. at 90 DAP.

3.6.2.3 Number of seeds per bulb

Seeds from all umbels of each bulb were aggregated and counted at 15 DAP.

3.6.2.4 Seed weight (g) per bulb

Seeds from each plant of white and red onion were weighed and recorded in grams.

3.6.2.5 Colour of seed coat

Seeds produced by M_3 bulbs were observed for seed coat colour (i.e. black or brown).

3.6.3 Observations for M_4 bulb crop

3.6.3.1 Disease reaction for purple blotch disease

No fungicidal sprays were undertaken for M_4 bulb crop. The observations were recorded at 60 and 90 DAT crop stage by 0-9 scale (i.e. six grading system). At harvest the plants showing minimum disease attack (10-15%) of purple blotch disease were identified as promising selections.

0-9 scale (i.e. Six grading system)

Sr. No.	PDI	Scale	Details
1	0	0	No symptoms on leaf
2	1-10	1	Small white spots on the leaf covering upto 1% or less of the leaf area.
3	11-25	3	Small powdery patches covering 1 to10% of the leaf area.
4	26-50	5	Powdery lesions enlarged covering 11-25% of the leaf area.
5	51-75	7	Powdery patches irregular in size covering 26 to50% of the leaf area.
6	76-100	9	White powdery growth covering more than 50% leaf area.

On the basis of PDI the test entries were categories as :

Rating

0%	:	Disease free
1-10%	:	Resistant
11-25%	:	Moderately resistant
26-50%	:	Moderately susceptible
51-75%	:	Susceptible
75% above	:	Highly susceptible

3.6.3.2 Plant height (cm)

The plant height of 10 plants from each bulb progeny was recorded at 90 DAT crop stage.

3.6.3.3 Number of leaves

Number of leaves of individual plant of each bulb progeny were recorded at 90 DAT crop stage.

3.6.3.4 Shape of bulb

Bulb shape was recorded of 10 plants of each bulb progeny by using bulb shape index which is ratio of equatorial to polar diameter.

3.6.3.5 Weight of bulb (g)

Bulb weight (gm) was recorded on the basis of average of 10 bulbs of each bulb progeny.

3.6.3.6 TSS (%)

Total soluble solid content of 10 bulbs of each bulb progeny were recorded by using hand refractometer.

3.6.3.7 Per cent number of disease affected leaves per plant

These observations was recorded for individual bulb progeny at 90 DAT crop stage.

3.7 Cultural practices

3.7.1 M_3 generation bulb crop

1. Date of seed sowing	:	15th June, 2003
2. Date of transplanting	:	4th August, 2003
3. Spacing	:	1) Between plants 15 cm
		2) Between rows 10 cm
4. Fertilizers	:	100:50:50 kg/ha NPK

5. Weeding : 2 times
6. Irrigations : At 7 days interval
7. Plant protection : No spraying of any fungicide
8. Spraying of inoculum of purple blotch disease : At 50 and 80 DAT crop stages
9. Date of harvesting : 30th January, 2004

3.7.2 M_3 generation seed crop

1. Date of seed bulb planting : 12th December, 2003
2. Spacing : 60 x 30 cm
3. Fertilizers : 100:50:50 kg/ha NPK
4. Weeding : Two times
5. Irrigations : Once in every 8 days
6. Spraying of inoculum of purple blotch disease + stemphylium leaf blight disease : At 30 DAP stages
7. Date of harvesting : 29th April, 2004

3.7.3 M_4 generation bulb crop

1. Date of seed sowing : 23rd June, 2004
2. Date of transplanting : 23rd August, 2004
3. Spacing : 1) Between plants : 15 cm
   2) Between rows : 10 cm
4. Fertilizers : 100:50:50 kg/ha NPK
5. Weeding : Four times
6. Irrigations : At 7 days interval

7. Plant protection : No sprayings of any fungicide.
8. Date of harvesting : 24th December, 2004

3.8 Statistical methodology

For comparison of average performance and variability between two populations i.e. irradiated and control, t and F tests were used respectively as described by Panse and Sukhatme (1969).

Experimental Results

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4. EXPERIMENTAL RESULTS

Present investigation entitled, "Mutation breeding for disease resistance in onion (*Allium cepa* L.)", has been undertaken to create resistance against purple blotch disease in onion which is the major constraint in onion breeding programme. It is known fact that at present, in onion germplasm, very limited variability is present for resistance against purple blotch disease and also for high TSS content. Hence, in present investigation efforts were made to locate the genetic variability in M_3 and M_4 generations particularly for these traits in white and red onions through mutation breeding.

In present investigation effect of mutation was studied for three crops of two generations i.e. M_3 bulb and seed crops and M_4 bulb crop; with basic objectives to screen the irradiated populations against purple blotch blight disease and high TSS content. Also other horticultural traits i.e. plant growth and bulb characteristics of mutated onion plants were assessed.

4.1 Evaluation of M_3 generation for per cent disease intensity of purple blotch disease

In M_3 generation, 1625 plant population of white onion and 1175 plant population of red onion were screened against purple blotch disease under artificial epiphytotic conditions during *kharif* 2003 along with control i.e. M_0 plants of red and white genotypes where 25 plants randomly selected from population of 500 plants.

The experimental plot was not sprayed with any fungicide but artificial inoculation for purple blotch was done twice at 50 and 80 DAT

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stages. Observations were recorded in per cent disease intensity under six grading system (i.e. 0-9 scale).

The data of Table 1 revealed that 26.83 PDI was recorded (i.e. moderately susceptible) in irradiated population of white onion as compared to control plants which showed 50.60 PDI (i.e. susceptible) for the purple blotch disease. Similarly in case of red onion irradiated population was recorded 40.79 PDI at 90 DAT while the control plants showed 52.00 PDI for purple blotch disease. Thus, in both cases, irradiated M_3 population recorded lower disease reaction than the control.

As 't' test was found significant for both red and white onions, the average performance of two populations (i.e. M_3 generation and control) for PDI was different. Furthermore, 'F' test was also found significant thus variability between these two populations was also different for both red and white onion.

Hence, it is proved that for disease reaction. M_3 population showed different performance and variability than the control. Therefore, it can be basis for present study to utilize the variability induced by mutation for further crop improvement.

4.2 Evaluation of M_3 seed bulbs

For advancement of M_3 seed crop, 58 bulbs of white onion and 40 bulbs of red onion were selected on the basis of minimum per cent disease intensity against purple blotch disease (5-20 PDI; Table 2 & 3) along with desirable bulb characteristics such as higher bulb weight (46-185 g and 55-174 g, respectively of white and red onion) and bigger bulb size (i.e. equatorial bulb diameter 4.0-7.5 cm and 4.5-7.4 cm, respectively of red and

Table 1. Screening of M_3 bulb crop of white and red onions for purple blotch disease at 90 DAT crop stage (*Kharif*, 2003)

Characters / Test	Per cent disease intensity of white onion*		Per cent disease intensity of red onion*	
	Irradiated	Control	Irradiated	Control
Mean	26.83	50.60	40.79	52.00
Range	5-90	15-100	10-90	25-95
Variance	533.06	450.66	628.54	437.49
Observations	1625	25	1175	25
df for 't'	1648		1198	
't' (cal)	5.1138		2.2177	
't' (table)	1.96		1.96	
Results	Significant		Significant	
df for 'F'	1624,24		1174,24	
F cal	26.151		4.918	
'F' table	1.73		1.73	
Results	Significant		Significant	

* Inoculum of purple blotch was sprayed at 50 and 80 DAT crop stages.

white onion) (Table 2 and 3). Observations were recorded on PDI of purple blotch disease, bulb diameter (equatorial and polar diameter), TSS content, bulb weight and bulb shape index.

4.2.1 Per cent disease intensity of purple blotch disease in selected seed bulb plants

A) White onion

The data of Table 2 revealed that in M_3 generation, selected 58 white onion bulb plants recorded mean PDI 14.05 (i.e. moderately resistant) while the control plants showed mean PDI 32.5 (i.e. moderately susceptible). Thus, it showed that effective selection pressure was applied on seed bulb for disease resistance. The range of disease was 5-20 per cent in irradiated white 15-50 per cent in control plants. It means that in irradiated population, selection was applied in the range of resistant to moderately resistant while in control population, selection was applied in the range of moderately resistant to moderately susceptible.

As 't' and 'F' tests were found significant which showed that the average performance and also variability of seed bulbs selected from two populations (i.e. M_3 generation and M_0 generation) were different for disease reaction.

B. Red onion

Similarly in red onion 't' and 'F' tests were found significant so that the average performance and variability of seed bulbs selected from two populations (i.e. control and M_3 generation) were different (Table 3). For mean and range of per cent disease intensity, the similar trend was observed in red onion that of white onion and selection pressure was applied on M_3 red onion seed bulbs within range of resistant and moderately resistant (10-20 PDI,

Table 2. White onion : Characterization of selected M_3 seed bulbs for advancing seed production i.e. selection pressure applied for advance M_4 generation (Season: *Rabi*, 2003-04)

Characters / Test	Per cent disease intensity of purple blotch		Bulb weight (g)		Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		TSS (%)	
	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control
Mean	14.05	32.50	104.94	100.90	5.94	5.67	5.13	4.47	1.17	1.27	10.96	11.16
Range	5-20	15-50	46-185	66-141	4.0-7.5	4.2-7	3.5-7	3.5-5.5	0.78-1.71	0.875-1.71	7-15	9.6-13
Variance	18.82	95.13	645.41	714.99	0.589	1.322	0.661	0.3890	0.044	0.068	1.4925	1.5092
Observations	58	10	58	10	58	10	58	10	58	10	58	10
df for 't'	66		66		66		66		66		66	
't' (cal)	9.9497		0.4620		0.9608		2.4690		1.3488		0.4728	
't' (table)	1.96		1.96		1.96		1.96		1.96		1.96	
Results	Significant		Non-significant		Non-significant		Significant		Non-significant		Non-significant	
df for 'F'	57,9		57,9		57,9		57,9		57,9		57,9	
F cal	98.996		0.213		0.923		6.096		1.1819		0.224	
'F' table	2.71		2.71		2.71		2.71		2.71		2.71	
Results	Significant		Non-significant		Non-significant		Significant		Non-significant		Non-significant	

Table 3. Red onion : Characterization of selected M_3 seed bulbs for advancing seed production i.e. selection pressure applied for advance M_4 generation (Season: *Rabi*, 2003-04)

Characters / Test	Per cent disease intensity of purple blotch		Bulb weight (g)		Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		TSS (%)	
	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control
Mean	16.35	40.50	98.97	109.8	5.91	6.12	5.16	5.35	1.1490	1.1580	11.77	12.36
Range	10-20	25-55	55-174	86-132	4.5-7.4	4-7	4.3-6.3	4.7-6.3	0.90-1.55	0.76-1.32	10.2-15.4	10.8-13.8
Variance	15.25	108.25	731.41	239.28	0.5296	0.8306	0.206	0.300	0.0267	0.0275	0.9225	0.8781
Observations	40	10	40	10	40	10	40	10	40	10	40	10
df for 't'	48		48		48		48		48		48	
't' (cal)	11.9527		1.2111		0.7481		1.1360		0.1552		1.7379	
't' (table)	1.96		1.96		1.96		1.96		1.96		1.96	
Results	Significant		Non-significant		Non-significant		Non-significant		Non-significant		Non-significant	
df for 'F'	39,9		39,9		39,9		39,9		39,9		39,9	
F cal	142.866		1.467		0.560		1.291		0.024		3.020	
'F' table	2.71		2.71		2.71		2.71		2.71		2.71	
Results	Significant		Non-significant		Non-significant		Non-significant		Non-significant		Significant	

Table 3) while mean PDI of selected M_3 red seed bulb was 16.35, which showed moderate resistant disease reaction.

Thus, in both onion genotypes (white and red) M_3 generation induced genetic variability for resistant to moderately resistant disease reaction, which was utilized for advancing M_4 generation.

4.2.2 Bulb weight

Apart from disease reaction, bulb weight is an important horticultural trait responsible for higher yield. Therefore, this trait of selected seed bulb was assessed.

The non-significant difference between average performance and variability was observed as 't' and 'F' tests were found non-significant for both the red and white onion for the character bulb weight (Table 2 and 3). It clearly showed that mutation breeding at M_3 generation could not induce significant variation in this particular trait, for crop improvement.

The higher mean bulb weight (104.94 g) was recorded in M_3 seed bulbs of white onion than control seed bulbs (100.90 g, Table 2) while lower bulb weight (98.97 g) was observed in M_3 bulb crop of red onion as compared to control bulb crop (109.8 g, Table 3). It means that selection pressure applied on seed bulbs of white onions was more effective than the red onions for advancing M_4 generation.

Furthermore, in M_3 generation, white onion seed bulbs recorded wide ranged variability (46-185 g) than control (66-141 g, Table 2). Similarly in red onion wide range variability (55-174 g) was observed in M_3 seed bulbs than the control (86-132 g, Table 3).

In fact, application of wide range selection pressure is not desirable for crop improvement. However, main objective of present study was disease resistance rather than improvement of horticultural traits. Also irradiated M_3 population was more variable than control. It ultimately resulted in wide range selection pressure applied on M_3 seed bulbs.

4.2.3 Equatorial bulb diameter

Like bulb weight similar trend was observed in equatorial bulb diameter of red and white onions which is another important yield contributing character; showing non-significant difference for average performance of variability in between two plant populations (i.e. control and irradiated M_3 generation; Table 2 and 3). Furthermore, it was observed that almost similar values were observed for mean and range of both populations (i.e. M_3 and control) in red and white onions (Table 2 and 3). Thus, close similarity was observed for equatorial bulb diameter among seed bulbs of two populations. However, M_3 selected white seed bulbs showed higher mean value (5.94 cm) than the control (5.67 cm; Table 2) indicating desirable effect of mutation on this trait. But reverse trend was noticed in red seed bulbs as M_3 generation recorded slightly lower mean (5.91 cm) than control (6.12 cm; Table 3).

4.2.4 Polar bulb diameter

In polar bulb diameter, differential response was noticed than equatorial diameter. In white onions, as both t ad F tests were found significant (Table 2). Significant differences were found in between seed bulbs of irradiated and control populations for average performance and variability. The higher mean value (5.13 cm) was recoded in irradiated M_3 seed bulbs than control (4.47; Table 2).

However, reverse trend was observed in seed bulbs of red onion as non-significant differences were observed in between two populations for average performance and variability (Table 3).

4.2.5 Bulb shape index

Bulb shape index of selected seed bulbs neither influenced significantly for average performance nor for variability in both populations (i.e. control and irradiated M_3) of white and red onion genotypes (Table 2 and 3). Thus, it showed that mutation was ineffective in creating variability for bulb shape; which otherwise a good sign for breeder because consumer acceptance is for uniform onion bulb shape (e.g. oblong round or flatish round).

Bulb shape index is a ratio of equatorial to polar diameter; which represent the shape of onion bulb. If the ratio is more than 1.5 then onion bulb is considered as flat shape. If the ratio is between 1.0-1.5 then onion bulb is treated as globose round shape, while if ratio is less than one, then bulb is of oblong shape.

In this context, in white and red onions, the mean values of both populations (i.e. M_3 generation and control) were observed about one (Table 2 and 3) which represented round bulb shape.

4.2.6 Total soluble solids

TSS content is a prime important character in onion breeding programme, particularly when white onion cultivar is developed for processing (i.e. dehydration) At present, the TSS content is very low (9-13.5%) among Indian onion germplasm. With this regard, in present investigation, seed bulbs were particularly screened for TSS content. However, the mean TSS content of white M_3 seed bulbs (10.96%) was slightly differed from control seed bulbs (11.16%; Table 2). Furthermore, both 't' and 'F' tests showed non-significant differences between control and M_3 generation population. It proved that for TSS content, average performance and variability were similar to each other. However, within white M_3 seed bulb population, wide range of TSS (7-15%) was observed as compared to narrow ranged (9.6-13%; Table 2) of control population.

In red onion, mean TSS content of M_3 seed bulbs (11.77%) was also similar to control seed bulbs (12.36%; Table 3). The 't' test showed non-significant difference between two populations (M_3 generation and control) while 'F' test showed significant variability between two populations. Similarly to white onion, wide range variability (10.2-15.4%; Table 3) was observed in M_3 red seed bulbs than the control seed bulbs (10.8-13.8%; Table 3).

It was worthy note that the higher TSS content (i.e. >16%) was not observed among the seed bulbs of red and white onions in either control or irradiated generation.

4.3 Evaluation of M_3 seed crop

The 58 M_3 seed bulbs of white onion and 40 M_3 seed bulbs of red onion were selected as a source of disease resistance and used to raise seed crop during *rabi* 2003-04. The observations were recorded for per cent disease intensity for leaf blight disease, floral and seed characters of both red and white onions (Table 4 and Table 5).

Table 4. Characterization of M_3 seed crop of white onion during *Rabi*, 2003-04

Characters / Test	Per cent disease intensity of leaf blight at 45 DAT*		No. of umbels/ bulb		No. of seeds/bulb		Seed weight/ bulb (g)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
Mean	33.34	77.00	1.44	1.50	83.63	97.40	0.3612	0.4040
Range	20-55	50-100	1-3	1-4	93-293	80-116	0.40-1.27	0.30-0.59
Variance	83.51	256.66	2.006	0.9443	9295.56	136.044	0.1734	0.0059
Observations	58	10	58	10	58	10	58	10
df for 't'	66		66		66		66	
't' (cal)	12.2890		0.128		0.4481		0.3220	
't' (table)	1.96		1.96		1.96		1.96	
Results	Significant		Non-significant		Non-significant		Non-significant	
df for 'F'	57,9		57,9		57,9		57,9	
F cal	151.020		0.011		0.201		0.104	
'F' table	2.71		2.71		2.71		2.71	
Results	Significant		Non-significant		Non-significant		Non-significant	

* PDI recorded 15 days after artificial inoculation.

Table 5. Characterization of M_3 seed crop of red onion during *Rabi*, 2003-04

Characters / Test	Per cent disease intensity of leaf blight at 45 DAT*		No. of umbels/ bulb		No. of seeds/bulb		Seed weight/ bulb (g)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
Mean	29.00	75.00	2.70	2.90	95.32	103.60	0.3928	0.4300
Range	20-45	55-100	1-5	2-6	79-137	76-140	0.29-0.59	0.28-0.60
Variance	50.25	194.44	1.292	1.655	217.50	323.37	0.0052	0.0090
Observations	40	10	40	10	40	10	40	10
df for 't'	48		48		48		48	
't' (cal)	14.7991		0.4852		1.5192		1.3597	
't' (table)	1.96		1.96		1.96		1.96	
Results	Significant		Non-significant		Non-significant		Non-significant	
df for 'F'	39,9		39,9		39,9		39,9	
F cal	219.015		0.227		2.308		1.849	
'F' table	2.71		2.71		2.71		2.71	
Results	Significant		Non-significant		Non-significant		Non-significant	

* PDI recorded 15 days after artificial inoculation.

4.3.1 Per cent disease intensity of leaf blight disease

In general, seed crop of onion is more susceptible to diseases as compared to bulb crop. But still to have vigorous screening for disease resistance, the M_3 seed crop was screened against leaf blight diseases under artificial epiphytotic conditions where inoculum was spread at 30 DAP crop stage. The per cent disease intensity for leaf blight disease were recorded by 0-9 scale i.e. six grading system after 15 days of artificial inoculation i.e. 45 DAP crop stage.

The data of Table 4 revealed that in white onion lower mean per cent disease intensity (i.e. 33.44 PDI) was recorded in M_3 seed crop as compared to control seed crop (i.e. 77.00 PDI). The 't' and 'F' tests were found significant for white onion, it means that the average performance and variability between two populations (M_3 generation and control) was different for disease reaction.

While in red onion, 29.00 PDI was observed in M_3 seed crop than 75.00 PDI in control population (Table 5). The 't' and 'F' tests were also found significant (Table 5).

Thus, it was worthy to note that irradiated population of M_3 seed crop of both onions (i.e. red and white) significantly differed in average performance and variability than control seed crop for disease reaction.

4.3.2 Number of umbels per plant

In white onion seed crop, almost similar number of umbels per plant was recorded in mutated M_3 and the control population (i.e. 1.44 and 1.50, respectively; Table 4). Similar trend was also noticed in red onion i.e. 2.70

umbels per M_3 plant than 2.90 umbels per plant in control (Table 5). Thus, deleterious effect of mutation on seed crop was not noticed at M_3 generation.

The average performance and variability between two populations (i.e. M_3 generation and control) was similar in both red and white onion as 't' and 'F' tests were found non-significant (Table 4 and 5).

4.3.3 Seed coat colour

Normally fertile onion seed plants display black seed coat colour while male sterile plants show brown seed coat. In this context, the seed of M_3 generation was checked for seed coat colour. However, normal black seed coat colour was uniformly observed in all M_3 plants of both red and white onions. Thus, it showed that there was no male sterility observed in M_3 generation.

4.3.4 Number of seeds per plant

The lower number of seeds (83.63) was observed in M_3 generation of white onion than the control population (97.40; Table 4). Similar trend was also noticed in red onion i.e. 95.32 and 103.60, respectively (Table 5). In general, lower seed yield was resulted due to severe susceptibility of seed crop of leaf blight disease.

As 't' and 'F' tests were found non-significant for both white and red onions (Table 4 and 5) which showed that there was non-significant differences between irradiated and control populations for average performance and variability. It also proved that mutated population showed normal behaviour for seed production.

4.3.5 Seed weight per plant

In case of both, white and red onions, the mean seed weight per bulb of irradiated M_3 plants were slightly lower than that of control plants (0.36 and 0.40 g in Table 4 and 0.39 and 0.43 g in Table 5, respectively). Similarly non-significant differences were observed between M_3 and control populations of both white and red onions (Table 4 and 5). Thus, similar trend was observed that of number of seeds per plant.

4.4 Evaluation of M_4 generation

4.4.1 Evaluation of M_4 generation of white onion

While evaluating 58 M_3 white seed bulbs under artificial epiphytotic conditions, 20 seed plants remained non-bolting while 18 seed plants showed severe blight at later crop stages, which had adverse effect on viable seed production. Therefore, eventually out of 58 white M_3 seed bulbs, seed progeny only 20 white seed bulbs was succeeded to advance M_4 bulb crop.

Thus, M_4 bulb crop was assessed during *kharif* 2004 where 500 plant population of M_4 generation from 20 genotypes were compared with control (M_0 generation). A control population was comprise of 500 plants where 25 plants were randomly selected for recording observations.

I. Pathological observations

4.4.1.1 Per cent disease intensity of purple blotch disease

The 500 plant population of M_4 generation was screened against purple blotch disease under natural field conditions at 60 and 90 DAT crop

Plate :1 White onion screening of M_4 bulb crop against purple blotch (*Alternaria Porri*) disease

Control (Mo) M_4

Screening at 60 DAT

Screening at 90 DAT

A B C D E

A & B - 1-10 PDI

C - 11-25 PDI

D - 26-50 PDI

E - 51-75 PDI

Disease grades for purple blotch disease stages. The experimental plot was not sprayed with any fungicides. After 60 DAT crop stage, congenial situation for disease occurrence (>50 PDI) was noticed in the field, therefore, artificial inoculation was not done. Observations for this character were recorded in per cent disease intensity under 0-9 scale i.e. six grading system.

The noticeable lower disease intensity of purple blotch disease was observed in M_4 generation at 60 and 90 DAT crop stage (8.38 and 19.50%), respectively; Table 6) in M_4 generation than the control plants (i.e. 30.08% and 58.80% at 60 and 90 DAT crop stage, respectively). Also 't' and 'F' tests were found significant for both the stages i.e. at 60 and 90 DAT crop stage (Table 6). It means that both populations were significantly different in average performance and variability for disease reaction.

Selection basis for M_5 generation

As there was significant variability observed for PDI of purple blotch disease in M_4 generation; therefore to advance M_5 generation selection can be suggested on the basis of population mean of M_4 generation minus once the standard deviation (i.e. 12.40 PDI at 90 DAT; Table 9). There were eighty-five genotypes which recorded PDI lower than 12.40% (Appendix-III A.I) which can be selected for M_5 generation.

Disease reaction of plants under six grading system

The 500 plant population of each generation i.e. M_4 and control were assessed for purple blotch disease at 60 and 90 DAT crop stage.

The data of Table 7 revealed that initially at 60 DAT stage; 78 per cent M_4 plants recorded resistance against purple blotch disease while only 24% control plants showed moderate resistance. This situation drastically

Table 6. Screening of M_4 white onion bulb crop for purple blotch disease under natural field conditions during *Kharif*, 2004

Characters / Test	Per cent Disease Intensity (PDI)*				Per cent no. of disease affected leaves/plant		No. of leaves per plant		Plant height (cm)	
	60 DAT		90 DAT		Irradiated	Control	Irradiated	Control	Irradiated	Control
	Irradiated	Control	Irradiated	Control						
Mean	8.38	30.08	19.50	58.80	45.50	67.29	11.16	12.56	63.07	59.48
Range	2-20	24-40	8-45	40-80	16.67-69.24	53.82-85.00	5-25	8-19	39.8-80.4	52.8-67.8
Variance	13.56	16.57	50.33	148.50	128.82	54.72	12.981	9.090	59.59	21.786
Observations	500	25	500	25	500	25	500	25	200	10
df for 't'	523		523		523		523		208	
t (Cal)	28.5977		25.8918		9.4949		1.9064		1.4560	
t (table)	1.96		1.96		1.96		1.96		1.96	
Results	Significant		Significant		Significant		Non-significant		Non-significant	
df for 'F'	499,24		499,24		499,24		499,24		199,24	
F cal.	817.827		670.386		90.154		3.635		2.120	
'F' table	1.73		1.73		1.73		1.73		2.71	
Results	Significant		Significant		Significant		Significant		Non-significant	

* After 60 DAT crop stage congenial situation for disease occurrence (>50% PDI) was observed in field, therefore artificial inoculation was not done.

Table 7. Per cent disease intensity (PDI) of purple blotch (*Alternaria porri*) under 0-9 scale i.e. six grading system of disease occurrence of white onion (Season : *Kharif*, 2004).

Sr. No.	PDI	Grade	At 60 DAT				At 90 DAT			
			M_4 generation		Control		M_4 generation		Control	
			No. of plants	%	No. of plants	%	No. of plants	%	No. of plants	%
1	0 (I)	0	-	-	-	-	-	-	-	-
2	1-10 (R)	1	390	78	-	-	79	15.8	-	-
3	11-25 (MR)	3	110	22	120	24	359	71.8	-	-
4	26-50 (MS)	5			380	76	62	12.4	160	32
5	51-75 (S)	7							320	64
6	76-100 (HS)	9							20	4
Total no. of plants			500		500		500		500	

I = Immune
R = Resistant
MR = Moderately resistant
MS = Moderately susceptible
S = Susceptible
HS = Highly susceptible

changed at advanced stage i.e. 90 DAT; as only 15.8 per cent (79 plants) of M_4 bulb crop showed resistance to purple blotch disease while most of control plants i.e. 64% showed susceptibility and furthermore, 4% control population displayed highly susceptibility to the disease. It was important to note that an immunity was not observed for purple blotch disease either in M_4 generation or control population.

4.4.1.2 Per cent number of disease affected leaves per plant

It is a quantitative measure to assess disease resistance. Therefore, this trait was studied in detail at 90 DAT crop stage as an additional support for disease resistance. Accordingly, in M_4 generation considerable lower per cent disease affected leaves per plant (45.50%) was observed as compared to control population (67.29%; Table 6).

Furthermore, the 't' and 'F' tests were also found significant (Table 6). This showed that there was significant difference for average performance and variability between disease reaction of two populations. Thus, similar trend was observed that of per cent disease intensity (PDI). Hence these two critical observations clearly indicated that the mutated population showed significantly different genetic variability for disease reaction than control population and offered field resistance against purple blotch disease.

Selection basis for M_5 generation

The range for per cent disease affected leaves per plant in M_4 generation and control was 16.67 - 69.24% and 53.85 - 85.00%, respectively (Table 6). As significant variability was observed, a selection can be made particularly on the basis of population mean of M_4 generation minus twice of standard deviation value (22.8; Table 9). There were twenty three M_4 genotypes which recorded lower per cent number of disease affected leaves per plant than the selection pressure i.e. 22.8 (Appendix-III AI) which can be selected for M_5 generation.

II. Plant growth characters

4.4.1.3 Number of leaves per plant

This character was assessed only at 90 DAT crop stage. The slightly lower mean value for number of leaves per plant was recorded in M_4 generation than the control (11.16 and 12.56, respectively; Table 6).

For this trait 't' test found non-significant while 'F' test was found significant. It revealed that eventhough average performance of irradiated M_4 population and control was similar but variability was present between two populations.

Selection basis for M_5 generation

Considering wide range and significant variability present in M_4 generation for number of leaves, there was scope for selecting vigorous plants for M_5 generation. Therefore, on the basis of mean plus twice of standard deviation value (i.e. 18.36 leaves per plant at 90 DAT; Table 9) 20 M_4 genotypes can be selected for M_5 generation (Appendix-III A-I). Furthermore, on the basis of mean plus thrice of standard deviation (i.e. 21.96 leaves per plant at 90 DAT; Table 9) there were 4 M_4 genotypes which can be selected for M_5 generation (Appendix-III AI).

4.4.1.4 Plant height

This character was assessed at 90 DAT crop stage and observations were recorded on 10 randomly selected plants per M_4 line and control. The mean of plant height of M_4 generation was 63.07 cm (Table 6) while 59.48 cm of control population. However, the 't' and 'F' tests were non-significant (Table 6), it means that eventhough, slightly vigorous plant growth was recorded in M_4 generation, there was non-significant difference between two populations (M_4 and M_0) for average performance and variability of plant height.

Selection basis for M_5 generation

For plant height, non-significant variability was observed between two populations (M_4 and M_0), selection basis for next generation (M_5) was not suggested for this particular trait.

III. Bulb characters

4.4.1.5 Bulb weight

This is one of an important yield contributing character in onion. The slightly lower bulb weight (100.75 g; Table 8) was recorded in M_4 bulb crop as compared to control (119.90 g). However, wide range variability (9-268 g) was observed in mutated population, it showed scope for yield improvement.

The 't' and 'F' tests were found non-significant (Table 8), this means that there was non-significant difference between average performance and variability of two populations (M_4 generation and control).

Table 8. Characterization of M_4 white onion bulb crop during *Kharif*, 2004

Characters / Test	Bulb weight (g)		Equatorial bulb diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Total soluble solids (%)	
	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control
Mean	100.75	119.90	6.27	5.64	5.31	4.54	1.21	1.24	2.18	1.78	13.06	12.84
Range	9-268	44-195	3.0-8.4	4.5-6.3	3.9-7.5	3.5-5.1	0.70-1.68	1.12-1.34	0.6-3.7	1.0-2.7	9.8-15.4	11.0-14.2
Variance	1380.93	2853.87	0.8632	0.2893	0.3852	0.2181	0.1992	0.0049	0.2624	0.3173	0.9828	1.0916
Observations	200	10	200	10	200	10	200	10	200	10	200	10
df for 't'	208		208		208		208		208		208	
't' (cal)	1.4899		2.1318		3.88		0.1896		2.3989		0.6956	
't' (table)	1.96		1.96		1.96		1.96		1.96		1.96	
Results	Non-significant		Significant		Significant		Non-significant		Significant		Non-significant	
df for 'F'	199,9		199,9		199,9		199,9		199,9		199,9	
F cal	2.220		4.545		15.130		0.036		5.755		0.484	
'F' table	2.71		2.71		2.71		2.71		2.71		2.71	
Results	Non-significant		Significant		Significant		Non-significant		Significant		Non-significant	

Table 9. Summation of mean and standard deviation of white onion for different characters of M_4 generation : A selection base for M_5 selection

	PDI of purple blotch (At 90 DAT)	Per cent no. of affected leaves/ plant (At 90 DAT)	No. of leaves/ plant (90 DAT)	Plant height (cm) (90 DAT)	Bulb weight (gm)	Equatorial diameter (cm)	Polar diameter (cm)	Neck thickness (cm)	T.S.S. (%)
Mean (X)	19.50	45.50	11.16	63.07	100.75	6.27	5.31	2.18	13.06
S.D.	7.0950	11.3503	3.6030	7.7199	37.1609	0.9291	0.6207	0.5123	0.9914
X ± S.D.	12.40*	34.15*	14.76	70.78	137.91	7.19	5.93	1.66*	14.05
X ± 2 S. D.	5.31**	22.80**	18.36	78.50	175.07	8.12	6.55	1.15**	15.04
X ± 3 S. D.	-1.785***	11.45***	21.96	86.22	212.33	9.05	7.17	0.64***	16.03

* X - SD, ** X - 2 SD, ** * X - 3 SD

Selection basis for M_5 generation

Eventhough for bulb weight, similar performance and variability was noticed within two populations, but considering importance of this trait for yield improvement and wide range variability observed in M_4 generation; selections be effectively exploited for further crop improvement programme. The six M_4 genotypes recorded higher bulb weight than population mean plus twice of standard deviation value of M_4 generation (175.07 g; Table 9 and Appendix-III AII). Thus, these seven bulbs can be selected for M_5 generation or even further higher selection pressure can be applied on M_5 generation as one genotype of M_4 generation recorded more bulb weight than its population mean plus thrice of standard deviation value (i.e. 212.33 g; Table 9 and Appendix-III, AII) can be selected for M_5 generation.

4.4.1.6 Bulb diameter (Polar and equatorial)

Bulb diameter is an another important yield contributing character in onion. The higher mean values for both bulb diameters (equatorial and polar) were recorded in M_4 generation than the control population (i.e. for equatorial diameter 6.27 and 5.64 cm, respectively; and for polar diameter 5.31 and 4.54 cm, respectively; Table 8). Thus, M_4 generation showed certain improvement for crop yield. Accordingly, average performance of both populations was significantly different as 't' test was found significant (Table 8). It was mainly due to wide range variability observed for bulb diameters in M_4 generation (3.0-8.4 cm for equatorial diameter and 3.9-7.5 cm for polar diameter; Table 8) than the narrow range variability of control population (4.5-6.3 cm for equatorial diameter and 3.5-5.1 cm for polar diameter; Table 8). Thus, significant differences were also observed for both diameters among the variability of two populations as 'F' test was found significant (Table 8).

Selection basis for M_5 generation

As in M_4 generation wide range variability was observed for bulb diameters, it could be effectively exploited for further selections. As most of onion cultivars in India are with globose to flat in shape, equatorial bulb diameter is more important than the polar bulb diameter; which has more consumer acceptance and also it is one of major yield contributing factor in onion. Accordingly, two M_4 genotypes recorded higher equatorial diameter than its population mean plus twice of standard deviation value (i.e. 8.12 cm; Table 9), they can be selected for M_5 generation.

4.4.1.7 Bulb shape index

The bulb shape index of M_4 generation and control were 1.21 and 1.24, respectively (Table 8) which represent globose round shape. The bulb shape index did not differ between two populations (M_0 and M_4) as 't' and 'F' tests were non-significant (Table 8).

4.4.1.8 Neck thickness

In onion thin bulb neck is desirable character. However, in M_4 generation higher mean neck thickness (2.18 cm; Table 8) was noticed as compared to control population (1.78 cm; Table 8). But the wide range variability was observed in M_4 generation (0.6-3.7 cm; Table 8) than the control population (1.0-2.7 cm; Table 8). Accordingly, 't' and 'F' tests were found significant (Table 8); it means that significant differences were observed for average performance and variability of two populations (i.e. M_4 generation and control population).

Selection basis for M_5 generation

As thin bulb neck thickness is a desirable character, the selection can be made on the basis of population mean of M_4 generation minus thrice of standard deviation value (i.e. 0.64 cm; Table 9). Thus, one M_4 genotype can be selected for M_5 generation (Appendix-III, AII).

4.4.1.9 TSS content

Eventhough, TSS content particularly in white onion is an important parameter, the average performance and variability between two populations was not significantly differed as 't' and 'F' tests were found non-significant (Table 8). This indicated that M_4 generation could not create expected variability for high TSS content (i.e. within range of 16-18% TSS) in white onion.

The mean and range of TSS content for two populations (M_4 and control) were closely related (i.e. mean : 13.06 and 12.84 per cent, respectively and range : 9.8-15.4 and 11-14.2%, respectively; Table 8).

4.4.2 Evaluation of M_4 generation of red onion

The M_4 generation of red onion was advanced by growing seed progeny of forty M_3 seed bulbs.

For evaluation of M_4 bulb crop of red onion, 25 plants of each M_4 line were grown. Thus 1000 plant population from 40 M_4 lines constituted M_4 generation. Control population consist of 500 plants where 25 plants were randomly selected for recording observations. The observations were recorded for per cent disease intensity of purple blotch disease, plant growth and bulb characteristics (Table 10 to Table 12).

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I) Pathological observations

4.4.2.1 Per cent disease intensity of purple blotch disease

The M_4 plant population of 1000 plants was individually assessed for purple blotch disease at 60 and 90 DAT crop stage. The experimental plot was not sprayed with any fungicides. After 60 DAT crop stage congenial situation for disease occurrence (>50% PDI) was observed in field, therefore, artificial inoculation was not done. Observations for this character were recorded in per cent disease intensity under 0-9 scale i.e. six grading system.

Lower mean for per cent disease intensity was observed in M_4 generation at 60 and 90 DAT crop stages (9.79 and 23.63 PDI, respectively; Table 10) than the control population (35.00 and 63.60 PDI, respectively). Thus, 't' and 'F' tests were found significant at 60 and 90 DAT crop stages (Table 10). It means that both populations were significantly differed in disease reaction for average performance and variability.

Selection basis for M_5 generation

Selection can be made on the basis of population mean of M_4 generation minus twice the standard deviation value (i.e. 7.56; Table 13) which comes under resistant disease reaction. Thus, there were ten ·en M_4 bulbs (Appendix-III B-I) which can be selected for advancing M5 generation.

Disease reaction under six grading system

The 1000 plant population of M_4 generation and 500 plants of control were individually assessed for purple blotch disease at 60 and 90 DAT crop stages.

Table 10. Screening of M_4 red onion bulb crop for purple blotch disease under natural field conditions during *Kharif*, 2004

Characters / Test	Per cent Disease Intensity (PDI)*				Per cent no. of disease affected leaves/plant		No. of leaves per plant		Plant height (cm)	
	60 DAT		90 DAT		Irradiated	Control	Irradiated	Control	Irradiated	Control
	Irradiated	Control	Irradiated	Control						
Mean	9.79	35.00	23.63	63.60	46.12	70.20	13.34	13.16	60.53	62.62
Range	2-22	20-45	6-90	35-10	7.69-70.00	54.55-90.00	3-34	8-21	35.3-80.1	56.5-67.3
Variance	10.46	45.83	64.54	263.58	144.53	93.75	14.487	15.306	37.32	13.688
Observations	1000	25	1000	25	1000	25	1000	25	400	10
df for 't'	1023		1023		1023		1023		408	
t (Cal)	37.0407		23.7226		9.9346		0.2451		1.0744	
t (table)	1.96		1.96		1.96		1.96		1.96	
Results	Significant		Significant		Significant		Non-significant		Non-significant	
df for 'F'	999,24		999,24		999,24		999,24		399,24	
F cal.	1372.016		562.763		98.696		0.060		1.154	
'F' table	1.73		1.73		1.73		1.73		2.71	
Results	Significant		Significant		Significant		Non-significant		Non-significant	

* After 60 DAT crop stage congenial situation for disease occurrence (>50% PDI) was observed in field, therefore artificial inoculation was not done.

Table 11. Per cent disease intensity (PDI) of purple blotch (*Alternaria porri*) under 0-9 scale i.e. six grading system of disease occurrence of red onion (Season : *Kharif*, 2004).

Sr. No.	PDI	Grade	At 60 DAT				At 90 DAT			
			M_4 generation		Control		M_4 generation		Control	
			No. of plants	%	No. of plants	%	No. of plants	%	No. of plants	%
1	0 (I)	0	-	-	-	-	-	-	-	-
2	1-10 (R)	1	731	73.1	-	-	22	2.2	-	-
3	11-25 (MR)	3	269	26.9	80	16	754	75.4	-	-
4	26-50 (MS)	5	-	-	420	84	220	22.0	120	24
5	51-75 (S)	7	-	-	-	-	3	0.3	300	60
6	76-100 (HS)	9	-	-	-	-	1	0.1	80	16
Total no. of plants			1000		500		1000		500	

I = Immune
R = Resistant
MR = Moderately resistant
MS = Moderately susceptible
S = Susceptible
HS = Highly susceptible

Plate : 2 Red onion screening of M_4 bulb crop against purple blotch (*Alternaria Porri*) disease

Control (Mo)

M_4

Screening at 60 DAT

Screening at 90 DAT

A B C D E

A & B - 1-10 PDI

C - 11-25 PDI

D - 26-50 PDI

E - 51-75 PDI

Disease grades for purple blotch disease

The data of Table 11 revealed that at 60 DAT stage; 73.1% M_4 generation plants recorded resistance against purple blotch disease. While only 16% control plants were moderately resistant to the disease while at 90 DAT crop stage, only 2.2% (i.e. 22 plants) and 75.4% (754 plants) were resistant and moderately resistant, respectively of M_4 generation. On the other hand, 60% and 16% plants of control were susceptible and highly susceptible, respectively to the purple blotch disease. Similarly as that of white onion, immunity was also not observed either in M_4 generation or control population of red onion.

4.4.2.2 Per cent number of disease affected leaves per plant

Lower per cent number of disease affected leaves per plant of M_4 generation was recorded as compared to control population (46.12% and 70.20% respectively; Table 10).

The 't' and 'F' tests were found significant (Table 10); this showed that there was significant difference in disease reaction for average performance and variability between two populations (M_4 and M_0).

Selection basis for M_5 generation

The range of per cent disease affected leaves per plant of M_4 generation and control were 7.69-70.00% and 54.55-90.00% (Table 10), respectively. As significant variability was observed in M_4 generation, a selection can be made on the basis of population mean of M_4 generation minus twice of standard deviation value (i.e. 22.07 per cent number of disease affected leaves; Table 13). There were forty-six M_4 genotypes recorded lower per cent number of disease affected leaves per plant than 22.07% (Appendix-III BI) which can be selected for advancing M_5 generation. It was possible to apply selection pressure on still higher side. There were two M_4

genotypes which had less per cent number of disease affected leaves per plant than population mean of M_4 generation minus thrice of standard deviation value (i.e. 10.06%; Table 13, Appendix-III BI) which can also be selected for M_5 generation under tight selection pressure.

II. Plant growth characters

4.4.2.3 Number of leaves per plant

This character was assessed only at 90 DAT crop stage. The slightly lower mean value of M_4 generation was recorded than the control population (13.34 and 13.16, respectively; Table 10).

The 't' and 'F' tests were found non-significant (Table 10); it means that average performance and variability of two populations were similar. However, wide range was observed in M_4 generation than the control population (i.e. 3-34 and 8-21 respectively; Table 10).

Selection basis for M_5 generation

Due to similar variability and average performance was noticed between M_4 and M_0 populations, selection basis was not suggested for this character to advance M_5 generation.

4.4.2.4 Plant height

This character was assessed at only 90 DAT crop stage. The slightly lower mean value (i.e. 60.53 cm; Table 10) for M_4 generation was recorded than the control population (i.e. 62.62 cm). Also 't' and 'F' tests were found non-significant (Table 10); it means that there was non-significant difference between two populations for average performance and variability of plant height.

Selection basis for M_5 generation

Due to similarity of two populations, selection basis was not suggested for this trait to advance further generation (M_5).

III. Bulb characters

4.4.2.5 Bulb weight

The higher mean bulb weight (98.77; Table 12) was recorded in M_4 generation than the control population (95.70 g). The 't' and 'F' tests were found non-significant, this means that there was non-significant difference between average performance and variability of two populations (M_4 generation and control).

Selection basis for M_5 generation

However, wide range for bulb weight was observed in M_4 generation (19-287 g) as compared to narrow range of control population (70-149 g; Table 12). Therefore, selection can be made on the basis of population mean of M_4 generation plus twice of standard deviation value (171.38 g; Table 13). There were seventeen M_4 genotypes which recorded higher bulb weight than 171.38 g (Appendix-III, BII) can be selected for advancing M_5 generation.

4.4.2.6 Bulb diameters (Polar and equatorial)

The slightly lower mean values for both bulb diameters (equatorial and polar) were recorded in M_4 generation than the control population (i.e. for equatorial diameter, 5.98 and 6.66 cm while for polar diameter 5.15 and 5.57 cm respectively; Table 12).

The 't' and 'F' tests were found significant for equatorial diameter while these tests were non-significant for polar diameter (Table 12). The wide

Table 12. Characterization of M_4 red onion bulb crop during *Kharif*, 2004

Characters / Test	Bulb weight (g)		Equatorial bulb diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Total soluble solids (%)	
	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control	Irradi-ated	Control
Mean	98.77	95.70	5.98	6.66	5.15	5.57	1.1699	1.1620	1.86	1.70	12.90	12.54
Range	19-287	70-149	2.9-8.5	5.4-8.0	2.6-7.5	3.0-5.1	0.56-1.85	0.9-1.33	0.4-3.5	1.0-2.5	8.0-16.0	11.0-14.8
Variance	1318.15	666.89	1.057	0.678	0.6860	0.346	0.034	0.024	0.2975	0.2266	1.622	1.129
Observations	400	10	400	10	400	10	400	10	400	10	400	10
df for 't'	408		408		408		408		408		408	
't' (cal)	0.2662		2.0648		1.5926		0.1333		0.9257		0.8883	
't' (table)	1.96		1.96		1.96		1.96		1.96		1.96	
Results	Non-significant		Significant		Non-significant		Non-significant		Non-significant		Non-significant	
df for 'F'	399,9		399,9		399,9		399,9		399,9		399,9	
F cal	0.071		4.263		2.536		0.018		0.857		0.789	
'F' table	2.71		2.71		2.71		2.71		2.71		2.71	
Results	Non-significant		Significant		Non-significant		Non-significant		Non-significant		Non-significant	

Table 13. Summation of mean and standard deviation of red onion for different characters of M_4 generation : A selection base for M_5 selection

	PDI of purple blotch (90 DAT)	Per cent no. of affected leaves/ plant (90 DAT)	No. of leaves/ plant (90 DAT)	Plant height (cm) (90 DAT)	Bulb weight (gm)	Equatorial diameter (cm)	Polar diameter (cm)	Neck thickness (cm)	T.S.S. (%)
Mean (X)	23.63	46.12	13.34	60.53	98.77	5.98	5.15	1.86	12.90
S.D.	8.0343	12.0224	3.8063	6.1093	36.3034	1.0282	0.8283	0.5455	1.2736
X ± S.D.	15.59*	34.09*	17.14	66.63	135.07	7.00	5.97	1.31*	14.17
X ± 2 S. D.	7.56**	22.07**	20.95	72.74	171.38	8.03	6.80	0.769**	15.44
X ± 3 S. D.	-0.4729***	10.06***	24.75	78.85	207.68	9.06	7.63	0.2235**	16.72

* X - SD, ** X - 2 SD, *** X - 3 SD

(A) : At 100 DAT crop stage

Control (M_o) M_4 generation


White Onion


Red Onion

(B) : - At 120 DAT stage ie upon bulb harvest
M_4 Plants of white & red Onion


range variability was observed for both bulb diameters in M_4 generation (2.9-8.5 cm for equatorial and 2.6-7.5 cm for polar diameter; Table 12) over the narrow range for control population (5.4-8.0 cm and 3.0-5.1 cm for equatorial and polar diameter, respectively; Table 12).

Selection basis for M_5 generation

As equatorial bulb diameter is more important than polar bulb diameter therefore, selection can only be suggested for equatorial bulb diameter. The seven M_4 genotypes which recorded bigger equatorial diameter than its population mean plus twice of standard deviation value (8.03 cm; Table 13) can be selected for advancing M_5 generation (Appendix-III BII).

4.4.2.7 Bulb shape index

The mean value of bulb shape index of M_4 generation and control popultions were 1.16 and 1.16, respectively (Table 12) which represent globose round shape for both populations. The trend of bulb shape index for 't' and 'F' tests were similar to that of bulb weight i.e. non-significant differences for average performance and variability among M_4 generation and control population (Table 12).

Selection basis for M_5 generation

The bulb shape index was nearly similar in two populations so the selections were not offered for this particular trait.

4.4.2.8 Neck thickness

In M_4 generation, slightly higher mean neck thickness (1.86 cm; Table 12) was recorded as compared to control population (1.70 cm). Furthermore, 't' and 'F' tests were also found non-significant.

Selection basis for M_5 generation

However, as wide range variability was observed in M_4 population (0.4-3.5 cm, Table 12) and thin bulb neck is a desirable character in onion, the selection can be applied on the basis of population mean of M_4 generation minus twice of standard deviation value (0.76 cm; Table 13). Thus, two M_4 genotypes can be selected for advancing M_5 generation.

4.4.2.9 TSS content

The average performance and variability between M_4 generation and control was non-significantly differed as 't' and 'F' tests were fond non-significant (Table 12). Nevertheless mean values and range for two populations were closely related (i.e. mean 12.90 and 12.54 per cent and range 8-16 per cent and 11-14.8 per cent for M_4 generation and control population, respectively; Table 12).

Thus, similar trend for TSS content was observed in red and white onions. It was noticed that mutation breeding upto M_4 generation could not effective in creating variability for higher TSS content (>16%) in white or red onion bulbs.

4.4.3 Effect of irradiation on premature bolting and natural topfall in red and white onion

At the harvest of onion bulbs (120 DAT), M_4 and control population two populations were also screened for two important horticultural traits of *kharif* cultivation i.e. premature bolting and natural topfall.

Table 14. Occurrence of premature bolting and natural topfall in onion

Onion types	Population	% pre-mature bolting at 120 DAT	% natural topfall at 120 DAT
White	M_4 generation	17.4	-
	Control	12.0	-
Red	M_4 generation	20.6	-
	Control	16.0	-

Data of Table 14 revealed that M_4 generation recorded slightly more premature bolting (17.4 and 20.6% in white and red onions, respectively) than the control (12 and 16% in white and red onions, respectively), while natural topfall at bulb harvest was not noticed either in M_4 generation or in control population. Thus mutation breeding at M_4 generation could not prove beneficial for these two horticultural traits.

Discussion

5. DISCUSSION

At present in onion germplasm very limited variability is present especially for resistance against purple blotch disease and high TSS content (16 to 18%) which are most wanted characters in Indian onion germplasm. *kharif* onion cultivation in Maharashtra is a unique example not only in India but in the world. The onion bulb development under cloudy atmosphere and bulb harvesting under cool and short day climate is possible only due to wealth of genetic variability present in Maharashtra. Because of availability of extreme short day onion cultivar, *kharif* onion cultivation is possible in Maharashtra. Now-a-days, *kharif* onion cultivation has been taken in Gujarath and recently initiated in other states like Rajathan, UP, Bihar, etc. to some extent but only with varieties developed from Maharashtra e.g. cvs. N-53, Nasik Red Local, Baswant-780, etc. Thus, Maharashtra served as a center of genetic variability for onion and most of the Indian onion varieties developed from land races and natural segregants obtained particularly from area around Nasik district.

Eventhough, *kharif* onion cultivation in Maharashtra is an outstanding feature of nation but it gives low productivity (10-25 t/ha). The major causes of low productivity of *kharif* onion are excessive late rains and severe losses due to pest and disease; where purple blotch disease is a crucial factor. Normally, an epidemic incidence of purple blotch accompanied especially during rainy period, in such circumstances, chemical control becomes more difficult. Thus, incorporation of genetical resistance against purple blotch disease into improved onion cultivars is the only permanent solution to overcome the problem and hence breeding for disease resistance has top priority in onion. However, unavailability of source of resistance in *Allium cepa* and sexual incompatibility of *Allium fistulosum* which accompanied with dominant nature of bunching type (i.e. non-bulbous) growth; interspecific hybridization also could not prove effective in transferring disease resistance in onion germplasm (Brewester, 1990). In such particular context, mutation breeding can play vital role in developing novel genetic variability for disease resistance in onion and therefore, present investigation has been undertaken.

The mutation in red and white onions was induced with 10 kR radiation of gamma rays and disease resistance was reported in M_1 and M_2 generations at this Agricultural University (Pawar, 2003). In present studies, the M_3 and M_4 generations were evaluated and results obtained are discussed in this chapter herewith appropriate headings.

5.1 Screening of M_3 and M_4 generations of red and white onions against purple blotch disease

5.1.1 M_3 generation

The M_3 bulb crop was screened under artificial epiphytotic conditions during *kharif* 2003. Eventhough the mean values of M_3 generation of white and red onions recorded under moderate susceptible disease reaction (26.83% and 40.79% PDI respectively; Table 1); wide range variability was noticed in both onions (5-90% and 10-90% PDI, respectively; Table 1) which allowed selection of disease resistant (5-20% PDI) seed bulbs for growing M_3 seed crop. Thus, in white onion M_3 bulb crop, 3.56 per cent selection pressure was applied and 58 seed bulbs selected from 1625 plants. While in red onion M_3 bulb crop, 3.40 per cent selection pressure was applied and 40 seed bulbs selected from 1175 plants.

Normally, in onion the seed crop is more susceptible for disease occurrence than the bulb crop (Sidhu and Kaur, 2001) but to locate definite source of resistance, M_3 seed crop was also screened against blight disease under artificial epiphytotic conditions during *rabi* 2003-04. Thus, more disease intensity was observed in M_3 seed crop than that of M_3 bulb crop, which had adverse effect on viable seed development and production. However, an immunity against disease was not observed either in M_3 bulb or seed crops under artificial epiphytotic conditions. Nevertheless, irradiated M3 seed crop recorded lower mean disease intensity in white and red onion (14.05% and 16.35%, respectively) than their control (M_0) seed crops (32.50% and 40.50%, respectively) at 45 DAP crop stage.

5.1.4 M_4 generation

Twenty lines of white onion and forty lines of red onion were evaluated for M_4 generation. As natural disease occurrence was noticed, M_4 bulb crop was screened against purple blotch disease under natural field conditions. However, still an immunity was not observed either in M_4 bulb crop of red and white onion or control. But disease resistance was recorded by 15.8% and 2.2% M_4 plants of white and red onion, respectively at 90 DAT crop stage.

The results obtained in present investigations confirmed the findings of Pawar (2003), she noted that only 7.6% M_2 plants showed resistance to purple blotch disease while most of control plants showed susceptible to highly susceptible disease reaction.

The disease resistance observed in M_3 and M_4 generations, was probably due to dark green waxy leaves. Pawar (2003) reported that in M_2

generation, disease resistance was mainly associated with dark green waxy foliage containing double amount of total chlorophyll (95.8-108 mg/100 g). The exotic disease resistant onion cultivars also displayed waxy foliage containing antifungal compounds in waxy coating (Gupta *et al.* 1986). Therefore, it is of prime important to apply selection pressure in M_5 generation for dark green waxy foliage genotypes and should be screened against purple blotch disease. These resistant plants may provide basis for breeding for disease resistance.

Thus, this aspect of disease resistance in onion is of prime importance as so far no genetic resistance source is available for purple blotch disease in onion germplasm (Sidhu and Kaur, 2001).

5.2 Effect of irradiation on plant growth

In M_4 generation, the bulb crops of white and red onions were assessed for plant growth characters like plant height, number of leaves, premature bolting and natural topfall at harvest.

Data of Table 6 revealed that in white onion mean plant height was slightly higher while mean number of leaves were slightly lower than the control population. While reverse trend was noticed in red onions where mean plant height of M_4 generation was lower and mean number of leaves per plant was higher than control population. But in general non-significant differences were observed between two populations for average performance and variability. It means that plant growth of mutated plants in M_4 generation is about to normal.

Furthermore, slightly higher premature bolting was noticed in M_4 generation than the control population (Table 14) which may be improved in future selections. Nevertheless, mutation could not produce any improvement for natural topfall at bulb harvest of *kharif* onion.

5.3 Effect of irradiation on bulb development

5.3.1 In M_3 generation

Higher mean values for bulb weight (104.94 g), equatorial diameter (5.94 cm), polar diameter (5.13 cm) was recorded in M_3 generation of white onion than control plants. While in M_3 generation of red onion, slightly lower mean values were observed for bulb weight (98.97 g), equatorial diameter (5.91 g) and polar diameter (5.16 cm) than the control population.

It clearly indicated that M_3 generation showed nearly normal bulb development without any severe deleterious effect of mutation. Nevertheless, wide range variation was noticed in M_3 bulbs which can be utilized for further crop improvement programme.

5.3.2 In M_4 generation

For bulb development, similar trend was observed in M_4 generation that of M_3 generation. In white onion, M_4 generation recorded higher mean values in bulb diameters (equatorial 6.27 cm and polar 5.31 cm) than the control. However, in red onion, M_4 population was recorded slightly lower values than the control one.

Thus, it showed that recovery of mutated white onion was faster than the red onion. These observations are in agreement with Kataria and Singh (1989).

Nevertheless, M_4 bulb crop displayed wide range variability which provides basis for further selection. For M_4 white onion, bulb weight was ranged from 9 to 268 g and for M_4 red onion it ranged from 19-287 g. While for equatorial diameter of M_4 white onion it ranged from 3.0-8.4 cm and 2.9 to 8.5 cm for M_4 red onion. Thus, availability of wide range variability for bulb characters in M_4 generations offered broad base for further selections. Combination of morphological characters and more translocation of phtosynthate from leaves to bulb may be the reasons for variation in bulb diameter (Pawar, 2003).

For bulb weight, M_4 seven bulbs recorded higher bulb weight than population mean plus twice of standard deviation

value (175.07 g) and only one white M_4 bulb recorded higher bulb weight than its population mean plus its thrice standard deviation value (i.e. 212.33 g). While in M_4 red onion, seventeen M_4 bulbs recorded more bulb weight than its population mean plus twice of standard deviation value (171.38 g) while two bulbs have higher bulb weight than its population mean plus its thrice standard deviation value (i.e. 207.68 g).

Similarly, for character equatorial bulb diameter, two white M_4 genotypes recorded bigger diameter than its population mean plus twice of standard deviation value (i.e. 8.12 cm) while in case of red onion five M_4 genotypes were recorded bigger equatorial diameter than its population mean plus twice of standard deviation value (8.03 cm).

These results are in agreement with findings of Pawar (2003) as in her studies, she recorded wide range variability in M_1 and M_2 generations and offered selections for M_3 generation. Pawar (2003) further reported that at earlier generations (M_1 and M_2) equatorial bulb diameter and bulb weight was improved by 10 kR treatment. Similar results were obtained by Kirtane (2002) who reported that equatorial bulb diameter was improved (6.49 cm) at 8 kR while the bulb weight (81.04 g) at 10 kR treatment.

The significantly out yielded mutants for the character bulb yield were obtained in chemical mutagenesis with N-nitroso-N-ethylurea, ethyleimine, dimethyl sulphae and 1-4 bidiazoacetylabutane (Vodyanova and Tynymbaeva, 1979).

Tynymbaeva (1981) also reported mutants with very high bulb yield after treatment with 0.25 N-nitroso-N-ethylurea and 0.2% ethyleneimine.

Kirtane (2002) recorded shift of mean for average weight of onion bulbs towards positive direction in combination of SA and gamma radiation. The highest bulb weight (24.39 g) increase was obtained by combination treatment of 6 kR + 0.5% SA.

As such, size of bulbs is one of the important yield contributing character and pre-requisite for local and export markets. Thus, mutation breeding may be helpful for qualitative and quantitative bulb production.

5.4 Effect of irradiation on TSS content

Mutated plant population in M_3 and M_4 generations could not provide expected wide range for higher TSS content (16 to 18%). Nevertheless, the average performance and variability between mutated and control population was similar at M_3 and M_4 generation. Therefore, for creating variability in this trait, either mutation may be induced with high irradiation doses (15-25 kR) or combination of chemical and physical mutagenes should be tried in future research.

The results obtained in present investigation confirmed the findings of Pawar (2003); in her studies the average performance and variability for TSS content was almost similar among control (M_0) and irradiated populations (i.e. M_1 and M_2 generations). The range of TSS was also certainly lower than expectation.

The present results obtained for TSS content were also in agreement with Kataria and Singh (1990). They concluded that with 10 to 15 kR treatments, mean TSS content was ranged in between 13and 15%. In their report, the highest mean TSS content (13.07%) of white onion cultivar was recorded by 15 kR irradiation which ranged from 11.9 to 14.2%.

Thus, the higher range of TSS (i.e. 16 to 20%) particularly in white onion cultivar, which is pre-requisite for onion processing industry, could not be induced either in present investigation or earlier studies.

5.5 Effect of irradiation on seed crop

The M_3 seed crop was assessed during *rabi* 2003-04 under artificial epiphytotic condition for disease resistance. The reduction in seed parameters observed in M_3 seed crop was mainly due to combination of diseased conditions and deleterious effects of mutation.

In present study, the crop was artificially inoculated at early crop stage (i.e. at 30 DAT) which showed severe disease infection particularly at advance crop stage (at 100 DAP), when seed setting was in progress and resulted in physical damage of flower stalk particularly at where disease lesions were developed.

However, prominent deleterious effect of mutation was noticed particularly in white onions where 20 seed bulbs did not produce flower stalk and remained non-bloom. Also lower mean values were observed in M_3 plants for traits like number of umbels, number of seed and seed weight per bulb than the control population.

These results were in agreement with the findings of Pawar (2003), Kirtane (2002) and Kataria and Singh (1989a) who also noticed deleterious effect of mutation on seed crop in onion.

Summary & Conclusion

6. SUMMARY AND CONCLUSIONS

The cv. Baswant-780 is an improved red onion cultivar for *kharif* season while cv. Phule Safed is a white onion cultivar and due to high TSS content (12-13.5%) year round cultivation, it is especially suitable for onion processing. Purple blotch disease is the main hindrance in improving productivity of *kharif* onion and at present no source of resistance is available in onion germplasm (*Allium cepa* L.). Therefore, to induce novel genetic variability for disease resistance and higher TSS content in onion germplasm; mutation breeding was undertaken at this university. In present investigations, M_3 and M_4 generations of white and red onions were evaluated especially for disease resistance. However, observations were also recorded on plant growth and bulb characteristics.

The M_3 bulb crop was screened during *kharif* 2003 while M_3 seed crop during *rabi* 2003-04 and M_4 bulb crop was evaluated during *kharif* 2004. The results obtained from present studies are herewith summarized and concluded.

6.1 Summary

6.1.1 Evaluation of M_3 bulb crop

The 1625 and 1175 plant populations of M_3 white and red onion, respectively were evaluated along with control and screened against purple blotch disease under artificial epiphytotic conditions. The M_3 bulb crop displayed significant different average performance and variability than control population for the PDI of purple blotch disease. The M_3 generation induced genetic variability within range of resistant to moderately resistant disease reaction.

On the basis of disease resistance 58 and 40 seed bulbs were selected to advance M_3 seed crop. Thus 3.56 and 3.40 per cent selection pressure was applied on white and red M_3 bulb crop. Selected M_3 seed bulbs showed significant different average performance and variability for disease reaction than that of control population.

However, M_3 selected bulbs displayed non-significant difference for most of bulb characters (e.g. bulb weight, equatorial bulb diameter, bulb shape index and TSS content) than the control population. It means that M_3 seed bulbs were isogenic lines for their parental genotype except disease resistance.

6.1.2 Evaluation of M_3 seed crop

As a source of disease resistance, from M_3 bulb crop, 58 bulbs of white onion and 40 bulbs of red onion were selected as seed bulbs to raise seed crop during *rabi* 2003-04. The M_3 seed crop was also evaluated under artificial epiphytotic conditions. The combined adverse effect of artificial inoculation and irradiation was also observed on M_3 seed crop as most of the characters (Number of umbels, number of seeds and seed weight per bulb) were recorded lower mean values in both white and red onions than the control population. Thus, M_3 seed crop showed significant different average performance and variability than the M_0 (Control population) for the character PDI of purple blotch disease under artificial epiphytotic conditions.

Adverse effect on M_3 seed crop was more pronounced in white onions than red one. As out of 58 white M_3 seed plants, 20 remained un-bloom or non-bolting while 18 failed to produce viable seeds. On the contrary, all 40 red M_3 seed plants yielded viable seed.

6.1.3 Evaluation of M_4 bulb crop

A. White onion

The M_4 bulb crop was assessed during *kharif* 2004 constituted of 500 plant population from 20 genotypes.

While evaluation of M_4 bulb crop, significant different average performance and variability was recorded by M_4 plants than the control population for the characters PDI of purple blotch (at 60 and 90 DAT crop stages) and per cent number of disease affected leaves per plant under natural field conditions. So it was possible to apply effective selection pressure for disease resistance on M_4 seed bulbs for advancing M_5 generation. With the basis of population mean minus once of its standard deviation, the genetic source of resistance for purple blotch disease was identified from M_4 generation as 79 plants (15.8%) showed resistance to purple blotch disease while most of control plants displayed susceptible to highly susceptible disease reaction. It was important to note that disease resistance was associated with dark green waxy foliage.

While M_4 bulb crop showed similarity with control population for most of plant growth and bulb characters (e.g. bulb weight, bulb shape index, TSS content), while significant differences were observed for the character equatorial and polar bulb diameter along with neck thickness. However, M_4 generation displayed wider variability for important economic, yield contributing bulb characters like equatorial bulb diameter and bulb weight. Hence, selection pressure on seed bulbs was suggested for advancing M_5 generation with the basis of mean plus or minus twice or thrice of standard deviation value.

B. Red onion

The 1000 plant population of M_4 generation of red onion was raised from the seeds of 40 genotypes of M_3 seed bulbs.

Similar trend was observed for PDI of purple blotch disease, per cent number of disease affected leaves per plant as that of white onion. Thus, M_4 red onion population showed significantly different disease reaction for average performance and variability than control population. However, most of plant growth and bulb characteristics of both populations were similar with non-significant differences.

In comparison with susceptible to highly susceptible disease reaction of control population, 22 M_4 plants (2.2%) showed resistant disease reaction while 754 pants (75.4%) displayed moderate resistance.

6.2 Conclusion

On the basis of results obtained in present investigation following conclusions were made :

1. The mutated plants of red and white onions could not induce immunity against purple blotch disease either in M_3 or M_4 generation. However, genetic variability was certainly created for resistant to moderate resistant type of disease reaction, which can be effectively exploited for further crop improvement.

2. For plant growth and bulb characteristics, mutated populations in M_3 and M_4 generations showed similarly with control population, as non-significant differences were observed for most of horticultural traits between two populations (i.e. control and mutated). Thus, at M_4

generation adverse effects of mutation on crop growth and development was recovered about to normal.

3. Some adverse effects on M_3 seed crop was noticed but it was a combined effect of artificial inoculation of disease and mutation. However, most of the seed characters of M_3 seed crop recorded non-significant differences for variability and average performance than control seed crop which was also screened under artificial epiphytotic conditions. Thus, M_3 seed crop also displayed similarity with the control seed crop which express minimal adverse effects on seed crop.

   However, comparatively more abnormality was noticed in M_3 seed crop of white onion than M_3 seed crop of red onion.

4. Eventhough mutated population showed normal behaviour but it created wide range variability for important yield contributing characters and disease reaction, which can be exploited for further crop improvement.

   However, for improvement of certain vital characters of onion such as male sterility and high TSS content, etc. modified mutation breeding proramme should be undertaken along with high irradiation doses of physical mutagene or in combination of chemical and physical mutagenes.

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Appendices

8. APPENDIX

Appendix I (A). Observations of Selected M_3 white onion seed bulbs

Sr. No.	PDI of P.B. (%)		Weight of bulb (g)		Equatorial diameter (cm)		Polar diameter (cm)		BSI		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	10	25	107	66	6.0	5.0	5.0	4.4	1.20	1.13	11.0	10.8
2	15	25	115	127	6.0	7.0	5.0	5.4	1.20	1.29	10.4	11.4
3	15	40	125	112	6.0	7.0	6.2	5.5	0.96	1.27	11.4	10.2
4	10	30	112	73	6.0	4.5	6.3	4.0	0.95	1.12	9.2	13.0
5	20	40	115	733	6.6	4.2	5.0	4.8	1.32	0.85	12.2	9.8
6	20	35	100	95	6.2	5.0	5.2	4.4	1.19	1.13	15.0	11.2
7	10	30	141	141	7.0	7.0	6.5	4.2	1.07	1.66	12.4	12.8
8	15	50	133	84	6.2	6.0	6.4	3.5	0.96	1.71	11.8	12.4
9	10	35	92	103	5.5	6.5	5.5	4.5	1.00	1.44	13.0	10.4
10	20	15	104	75	5.8	4.5	5.5	4.0	1.05	1.12	11.0	9.6
11	15		106		5.5		5.0		1.1		11.4	
12	10		94		6.2		4.2		1.47		9.0	
13	8		156		6.8		7.0		0.92		7.0	
14	10		102		6.4		4.0		1.60		9.4	
15	15		116		6.2		4.5		1.37		10.2	
16	20		134		6.3		5.2		1.21		11.2	
17	15		132		6.5		5.8		1.12		11.2	
18	10		105		5.5		5.5		1.00		10.0	
19	10		130		6.0		6.5		0.90		10.0	
20	8		120		6.5		4.5		1.44		11.0	
21	10		144		7.0		6.5		1.07		10.8	
22	20		65		4.5		4.0		1.12		10.0	
23	15		185		6.0		3.5		1.71		11.0	
24	15		100		5.5		5.5		1.00		13.2	
25	20		87		6.5		4.3		1.51		11.2	
26	25		105		6.0		4.0		1.50		10.0	
27	10		134		7.0		5.0		1.40		10.4	
28	15		73		4		4.5		1.00		11.0	
29	15		85		5.0		4.5		1.11		11.2	
30	15		84		5.5		5.0		1.10		11.6	

Appendix-I (A) (Contd..)

Sr. No.	PDI of P.B. (%)		Weight of bulb (g)		Equatorial diameter (cm)		Polar diameter (cm)		BSI		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
31	10		66		5.0		4.4		1.13		12.0	
32	8		105		7.0		5.0		1.40		12.8	
33	10		95		5.5		6.5		0.84		12.0	
34	20		83		5.5		5.0		1.10		12.4	
35	15		70		5.2		5.0		1.04		12.0	
36	15		141		7.5		5.5		1.36		10.0	
37	20		127		7.0		5.4		1.29		10.4	
38	10		95		6.0		4.2		1.42		10.4	
39	15		100		5.6		5.2		1.07		11.0	
40	5		123		7.0		5.5		1.27		11.0	
41	10		103		6.5		5.0		1.30		9.0	
42	8		112		7.0		5.5		1.27		10.2	
43	15		80		6.0		5.0		1.20		11.0	
44	20		167		6.0		4.8		1.25		10.0	
45	10		126		6.0		4.5		1.33		10.4	
46	10		133		6.0		6.0		1.00		10.0	
47	10		109		5.5		7.0		0.78		11.0	
48	15		124		7.0		4.2		1.66		10.4	
49	20		46		6.2		6.3		0.98		10.6	
50	15		106		6.2		4.4		1.40		12.2	
51	10		106		6.0		4.8		1.25		11.0	
52	20		112		6.0		5.4		1.11		10.2	
53	15		88		5.5		5.0		1.10		11.8	
54	20		57		4.4		4.8		0.91		11.8	
55	15		59		5.0		4.4		1.13		10.0	
56	20		64		4.2		4.8		0.87		10.2	
57	15		85		4.0		4.0		1.00		10.2	
58	20		107		5.2		4.8		1.08		11.6	

Appendix I (B). Observations of Selected M_3 red onion seed bulbs

Sr. No.	PDI of P.B. (%)		Weight of bulb (g)		Equatorial diameter (cm)		Polar diameter (cm)		BSI		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	15	35	138	128	5.7	5.4	5.6	4.9	1.01	1.10	12.5	12.8
2	10	40	132	132	6.8	6.6	6.3	6.3	1.07	1.04	10.2	12.6
3	20	35	98	113	5.5	6.8	5.7	5.3	0.96	1.28	10.4	12.8
4	15	55	90	95	6.0	6.2	5.8	4.8	1.03	1.29	12.5	13.8
5	12	50	112	104	6.2	5.9	5.6	5.4	1.10	1.09	11.3	11.4
6	20	45	88	97	6.0	4.0	5.4	5.2	1.11	0.76	15.4	10.8
7	20	35	134	86	7.2	7.0	6.0	5.9	1.20	1.18	11.1	11.8
8	15	30	136	123	6.5	6.9	4.8	6.0	1.35	1.15	12.3	12.6
9	10	25	114	101	6.3	5.8	5.3	4.7	1.18	1.27	12.4	11.6
10	10	55	118	119	6.6	6.6	5.5	5.0	1.20	1.32	11.9	13.4
11	15		174		7.2		5.2		1.38		12.0	
12	20		88		5.5		4.5		1.22		11.9	
13	20		55		4.5		4.7		0.95		12.3	
14	10		68		5.7		4.4		1.29		10.4	
15	20		106		5.0		4.7		1.06		12.4	
16	15		62		7.0		4.5		1.55		11.8	
17	10		69		6.0		4.3		1.39		11.4	
18	12		76		5.0		4.5		1.11		13.0	
19	20		95		6.2		5.7		1.08		10.8	
20	20		73		5.4		5.3		1.01		10.9	
21	20		102		6.1		5.3		1.15		12.0	
22	15		66		6.3		4.5		1.40		12.2	
23	20		69		5.0		5.0		1.00		12.0	
24	15		118		6.1		4.9		1.24		12.2	
25	10		82		5.5		5.3		1.03		11.2	
26	20		108		6.6		4.9		1.34		12.0	
27	20		65		5.0		5.2		0.96		11.0	
28	10		85		5.5		5.4		1.01		11.0	
29	20		93		5.0		4.9		1.02		14.0	
30	15		62		5.0		5.4		0.92		11.8	
31	15		110		6.5		5.4		1.20		11.0	
32	20		121		6.4		4.8		1.33		11.6	
33	20		113		6.5		5.0		1.30		11.8	
34	20		123		6.0		5.1		1.17		11.2	
35	15		91		5.5		5.3		1.03		12.4	
36	15		102		6.5		5.1		1.27		12.0	
37	20		77		5.0		5.4		0.92		11.4	
38	20		153		7.4		5.2		1.42		11.2	
39	15		94		5.5		5.0		1.10		11.0	
40	20		69		5.0		5.5		0.90		11.0	

Appendix II(A). Observations of M_3 white onion seed crop

Sr. No.	PDI of leaf blight disease (%)		No. of umbels / bulb		No. of seed / bulb		Seed weight / bulb (g)		Selection for M4 bulb crop
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	
1	40	50	1	1	0	97	0.00	0.41	
2	20	70	2	2	136	103	0.59	0.43	√
3	20	75	1	1	217	106	0.94	0.44	
4	20	90	0	1	0	85	0.00	0.35	
5	30	85	0	4	0	93	0.00	0.36	
6	25	60	2	1	278	112	1.20	0.59	
7	35	65	0	1	0	92	0.00	0.37	
8	25	80	3	1	212	116	0.91	0.40	√
9	35	95	0	1	0	90	0.00	0.39	
10	30	100	3	2	210	80	0.91	0.30	√
11	50		2		0		0.00		
12	55		0		0		0.00		
13	40		0		0		0.00		
14	40		5		0		0.00		
15	40		3		0		0.00		
16	25		2		137		0.59		√
17	35		0		0		0.00		
18	30		1		126		0.54		√
19	30		3		198		0.86		√
20	40		0		0		0.00		
21	30		2		198		0.86		√
22	20		1		137		0.59		√
23	30		0		0		0.00		
24	40		2		0		0.00		
25	35		1		206		0.84		
26	30		1		113		0.49		√
27	40		0		0		0.00		
28	25		3		187		0.81		√
29	40		2		209		0.90		
30	30		2		195		0.84		√

Appendix II (A) (Contd…)

Sr. No.	PDI of leaf blight disease (%)		No. of umbels / bulb		No. of seed / bulb		Seed weight / bulb (g)		Selection for M4 bulb crop
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	
31	30		1		170		0.74		√
32	30		3		93		0.40		√
33	30		0		0		0.00		
34	45		1		293		1.27		
35	50		2		231		1.00		
36	35		0		0		0.00		
37	20		1		0		0.00		
38	35		0		0		0.00		
39	40		0		0		0.00		
40	25		2		107		0.46		√
41	35		0		0		0.00		
42	40		2		0		0.00		
43	30		3		187		0.81		√
44	35		1		0		0.00		
45	25		4		175		0.76		√
46	25		1		132		0.57		√
47	25		3		148		0.64		√
48	30		1		217		0.94		√
49	25		0		0		0.00		
50	55		3		0		0.00		
51	50		5		0		0.00		
52	20		1		136		0.59		
53	30		4		0		0.00		
54	36		4		209		0.90		√
55	40		0		0		0.00		
56	30		0		0		0.00		
57	35		0		0		0.00		
58	55		0		0		0.00		

Appendix II(B). Observations of M_3 red onion seed crop

Sr. No.	PDI of leaf blight disease (%)		No. of umbels / bulb		No. of seed / bulb		Seed weight / bulb (g)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	35	90	2	3	83	105	0.33	0.45
2	30	70	5	4	137	113	0.59	0.49
3	30	75	3	2	105	118	0.45	0.50
4	45	85	1	2	136	140	0.59	0.60
5	25	100	4	3	107	107	0.46	0.46
6	20	65	3	2	126	92	0.51	0.37
7	35	55	3	6	81	102	0.33	0.43
8	30	70	2	2	80	85	0.32	0.30
9	30	80	4	2	93	98	0.40	0.42
10	30	60	3	3	85	76	0.32	0.28
11	35		1		90		0.39	
12	35		2		91		0.40	
13	25		5		89		0.37	
14	40		3		80		0.30	
15	45		2		102		0.43	
16	30		4		92		0.37	
17	20		3		96		0.41	
18	25		2		87		0.37	
19	35		1		91		0.36	
20	20		5		106		0.42	
21	25		3		85		0.35	
22	40		2		88		0.37	
23	25		4		107		0.42	
24	30		2		127		0.55	
25	20		3		93		0.38	
26	35		1		82		0.33	
27	30		3		100		0.42	
28	25		5		79		0.29	
29	20		4		83		0.32	
30	35		3		93		0.40	
31	20		2		85		0.32	
32	35		1		97		0.41	
33	20		3		104		0.43	
34	25		3		96		0.40	
35	35		4		80		0.30	
36	20		5		90		0.39	
37	25		3		92		0.37	
38	30		4		96		0.42	
39	20		1		80		0.30	
40	25		2		99		0.42	

Appendix III (A-I). Observations of M4 white onion bulb crop

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	3	35	20	60	8	10	37.5	70.00	52.2	56.8
2	5	30	15	40	7	12	42.86	66.67	58.5	60.2
3	10	24	25	45	11	11	45.46	72.73	60.8	65.8
4	10	30	18	50	9	14	44.45	64.29	47.3	57.4
5	3	32	15	60	9	16	44.45	68.75	60.4	58.9
6	3	28	10	40	8	18	50.00	80.00	53.7	55.4
7	5	30	15	65	11	13	45.46	69.24	55.4	52.8
8	3	30	10	60	8	14	37.50	64.29	59.2	62.4
9	5	35	12	75	8	12	20	71.42	62.6	67.8
10	5	25	10	70	7	11	28.28	63.64	50.1	57.3
11	5	30	10	45	5	19	40.00	64.28	60.2	
12	2	30	12	55	7	14	42.86	57.15	58.7	
13	2	35	15	65	9	13	55.56	53.85	41.4	
14	8	40	20	80	11	11	45.46	63.64	59.6	
15	5	30	10	60	9	13	55.56	85.00	60.6	
16	12	35	20	70	10	13	50.00	72.73	64.6	
17	5	25	15	75	14	14	50.00	71.43	69.7	
18	8	28	15	45	9	13	44.45	69.24	74.6	
19	12	25	20	40	15	12	46.67	58.34	44.2	
20	3	30	20	50	8	8	37.50	60.00	59.1	
21	5	25	15	65	7	8	42.86	62.50	44.4	
22	10	30	25	55	11	9	45.46	55.56	61.2	
23	3	35	18	70	9	18	44.45	72.73	39.8	
24	3	35	15	55	9	8	44.44	75.00	42.4	
25	5	30	10	75	8	10	25.00	70.00	51.2	
26	5		20		11		45.46	67.29	52.4	
27	8		15		11		45.45		54.6	
28	3		10		8		50.00		44.7	
29	2		15		8		37.50		52.4	
30	2		10		6		50.00		62.1	
31	8		12		11		54.55		71.4	
32	12		20		10		20.00		64.6	
33	8		25		12		41.66		62.6	
34	7		15		9		44.45		54.6	
35	12		20		12		20.00		69.8	
36	8		25		9		55.56		64.7	
37	5		15		12		41.66		63.8	
38	12		35		11		54.55		59.7	
39	5		20		11		54.55		72.4	
40	12		30		15		46.67		75.6	
41	15		15		7		42.86		61.4	
42	5		35		18		33.34		64.8	
43	8		20		11		54.55		71.4	
44	3		12		10		37.50		54.8	
45	2		10		12		41.66		59.7	
46	2		15		9		44.45		57.8	
47	8		10		11		45.46		54.7	
48	12		12		6		25.00		64.2	
49	8		20		9		44.45		60.8	
50	7		25		12		58.34		58.4	

Appendix III (A-I). (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
51	3		10		6		33.34		71.4	
52	5		15		13		46.16		49.7	
53	5		15		9		43.45		79.4	
54	3		8		6		33.34		64.8	
55	3		10		6		33.34		66.2	
56	5		10		7		42.86		59.4	
57	12		15		11		36.37		63.1	
58	5		8		6		33.34		57.3	
59	8		10		14		42.86		54.2	
60	10		10		5		40.00		56.4	
61	8		8		8		37.50		72.4	
62	3		20		12		41.66		59.4	
63	5		10		6		33.34		62.3	
64	5		15		11		36.37		64.2	
65	3		10		12		41.66		54.6	
66	3		15		8		37.50		57.4	
67	5		15		5		40.00		52.2	
68	12		8		14		42.86		74.7	
69	5		10		6		33.34		57.3	
70	8		10		11		36.37		64.2	
71	10		15		6		33.34		80.4	
72	8		8		9		44.45		61.7	
73	3		10		13		46.16		59.3	
74	5		10		6		33.34		64.4	
75	5		8		13		46.16		72.5	
76	15		20		11		45.46		65.7	
77	8		25		5		40.00		63.4	
78	12		30		6		33.34		79.5	
79	3		10		13		46.15		68.4	
80	5		15		7		42.86		74.4	
81	3		10		13		30.76		69.9	
82	8		15		7		42.86		64.6	
83	2		10		6		16.67		62.2	
84	15		20		7		42.86		64.1	
85	5		15		9		55.56		52.2	
86	10		8		13		53.85		54.4	
87	8		10		8		50.00		63.9	
88	9		10		13		30.77		74.4	
89	18		15		14		28.57		62.7	
90	15		20		15		53.34		63.5	
91	8		20		9		44.45		49.7	
92	5		10		15		46.67		54.3	
93	5		10		9		44.44		59.5	
94	15		8		15		46.67		47.4	
95	15		20		8		37.50		62.2	
96	8		25		15		53.34		64.1	
97	12		30		8		20.00		59.2	
98	3		10		12		25.00		63.1	
99	5		15		7		42.90		68.8	
100	3		10		12		41.66		63.4	

Appendix-III (A-I) (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
101	15		20		24		46.16		67.5	
102	10		10		13		44.45		64.2	
103	8		8		9		45.45		79.4	
104	5		10		11		41.18		64.3	
105	10		15		17		36.37		70.5	
106	5		8		11		44.45		73.4	
107	12		10		9		42.86		67.3	
108	18		15		7		20.00		64.2	
109	3		20		12		37.50		72.1	
110	5		20		8		33.33		63.2	
111	5		30		15		33.34		64.3	
112	8		15		6		53.34		62.6	
113	15		10		15		33.33		61.4	
114	8		20		8		44.45		63.4	
115	10		25		18		50.00		73.3	
116	3		15		8		44.45		63.9	
117	5		20		9		42.11		59.2	
118	5		25		9		46.67		57.9	
119	12		15		15		46.16		64.3	
120	8		20		13		37.5		71.9	
121	8		20		8		42.86		79.8	
122	8		10		7		44.45		72.4	
123	5		8		9		37.50		73.8	
124	8		10		8		33.33		72.1	
125	15		15		15		37.50		58.6	
126	10		20		8		37.50		57.4	
127	8		25		20		35.00		59.2	
128	7		15		11		54.55		58.8	
129	3		30		15		53.34		64.4	
130	10		35		15		40.0		72.3	
131	8		15		9		55.56		69.4	
132	5		10		6		33.34		74.8	
133	5		15		11		54.55		63.3	
134	5		10		8		37.50		64.4	
135	5		25		19		47.37		72.3	
136	10		20		17		52.95		64.8	
137	12		40		7		42.86		72.6	
138	18		40		13		30.76		63.7	
139	22		20		15		.33.33		74.2	
140	10		15		15		46.67		62.1	
141	5		20		9		44.45		74.4	
142	5		10		12		33.33		72.1	
143	8		15		9		44.45		58.2	
144	5		20		8		37.50		64.7	
145	10		25		9		44.45		57.3	
146	10		15		11		54.55		58.7	
147	15		30		17		52.95		67.5	
148	10		35		15		33.33		64.2	
149	8		15		15		40.00		62.1	
150	5		10		11		54.55		70.5	

Appendix-III (A-I) (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
151	10		20		17		52.95		57.2	
152	10		25		15		46.67		59.5	
153	12		15		23		43.47		58.2	
154	5		25		16		56.25		62.4	
155	8		30		20		25.00		64.3	
156	10		35		19		47.37		61.2	
157	10		30		11		36.36		54.3	
158	5		20		14		42.85		63.2	
159	5		15		11		54.55		54.4	
160	10		10		9		44.45		56.3	
161	12		15		14		42.85		74.9	
162	8		10		11		45.46		69.8	
163	8		15		13		46.15		68.4	
164	12		15		17		47.05		58.5	
165	10		20		11		36.36		67.5	
166	10		20		9		44.45		67.9	
167	12		25		16		43.75		68.2	
168	5		15		20		20.00		65.2	
169	8		25		14		42.85		57.7	
170	10		30		15		46.67		62.1	
171	10		35		23		43.47		58.4	
172	5		30		11		36.36		54.2	
173	5		20		9		44.45		64.3	
174	10		15		11		45.46		62.2	
175	12		10		13		38.47		74.4	
176	8		25		17		41.17		55.5	
177	15		15		14		35.71		57.4	
178	8		20		9		55.56		62.2	
179	8		15		10		40.00		64.9	
180	15		10		7		42.86		58.9	
181	12		8		7		42.86		73.4	
182	10		10		14		50.00		76.2	
183	12		15		9		44.45		63.5	
184	8		20		12		41.67		62.1	
185	3		15		9		55.56		72	
186	5		10		6		20.00		63.2	
187	8		10		7		42.86		72.4	
188	10		15		14		25.00		63.8	
189	3		20		14		42.86		64.7	
190	15		35		16		56.25		62.5	
191	15		30		13		53.85		71.4	
192	15		25		15		53.34		63.5	
193	20		15		15		46.67		57.3	
194	15		20		7		42.86		64.8	
195	18		25		14		50.00		72.3	
196	10		15		5		20.00		74.8	
197	12		20		6		50.00		70.5	
198	10		15		14		42.86		57.8	
199	12		10		16		56.25		71.8	
200	10		8		10		40.00		65.2	

Appendix-III (A-I) (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
201	8		20		10		50.00			
202	5		15		10		50.00			
203	12		15		7		42.86			
204	8		20		17		41.18			
205	10		30		23		56.53			
206	12		35		15		53.34			
207	3		10		10		30.00			
208	12		25		11		54.55			
209	15		30		11		45.54			
210	15		25		19		36.84			
211	15		20		17		29.41			
212	12		20		10		50.00			
213	10		35		14		28.57			
214	20		25		10		40.00			
215	20		20		13		46.16			
216	18		15		20		20.00			
217	15		20		10		50.00			
218	10		20		11		54.55			
219	8		15		10		50.00			
220	5		15		10		20.00			
221	10		20		11		54.55			
222	10		30		17		29.41			
223	10		35		14		28.53			
224	8		10		10		80.00			
225	15		25		10		50.00			
226	10		20		11		54.55			
227	5		20		18		44.45			
228	7		15		11		63.64			
229	5		20		10		40.00			
230	8		25		13		53.85			
231	8		15		11		45.46			
232	8		30		11		54.55			
233	12		25		10		50.00			
234	10		20		12		66.67			
235	12		15		13		61.54			
236	15		20		13		61.54			
237	10		15		21		52.39			
238	15		20		15		40.00			
239	18		20		9		44.45			
240	12		15		11		54.55			
241	15		20		10		50.00			
242	18		25		12		33.33			
243	15		15		13		61.54			
244	8		30		13		53.85			
245	5		25		11		36.36			
246	12		20		18		44.45			
247	8		15		11		54.55			
248	10		20		12		66.67			
249	12		15		13		61.54			
250	3		17		21		52.39			

Appendix-III (A-I) (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
251	2		20		6		33.34			
252	12		15		5		20.00			
253	5		20		11		54.55			
254	5		15		9		44.45			
255	10		20		14		50.00			
256	5		25		14		50.00			
257	8		15		12		33.33			
258	5		30		10		50.00			
259	5		35		11		54.55			
260	8		20		10		50.00			
261	5		15		6		33.34			
262	5		20		6		33.34			
263	8		15		10		50.00			
264	8		20		13		61.54			
265	3		20		7		42.86			
266	5		15		10		60.00			
267	5		20		9		55.56			
268	8		25		11		54.55			
269	8		15		12		41.66			
270	8		30		12		50.00			
271	5		25		12		41.67			
272	10		20		6		33.34			
273	5		15		6		33.34			
274	7		20		14		50.00			
275	5		15		12		66.67			
276	15		25		14		28.57			
277	10		20		10		50.00			
278	8		20		10		25.00			
279	12		15		15		53.34			
280	5		25		10		40.00			
281	8		25		14		50.00			
282	5		30		10		40.00			
283	5		10		7		42.86			
284	10		15		11		36.36			
285	8		20		11		54.55			
286	5		15		8		37.50			
287	5		20		6		33.34			
288	10		25		9		20.00			
289	10		20		11		54.55			
290	8		25		14		28.57			
291	5		20		10		50.00			
292	5		20		10		40.00			
293	10		25		14		25.00			
294	8		15		10		60.00			
295	15		25		7		47.86			
296	10		30		11		36.36			
297	8		10		11		54 55			
298	12		15		6		33.34			
299	5		20		11		54.55			
300	8		30		11		42.86			

Appendix-III (A-I) (Contd…)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
301	5		20		12		25.00			
302	8		15		8		50.00			
303	8		20		10		33.34			
304	8		15		12		33.33			
305	10		10		12		58.34			
306	5		25		7		42.86			
307	5		20		11		36.36			
308	5		15		10		40.00			
309	5		10		18		50.00			
310	5		10		9		44.45			
311	8		8		8		37.50			
312	8		20		10		40.00			
313	5		25		8		50.00			
314	10		10		9		55.58			
315	3		15		9		55.56			
316	10		25		9		55.56			
317	5		25		10		50.00			
318	5		15		11		54.55			
319	8		20		10		50.00			
320	5		20		13		38.46			
321	5		15		9		55.56			
322	8		10		12		50.00			
323	8		25		10		40.00			
324	10		20		9		44.45			
325	5		15		8		37.50			
326	12		20		13		53.85			
327	5		15		11		63.64			
328	8		15		12		58.34			
329	10		25		14		50.00			
330	8		20		12		58.34			
331	5		15		7		57 15			
332	10		15		10		60.00			
333	8		20		12		58.34			
334	8		25		11		63.64			
335	5		15		5		40.00			
336	10		20		9		55.56			
337	10		10		6		50.00			
338	15		20		11		27.27			
339	5		25		14		57.15			
340	8		30		13		46.16			
341	5		10		11		54 55			
342	5		15		16		25.00			
343	8		20		13		53.85			
344	10		25		12		50.00			
345	10		15		15		46 67			
346	12		25		10		60.00			
347	5		15		7		28.58			
348	5		10		5		40.00			
349	12		10		13		53.85			
350	5		15		11		36.36			

Appendix-III (A-I) (Contd…)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
351	8		25		12		50.00			
352	10		20		5		20.00			
353	5		15		13		30 76			
354	10		30		12		33.33			
355	12		25		8		50.00			
356	10		15		9		44.45			
357	5		20		12		58.34			
358	12		20		11		63.64			
359	5		25		11		54.55			
360	10		15		7		28.58			
361	8		20		12		50.00			
362	10		25		5		20.00			
363	8		20		12		66.67			
364	10		25		8		50.00			
365	8		20		9		44 45			
366	10		15		12		58.34			
367	10		30		11		63.64			
368	5		20		11		54 55			
369	5		20		7		28.58			
370	8		25		12		50.00			
371	8		15		5		20.00			
372	10		20		11		27.27			
373	5		25		16		50.00			
374	8		20		10		60.00			
375	12		15		12		50.00			
376	8		20		11		63.64			
377.	5		20		9		55.56			
378	5		15		9		55.56			
379	5		25		16		62.50			
380	12		30		13		61.54			
381	10		20		21		52.39			
382	10		25		13		46.16			
383	5		30		18		61.12			
384	5		35		11		18.18			
385	10		25		8		62.50			
386	5		30		11		63.64			
387	8		20		17		45 46			
388	5		25		10		40.00			
389	8		25		14		57.15			
390	8		20		14		42.86			
391	5		35		11		27.27			
392	5		40		9		55.56			
393	10		15		13		53.85			
394	12		20		11		45 45			
395	8		15		11		42.86			
396	5		20		17		52.95			
397	5		20		14		42.86			
398	5		15		13		61.54			
399	12		25		16		62.50			
400	10		30		13		30.77			

Appendix-III (A-I) (Contd…)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
401	12		20		11		54.55			
402	8		15		9		44 45			
403	15		25		14		64.29			
404	5		30		7		42 86			
405	8		25		13		53.85			
406	8		30		13		30.76			
407	5		25		10		20.00			
408	16		35		20		35 00			
409	5		20		11		63.64			
410	8		15		12		66.67			
411	5		20		8		50 00			
412	12		20		11		54.55			
413	8		15		14		64.19			
414	8		25		13		69 24			
415	10		30		13		46.16			
416	10		25		11		63.64			
417	8		35		14		57.15			
418	10		25		18		51.12			
419	8		20		9		55.56			
420	12		15		7		42.86			
421	12		20		13		53.85			
422	8		15		10		50 00			
423	10		12		20		65.00			
424	12		10		9		44.45			
425	8		15		11		54.55			
426	5		25		13		53.85			
427	8		30		12		33.33			
428	12		25		8		50.00			
429	8		25		9		55 56			
430	5		20		10		60.00			
431	5		35		7		52.86			
432	10		40		12		50.00			
433	12		25		5		20.00			
434	5		30		25		64.29			
435	15		20		12		66.67			
436	8		45		9		55.56			
437	5		20		9		55.56			
438	8		25		20		50.00			
439	12		15		10		60.00			
440	5		25		18		66.67			
441	5		30		13		53.85			
442	8		25		12		66.67			
443	8		20		8		50.00			
444	5		35		13		53.85			
445	8		25		13		69 24			
446	8		30		20		65.00			
447	10		20		12		66.67			
448	12		15		8		50.00			
449	5		15		14		64.29			
450	8		10		13		46.16			

Appendix-III (A-I) (Contd...)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/plant 90 DAT		Per cent no. of disease affected leaves/plant		Plant height	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
451	5		20		15		66.67			
452	15		15		14		64.29			
453	15		20		11		63.64			
454	5		15		7		28.58			
455	18		25		13		53.85			
456	8		20		13		46.16			
457	12		30		16		56.25			
458	5		25		19		36.84			
459	15		30		17		64.71			
460	8		20		10		40.00			
461	10		25		13		38.46			
462	8		35		13		53 85			
463	5		30		7		42.86			
464	5		20		14		66.67			
465	8		15		8		50.00			
466	8		20		9		55.56			
467	10		15		10		60 00			
468	12		25		13		30.76			
469	15		20		20		65.00			
470	15		25		13		46.15			
471	12		35		11		63.64			
472	8		40		7		42.86			
473	10		15		5		20.00			
474	8		10		12		33.33			
475	12		15		13		53.85			
476	5		20		11		36 36			
477	8		20		10		50 00			
478	10		25		14		57.15			
479	12		25		10		40.00			
480	8		15		10		25.00			
481	10		20		5		20.00			
482	5		25		9		55.56			
483	5		15		7		42 86			
484	5		20		9		33 34			
485	10		20		7		57.15			
486	10		25		5		40.00			
487	8		25		6		25.00			
488	12		20		6		33.33			
489	5		25		7		57.15			
490	5		30		9		33.33			
491	15		25		5		40.00			
492	10		30		9		55.56			
493	8		30		9		44.45			
494	8		20		10		60.00			
495	5		20		8		50.00			
496	8		25		7		57.15			
497	10		20		9		33.34			
498	12		15		10		60.00			
499	8		10		13		61.54			
500	10		15		13		53.85			

Appendix III(A-II). Observations of M_4 white onion bulb crop

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	5.0	6.0	4.7	5.0	1.06	1.20	2.1	2.3	141	195	13.0	12.0
2	6.8	4.5	6.6	3.5	1.03	1 28	2.4	2 7	127	80	10.0	13 0
3	6.0	6.0	5.8	4.5	1.03	1 33	3.1	2.1	101	90	12.4	12.0
4	6.5	5.5	6.1	4.5	1.06	1.22	3.0	1.0	84	105	13.2	13.0
5	5.4	6.0	5.5	5 1	0.98	1.17	2.0	1.5	102	187	12.0	12 2
6	5.6	6 3	5.1	4.7	1.09	1.34	2.1	1.9	78	190	13.0	13.0
7	5.5	6.0	5.4	4.6	1.01	1.30	2.3	2.0	110	92	11.0	14.0
8	6.0	5.1	5.7	4.1	1.05	1.24	2.5	1.3	80	83	13.0	14 2
9	5.5	5.5	5.5	4.9	1.00	1.12	1.9	2.0	98	125	10.2	11.0
10	6.0	5.5	5.1	4.5	1.17	1.22	2.5	1.0	79	144	13.2	14.0
11	5.6		5.8		96.00		2.5		134		13.0	
12	6.0		5.7		1.05		2.6		106		13.0	
13	5.2		5.0		1.04		2.5		120		11.0	
14	4.5		4.8		0.93		2.3		91		13.0	
15	7.5		6.4		1.17		3.4		131		14.0	
16	6.5		4.9		1.32		2.8		121		13.2	
17	7.0		5.5		1.27		2.5		84		12.2	
18	5.0		4.5		1.11		2.5		99		13.4	
19	6.7		5.7		1.17		2.6		98		13.0	
20	5.5		5.5		1.00		2.5		48		12.4	
21	7.2		5.5		1.30		2.5		154		13.0	
22	7.5		5.0		1 50		3.1		113		12.0	
23	4.2		3.9		1.07		2.2		127		14.0	
24	5.4		4.5		1.20		2.3		79		12.2	
25	6.5		5.9		1.32		2.5		151		12.8	
26	3.4		4.8		7.00		1.4		56		12.0	
27	4.1		3.9		1.05		2.1		44		12.0	
28	5.7		5.4		1.05		2.0		55		13.0	
29	4.5		4.2		1.07		2.0		31		13.8	
30	5 0		4.9		1.02		1.5		28		13.0	
31	6.4		5.6		1 14		2.0		125		12.0	
32	7 0		7.5		0.93		2.0		188		13.0	
33	6.9		5.8		1.18		2 2		133		13.0	
34	7.0		5 5		1.27		2.8		22		13.4	
35	8 0		5 6		1.42		2.0		104		12.0	
36	6.0		4 7		1.27		2.7		131		14.0	
37	4.7		4.0		1.17		2.0		9		12.0	
38	7.0		6 0		1.16		2.5		79		13.4	
39	6.5		5.8		1.12		1.7		63		13.0	
40	7.0		6 0		1.16		2.5		132		12.0	
41	3.0		4.0		0.75		2.0		109		14.0	
42	7.0		5.0		1.40		2.6		79		11.0	
43	5.4		4.9		1.10		2.5		70		13.6	
44	5.0		5.2		0.96		2.0		125		11.0	
45	5.4		5.0		1.08		1.8		108		14.0	
46	6.3		5.5		1.14		2.0		73		13.0	
47	6.2		5.0		1.24		2.0		102		13.0	
48	5.9		4.5		1.31		1.3		72		14.0	
49	6 0		5.4		1.11		2.7		60		13.2	
50	5 5		4 5		1.22		1.7		131		13.0	

Appendix III (A-II) (Contd....)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
51	6.3		5.8		1.08		2.4		114		14.2	
52	7.0		4.5		1.55		1.6		107		14.0	
53	6.5		4.5		1.44		2.1		109		11.0	
54	5.0		4.8		1.04		2.3		83		12.0	
55	5.5		5.0		1.10		2.5		117		13.0	
56	6.5		5.5		1.18		3.1		87		12.8	
57	6.5		5.5		1.18		3.0		96		12.0	
58	5.9		5.4		1.09		1.0		79		12.0	
59	6.5		5.1		1.27		2.2		107		12.2	
60	6.0		5.5		1.09		1.4		132		11.0	
61	6.0		5.0		1.20		1.6		155		13.4	
62	7.0		5.5		1.27		1.5		102		13.2	
63	7.0		5.1		1.37		2.5		133		13.6	
64	7.5		5.6		1.33		1.2		134		13.0	
65	6.5		5.6		0.98		2.7		107		13.0	
66	6.0		5.5		1.09		2.5		93		14.0	
67	6.2		5.6		1.10		2.4		128		12.8	
68	5.8		4.9		0.84		2.5		88		13.0	
69	6.5		5.6		1.16		0.6		79		12.6	
70	7.5		5.6		1.33		1.5		107		13.0	
71	8.2		6.0		1.36		1.5		127		11.0	
72	6.2		5.3		1.19		3.0		151		14.0	
73	6.5		6.5		1.00		1.6		91		13.0	
74	6.0		5.9		1.01		2.3		100		13.0	
75	6.7		5.7		1.17		2.7		138		13.2	
76	5.5		5.0		1.30		1.7		200		12.0	
77	7.2		4.9		1.46		2.5		268		12.0	
78	5.0		5.5		0.90		2.0		151		14.8	
79	5.8		5.4		1.07		1.7		105		14.0	
80	7.8		5.5		1.41		2.2		95		12.0	
81	6.0		5.0		1.20		1.8		143		13.0	
82	6.4		5.5		1.16		1.5		175		14.0	
83	6.0		6.3		0.95		2.5		120		13.0	
84	6.5		5.0		1.30		2.8		115		13.2	
85	7.0		5.8		1.20		2.5		98		14.0	
86	6.0		4.1		1.46		1.7		92		11.0	
87	5.5		4.9		1.12		2.0		99		13.0	
88	6.9		6.0		1.15		1.7		87		14.0	
89	7.5		6.3		1.19		2.5		66		14.0	
90	8.4		5.5		1.52		1.5		74		11.0	
91	7.3		6.7		1.08		2.2		106		13.0	
92	6.8		6.1		1.11		2.6		134		12.0	
93	5.0		5.5		0.90		2.9		154		14.0	
94	7.0		6.0		1.16		2.0		95		13.2	
95	5.7		5.0		1.14		3.0		159		13.8	
96	5.0		5.5		0.90		2.5		59		13.0	
97	7.3		6.7		1.08		2.2		99		12.8	
98	6.8		6.1		1.11		2.6		98		14.0	
99	5.0		5.5		0.90		2.9		66		14.2	
100	7.0		6.0		1.16		2.0		72		13.4	

Appendix III (A-II) (Contd....)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
101	4.4		4.5		0.97		2.5		148		13 4	
102	6.2		5.5		1.12		2.0		57		14.0	
103	6.3		6.2		1.01		2.4		117		15.0	
104	7.0		6.4		1.09		2.0		128		14.0	
105	7.0		6 2		1.12		2.0		111		13.6	
106	7.3		6.4		1.14		2.2		154		12.0	
107	5.5		5.1		1.07		2.3		133		13.0	
108	5.5		5.5		1.00		2.4		128		13.2	
109	6.8		5.3		1.28		2.2		100		13.0	
110	7.2		6.0		1.20		1.7		110		13.0	
111	6.0		5.3		1.13		2.2		98		15.0	
112	6.5		5.9		1.10		2.2		99		13.4	
113	6.5		5.7		1.27		2.1		112		14.0	
114	6.8		5.1		1.33		1.5		69		14.0	
115	7.2		5.9		1 22		3.0		98		13.6	
116	6.5		5.0		1.30		0.9		130		13.4	
117	6.0		5.3		1.13		2.4		116		13.0	
118	6.5		5.9		1.10		2.2		118		14.0	
119	6.5		5.1		1.27		2.1		119		12.8	
120	6.5		5.0		1.30		3.0		30		12.0	
121	6.5		5.5		1.18		2.5		94		14.0	
122	6.5		5.0		1.30		2.6		113		13.0	
123	6.5		4.8		1.35		2.0		89		14.0	
124	6.7		5.2		1.28		2.1		95		14.0	
125	6.0		6.1		0 98		1.9		106		13.0	
126	7.5		5.0		1.50		2.0		126		14.8	
127	7.0		5.0		1.40		2.0		85		14.0	
128	5.4		4.5		1.20		2.0		114		14.0	
129	7.1		5.5		1.29		1.6		85		14 2	
130	6.4		5.4		1.18		2.0		131		13 0	
131	5 8		5.2		1.11		2.5		101		13.0	
132	7.0		6.3		1.11		2.4		129		13.2	
133	6.0		6.0		1.00		2.5		71		13.0	
134	5.5		5.2		1.05		2.0		72		13.2	
135	5.5		5.3		1.03		2.9		62		14.0	
136	5.0		4.5		1 11		2.5		76		13.0	
137	4.5		5.6		0.80		2.0		76		13.0	
138	6.0		5.9		1.01		1.5		58		14.0	
139	6 3		5.2		1.21		1.9		45		12.0	
140	6.0		5.3		1.13		3.7		46		12.0	
141	6.0		5.5		1.09		2.5		187		13.4	
142	6.4		5.1		1.25		2.0		126		13.0	
143	8.0		5.5		1.45		1.7		66		13.0	
144	7.0		5.0		1.40		2.0		76		14.0	
145	5.9		4.3		1.37		2.1		104		14 0	
146	5.6		5.0		1.12		2.4		116		14.6	
147	7.1		5.9		1 20		2 0		98		14.0	
148	6.0		5.5		1 09		2.5		58		12 8	
149	6.4		5.1		1.25		2 0		45		12.2	
150	8 0		5.5		1 45		1.7		90		13 0	

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Appendix III (A-II) (Contd....)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
151	6.5		4.3		1.51		1.2		98		14.0	
152	7.2		5.0		1.44		1.9		113		14.4	
153	6.9		4.9		1.40		2.0		85		13.0	
154	7.2		5.3		1.35		2.0		118		13.2	
155	7.5		4.8		1.56		2.3		92		12.0	
156	6.5		4.0		1.62		1.0		89		13.0	
157	6.5		4.8		1.35		1.5		83		12.0	
158	6.9		5.9		1.16		2.0		116		12.0	
159	6.4		4.4		1.45		2.0		75		11.0	
160	5.0		4.8		1.11		2.6		46		12.0	
161	6.5		5.5		1.18		2.7		109		14.0	
162	7.0		5.4		1.29		2.8		129		13.0	
163	7.9		6.3		1.25		2.5		79		9.8	
164	6.5		5.5		1.18		2.2		67		12.0	
165	6.1		5.0		1.22		2.0		111		14.0	
166	5.7		5.3		1.07		2.5		152		14.8	
167	6.5		5.5		1.18		2.7		129		12.0	
168	6.1		5.0		1.22		2.8		109		13.2	
169	7.9		6.3		1.25		2.2		67		13.0	
170	6.5		5.5		1.18		2.0		79		12.0	
171	6.0		4.9		1.22		2.5		173		14.0	
172	8.0		5.2		1.53		2.9		120		14.2	
173	7.3		5.5		1.32		2.2		87		12.0	
174	6.0		5.0		1.20		2.8		95		15.0	
175	7.7		5.4		1.42		3.0		80		14.4	
176	6.6		4.5		1.46		1.2		86		13.0	
177	6.5		4.5		1.44		2.0		80		14.0	
178	6.2		4.0		1.55		1.0		90		12.0	
179	6.5		4.5		1.44		2.5		155		13.4	
180	6.0		4.9		1.22		2.8		181		13.0	
181	7.6		4.4		1.68		1.5		110		13.0	
182	5.0		5.5		0.90		1.8		52		14.0	
183	6.8		6.0		1.13		2.5		116		14.2	
184	7.5		6.4		1.17		2.5		24		14.8	
185	4.4		4.1		1.07		2.8		34		14.6	
186	6.5		4.5		1.44		1.5		125		14.2	
187	7.3		5.3		1.37		1.6		85		12.0	
188	7.4		4.4		1.68		1.5		57		13.0	
189	7.5		6.4		1.17		2.5		155		12.8	
190	6.5		4.5		1.44		2.5		181		12.6	
191	5.5		6.0		0.91		0.7		91		15.0	
192	5.0		5.0		1.00		1.9		105		12.0	
193	5.0		6.0		0.83		1.1		70		14.0	
194	7.0		5.0		1.40		2.0		62		14.4	
195	5.4		4.9		1.10		1.5		121		14.0	
196	5.5		4.4		1.25		2.6		70		12.0	
197	6.5		5.5		1.18		2.0		56		13.0	
198	5.5		5.0		1.10		2.7		57		13.0	
199	6.2		5.7		1.08		1.9		58		12.0	
200	3.3		4.3		0.76		2.4		33		14.0	

Appendix III (B-I). Observations of M_4 bulb crop of red onion

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	10	20	20	40	13	11	53.85	54.55	70.4	60.7
2	8	35	25	35	16	20	20.00	60.00	62.8	64.3
3	5	35	15	50	8	16	5.000	56.25	55.7	58.7
4	10	30	25	60	14	14	35.71	57.15	68.7	62.5
5	12	25	20	65	14	9	50.00	55.56	61.4	65.8
6	4	40	7	55	7	11	42.86	54.55	56 3	67.3
7	10	45	20	90	16	8	56.25	37.50	42.5	56.5
8	5	40	6	80	8	11	37.50	72.73	56.6	59.3
9	4	35	7	75	7	16	42.86	62.50	58.4	64.2
10	8	35	12	65	7	10	42.86	60.00	54.2	66.9
11	10	25	10	55	7	21	42.86	63.64	58.4	
12	8	45	15	95	11	12	36.36	58.34	74.2	
13	5	40	15	75	11	10	54.55	50.00	72.4	
14	10	30	20	60	7	10	42.86	60.00	62.1	
15	5	30	20	55	13	16	53.85	56.25	54.8	
16	10	25	25	45	11	18	54.55	62.50	57.3	
17	8	35	20	50	9	11	55.56	72.73	61.8	
18	12	40	15	65	10	10	50.00	70.00	66.5	
19	10	25	25	70	18	20	44.45	60.00	64.8	
20	8	25	20	65	14	9	50.00	42.86	58.2	
21	5	40	20	75	8	10	37.50	60.00	59.6	
22	10	35	15	60	7	15	42.86	62.50	64.8	
23	12	40	12	50	14	11	50.00	63.64	60.3	
24	8	40	12	55	7	18	42.86	60.00	62.1	
25	10	45	20	100	13	12	53.85	58.34	57.4	
26	5		7		9		44.45		56.7	
27	8		10		13		53.85		63.3	
28	8		15		14		50.00		69.4	
29	8		20		18		50.00		52.2	
30	10		25		16		50.00		58.4	
31	10		15		19		52.64		58.5	
32	8		20		18		38.88		64.4	
33	5		15		14		57.15		62.4	
34	8		20		8		20.00		54.3	
35	10		20		8		37.50		53.8	
36	8		15		10		60.00		52.7	
37	5		6		11		54.54		51.9	
38	5		12		14		25.00		58.2	
39	5		15		11		54.55		49.7	
40	15		20		9		55.55		63.4	
41	10		25		13		53.85		64.4	
42	10		30		13		53.84		58.8	
43	12		20		14		21.42		63.8	
44	15		15		14		20.00		55.7	
45	10		10		10		50.00		54.2	
46	10		15		13		53.85		59.1	
47	5		20		9		55.55		62.8	
48	8		25		19		42.85		58.2	
49	8		20		14		38.88		53.7	
50	10		15		18		38.88		57.4	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
51	5		20		13		53.84		65.5	
52	5		15		15		40.00		64.8	
53	18		20		17		41.17		63.7	
54	15		20		18		55.55		60.1	
55	10		15		14		35.71		65.6	
56	8		20		12		33.33		71.2	
57	8		15		11		36.36		70.8	
58	8		15		12		20.00		59.7	
59	8		20		9		55.55		57.4	
60	12		20		17		52.95		54.8	
61	15		20		8		12.50		59.7	
62	18		20		12		58.34		58.4	
63	8		25		13		53.85		54.7	
64	15		15		13		53.85		49.2	
65	15		20		8		50.00		51.4	
66	3		15		15		53.34		57.3	
67	18		20		13		53.85		60.3	
68	10		20		13		53.84		70.2	
69	12		15		15		40.00		63 8	
70	5		25		14		35.71		65.7	
71	18		25		12		33.33		65.3	
72	8		20		11		36.36		67.7	
73	15		15		12		20.00		59.8	
74	15		15		9		55.55		60	
75	3		25		11		36.36		63.4	
76	10		15		11		54.54		62.9	
77	15		10		11		54.55		57.2	
78	5		6		15		53.34		70.2	
79	15		10		26		53.84		68.1	
80	10		15		17		35.29		66 3	
81	12		20		23		52.17		64 3	
82	15		25		12		20.00		59.2	
83	10		15		16		37.50		58.1	
84	18		25		16		25.00		56 2	
85	15		20		13		53.85		50.5	
86	10		15		9		55.56		54.8	
87	8		20		18		33.33		53.2	
88	22		25		13		53.85		57.6	
89	12		30		15		20.00		53.2	
90	10		15		11		54.54		55.4	
91	10		20		14		57.15		55.3	
92	16		15		13		53.84		49.7	
93	18		30		13		53.85		53.4	
94	8		25		13		38.46		65 3	
95	10		20		13		53.85		55 1	
96	15		20		12		50.00		58.4	
97	10		15		11		54.54		60 3	
98	15		25		15		53.34		63.9	
99	10		30		16		37.50		59.5	
100	12		25		12		20.00		64.3	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
101	5		15		14		50.00		60.5	
102	6		7		9		66.66		58.2	
103	10		15		18		50.00		59.4	
104	12		20		12		58.33		56.7	
105	10		25		19		36.84		50.5	
106	8		20		10		30.00		57.3	
107	5		20		11		54.54		64.4	
108	10		15		11		54.55		66.7	
109	12		25		13		53.85		60.6	
110	8		25		10		30.00		59.8	
111	8		20		11		54.55		65.3	
112	5		15		11		45.80		67.8	
113	10		25		11		36.36		64.6	
114	12		20		15		26.66		60.3	
115	5		15		15		40.00		59.2	
116	8		15		19		52.64		49.5	
117	15		25		13		53.33		58.3	
118	12		25		15		45.33		60.1	
119	8		15		23		52.18		64.3	
120	5		20		18		55.55		57.2	
121	8		25		14		25.00		69.3	
122	10		25		12		58.33		50.1	
123	12		15		11		54.54		52.3	
124	10		20		10		30.00		55.4	
125	8		15		15		40.00		60.8	
126	12		10		17		41.17		58.3	
127	8		10		9		55.55		65.4	
128	5		7		10		60.00		53.1	
129	8		12		6		66.66		57.5	
130	5		15		13		53.84		63.2	
131	15		15		10		60.00		52.1	
132	10		15		10		60.00		60.4	
133	8		25		19		52.63		55.3	
134	10		20		18		25.00		60.9	
135	20		30		18		55.55		45.3	
136	8		20		15		53.33		50.3	
137	8		20		24		66.66		47.8	
138	12		25		10		50.00		46.3	
139	15		20		12		41.66		49.2	
140	18		20		15		33.33		63.4	
141	10		25		16		25.00		65.2	
142	10		30		17		52.94		60.4	
143	12		35		9		55.56		45.8	
144	18		30		19		52.63		55.2	
145	8		30		14		50.00		59.7	
146	10		25		19		26.31		50.4	
147	12		15		16		56.25		52.8	
148	8		10		11		63.63		57.3	
149	5		15		16		62.50		64.3	
150	8		15		9		55.56		61.2	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
151	12		21		11		36.36		60.3	
152	8		12		16		62.50		67.4	
153	10		15		9		55.55		65.3	
154	10		15		9		66.66		63.4	
155	10		15		10		50.00		60.7	
156	12		10		12		41.66		59.5	
157	15		15		16		56.25		61.5	
158	10		20		10		30.00		60.8	
159	8		10		10		20.00		64.3	
160	15		20		18		50.00		67.2	
161	15		25		18		55.56		64.3	
162	8		25		11		54.54		65.7	
163	10		15		14		50.00		70.2	
164	18		20		15		40.00		67.3	
165	8		15		12		41.66		60.4	
166	10		25		10		30.00		68.9	
167	12		25		9		55.55		63.4	
168	14		15		16		62.50		63.2	
169	8		20		18		55.56		60.1	
170	10		20		18		50.00		61.9	
171	12		25		12		41.66		56.3	
172	8		30		9		44.45		53.4	
173	14		25		16		55.55		64.7	
174	12		25		11		62.50		60.3	
175	10		15		18		36.36		70.2	
176	15		25		17		44.44		60.7	
177	10		25		9		52.94		62.3	
178	18		20		11		22.33		59.4	
179	8		20		15		63.63		57.3	
180	5		20		14		42.85		49.8	
181	8		15		10		20.00		64.3	
182	10		20		10		50.00		59.9	
183	5		15		11		54.55		63.7	
184	8		15		10		40.00		58.4	
185	8		25		23		52.18		62.8	
186	10		12		13		53.87		60.1	
187	8		15		12		58.33		55.4	
188	8		20		19		57.89		57.3	
189	5		15		10		40 00		65.3	
190	8		25		10		50.00		72.1	
191	12		20		12		66.66		63.4	
192	15		20		20		45.00		62.3	
193	18		15		16		56.25		65.3	
194	8		20		19		52.94		62.2	
195	16		25		17		47.06		66 7	
196	15		25		15		40.00		63.8	
197	10		15		14		35.29		67.2	
198	18		20		11		54.55		61 7	
199	8		15		23		52.18		60.4	
200	5		12		15		60.00		65 3	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
201	10		20		10		60.00		62.1	
202	8		20		7		57.14		64.3	
203	8		15		7		57.14		62.4	
204	15		20		9		44 44		56.9	
205	10		20		9		66.66		63.8	
206	8		20		12		58.34		64.4	
207	8		15		13		53.85		67 7	
208	8		20		15		53.33		62.9	
209	10		15		10		60.00		58 3	
210	8		15		10		50.00		65.2	
211	5		15		11		54.55		62.4	
212	5		6		13		53.85		63.7	
213	18		15		11		45.46		70.3	
214	10		20		13		54 55		65.1	
215	12		25		12		25.00		59.5	
216	8		20		11		53.85		55.4	
217	15		20		10		40.00		65.9	
218	8		20		10		50.00		61.7	
219	8		30		12		33.33		58.5	
220	18		25		10		40.00		58	
221	10		15		15		46.67		59.4	
222	8		20		10		40.00		79.5	
223	8		25		10		50.00		55.7	
224	15		20		11		54.55		60 6	
225	10		15		9		50.00		63.2	
226	8		20		12		50.00		64.8	
227	10		25		16		43.75		70.5	
228	12		25		13		53.85		73.2	
229	10		20		12		20.00		77.5	
230	8		15		8		25.00		68.4	
231	9		20		12		50.00		62.3	
232	10		20		11		45.46		58.4	
233	8		25		15		46.67		65.3	
234	12		30		16		46.75		66.9	
235	15		35		8		50.00		60.5	
236	15		35		17		52.95		63.8	
237	10		15		14		57.15		55.1	
238	10		20		11		53 85		60.7	
239	8		35		8		37.50		64.4	
240	15		20		6		33.34		62 1	
241	12		15		15		33.33		49.9	
242	8		25		17		47.06		58.7	
243	10		20		6		16.67		65.3	
244	10		20		14		20.00		70.4	
245	12		25		12		41.67		45.3	
246	8		20		12		25.00		55.8	
247	15		20		11		54.55		56.3	
248	10		25		12		50 00		57.6	
249	8		15		10		20 00		63 4	
250	8		20		12		50.00		61.9	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
251	8		20		18		44.45		63.4	
252	15		25		25		32.00		60.8	
253	10		30		14		57.15		62.7	
254	15		30		22		50.00		65.5	
255	8		15		9		55.56		61.7	
256	8		20		15		46.67		56.4	
257	15		30		16		25.00		54.4	
258	12		35		15		40.00		58.7	
259	10		40		9		55.56		70.5	
260	8		35		15		53.34		63.0	
261	15		50		18		55.56		65.3	
262	15		20		19		36.84		68.4	
263	10		15		10		30.00		65.7	
264	10		25		9		33.34		60.4	
265	5		20		17		58.83		63.7	
266	10		20		19		57.90		62.5	
267	18		20		12		41.67		49.5	
268	10		25		4		25.00		62.3	
269	15		25		8		37.50		55.8	
270	20		15		22		50.00		64.4	
271	8		20		16		50.00		64.9	
272	15		12		9		44.44		75.2	
273	10		25		15		53.34		60 7	
274	15		30		14		57 15		72.3	
275	8		35		16		50.00		80.1	
276	8		20		27		44.45		77.8	
277	10		20		14		35 71		67.3	
278	10		25		15		46.67		69.9	
279	8		20		15		53.54		63.4	
280	8		25		22		45.45		65.4	
281	5		35		17		41.17		73.3	
282	12		30		16		50.00		62.8	
283	15		30		24		45.84		63.4	
284	5		20		19		36.84		70.2	
285	10		25		18		50.00		65.3	
286	18		30		16		37.50		61.5	
287	18		20		16		37.50		68.7	
288	10		25		15		46.67		70.5	
289	10		20		12		41 67		67.4	
290	15		30		21		38.10		60.1	
291	12		20		15		53.34		60 5	
292	8		25		22		54.55		74.3	
293	5		25		16		20.00		64.3	
294	10		15		24		45.86		61.9	
295	18		20		19		36.84		65.7	
296	18		20		18		50.00		72.5	
297	10		25		15		46.67		66 2	
298	10		25		14		35.71		63.5	
299	15		15		16		20.00		58 2	
300	8		20		15		46.67		65.3	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
301	15		25		20		40.00		60.3	
302	8		25		22		40.91		58.4	
303	18		35		34		41.18		62.3	
304	15		20		9		44.45		55.7	
305	10		20		15		50.00		57.3	
306	15		25		14		35.71		56.7	
307	15		90		17		52.95		59.1	
308	8		30		9		11.11		65.3	
309	8		30		14		50.00		61.4	
310	10		35		12		33.33		60.5	
311	12		30		17		47.06		58.4	
312	10		35		12		50 00		60.2	
313	20		20		16		25.00		52.7	
314	12		30		14		42.85		65.4	
315	10		25		15		33.33		67 3	
316	10		30		17		58.83		65.3	
317	15		35		15		26.66		63.7	
318	8		35		10		30.00		55.5	
319	10		30		13		30.76		62.3	
320	8		25		16		50.00		61.7	
321	15		40		29		51.73		55.4	
322	8		35		17		47.06		50 9	
323	18		30		18		50 00		60.2	
324	10		35		20		40.00		52.7	
325	15		20		34		41.18		57.5	
326	8		20		13		46.16		53.5	
327	8		20		9		44.45		58 1	
328	8		25		16		43.25		54.4	
329	12		20		9		55 56		55.3	
330	15		30		22		50.00		59.4	
331	20		35		13		61.54		55.2	
332	8		40		15		66.67		53.4	
333	10		20		8		62 50		60.5	
334	8		25		17		58.83		58.4	
335	10		15		9		22.22		52.1	
336	12		25		10		20.00		54.2	
337	10		30		16		31 25		56.7	
338	15		35		14		28 57		51.9	
339	8		20		13		7.69		57.4	
340	10		20		10		40.00		49.8	
341	5		25		8		62.50		67.3	
342	18		20		12		66.67		68.5	
343	10		25		15		66.67		60.9	
344	8		35		14		50.00		58.5	
345	8		35		9		55.56		62.7	
346	8		40		9		55.56		60.2	
347	12		25		13		53.85		65.1	
348	15		25		17		64.71		63.4	
349	20		15		13		46.16		57.3	
350	8		20		9		44.45		66.4	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant		Plant height (cm)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
351	8		15		14		50.00		55.4	
352	8		20		25		26.67		62.1	
353	8		25		18		66.67		65.3	
354	12		20		13		69.24		57.3	
355	8		25		10		30.00		60.4	
356	10		25		8		25.00		53.8	
357	15		30		7		28 58		61 7	
358	15		45		9		55.56		58 3	
359	15		25		20		55.00		56.4	
360	10		30		12		25.00		58.5	
361	8		45		10		30.00		50.3	
362	8		40		14		28.57		60.4	
363	8		45		6		33.34		58.5	
364	12		30		13		53.85		57.9	
365	5		20		17		35.29		61.5	
366	5		20		7		57.15		65.3	
367	5		25		21		57.15		64.4	
368	10		20		19		47.37		62.3	
369	15		25		14		50.00		62.4	
370	12		30		15		46.67		63.9	
371	5		25		12		58.34		55.4	
372	8		30		13		53.85		65.5	
373	10		45		7		42.86		60.3	
374	15		30		18		33.33		59.9	
375	15		30		13		30.76		45.7	
376	10		20		19		47.37		64.3	
377	8		25		15		46.67		58.6	
378	5		25		14		42.86		62.2	
379	5		25		11		54.55		70.5	
380	10		20		17		41.18		68.5	
381	10		25		12		25.00		53.4	
382	8		25		15		53.34		52.2	
383	12		15		12		33.33		55.6	
384	8		15		12		58 34		55	
385	15		20		16		62.50		57.3	
386	15		30		19		57.90		60.3	
387	10		35		10		10.00		58 9	
388	18		20		14		57.15		61.4	
389	5		35		11		54.55		50.7	
390	18		25		11		45.46		49.8	
391	5		30		16		62.50		55.3	
392	5		30		15		53.34		60.1	
393	10		25		10		50.00		45.4	
394	8		15		17		41.18		35.3	
395	5		20		12		50.00		54.3	
396	5		15		12		33.33		58.7	
397	10		25		19		47.37		57.4	
398	10		30		15		46 67		50.5	
399	8		35		14		42.86		52.1	
400	12		40		12		58.34		53.5	

Appendix III (B-I) (Contd....)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
401	10		15		7		14.20	
402	12		20		17		47.06	
403	12		25		14		28.57	
404	10		25		20		45.00	
405	5		30		16		31.55	
406	12		25		17		58.83	
407	15		20		13		53.85	
408	5		30		8		20.00	
409	12		35		10		25.00	
410	10		20		16		50.00	
411	10		25		11		45.46	
412	10		25		11		45.46	
413	15		35		12		50.00	
414	15		30		18		50.00	
415	18		30		6		33.34	
416	15		35		14		42.86	
417	10		40		11		54.55	
418	10		25		16		50.00	
419	10		15		13		53.85	
420	12		20		14		28.57	
421	12		25		17		58.83	
422	10		30		3		53.83	
423	5		25		8		50.00	
424	12		25		17		52 54	
425	15		30		17		58.83	
426	18		20		17		52.94	
427	8		20		15		40.00	
428	12		25		14		50.00	
429	8		25		13		53.85	
430	12		15		12		53.85	
431	10		20		12		58.33	
432	15		25		14		50.00	
433	15		25		21		61.90	
434	8		20		10		60.00	
435	8		15		12		33.33	
436	10		30		18		61.12	
437	8		25		22		54.54	
438	8		20		7		57.15	
439	10		30		17		58 82	
440	10		35		8		75 00	
441	12		25		17		52.94	
442	12		20		15		60.00	
443	8		25		14		50.00	
444	10		20		21		61.90	
445	8		25		18		61 12	
446	12		30		22		54.54	
447	10		35		7		57.15	
448	14		20		17		52 94	
449	10		25		14		20.00	
450	10		25		15		60.00	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
451	8		15		11		54.55	
452	8		20		11		54.54	
453	12		25		21		61.90	
454	8		20		13		61.53	
455	8		25		12		58.33	
456	8		25		13		23.07	
457	10		20		20		40.00	
458	5		15		12		33.34	
459	10		15		20		23.07	
460	10		20		25		40.00	
461	10		15		20		45.00	
462	5		15		17		35.30	
463	10		20		13		46 16	
464	5		25		17		35.30	
465	5		25		10		60.00	
466	12		30		14		50.00	
467	10		35		10		50 00	
468	12		20		11		54 55	
469	10		20		14		28.57	
470	10		20		16		25.00	
471	10		30		15		66.67	
472	8		35		17		41.18	
473	10		40		10		40.00	
474	10		25		14		35.71	
475	8		15		19		47.37	
476	8		20		20		30.00	
477	12		25		13		38.47	
478	12		25		13		61.54	
479	8		20		13		46.16	
480	8		20		10		20.00	
481	12		25		10		25.00	
482	10		20		9		44.45	
483	10		20		12		50 00	
484	8		25		12		50 00	
485	12		20		12		50.00	
486	12		30		22		50.00	
487	8		20		11		54.55	
488	8		25		14		50.00	
489	5		30		15		46.67	
490	5		20		14		50 00	
491	8		20		20		30.00	
492	8		25		13		61.54	
493	5		15		10		20.00	
494	10		20		9		25.00	
495	12		25		12		50.00	
496	12		25		22		50 00	
497	8		20		11		54.55	
498	10		15		15		46.57	
499	10		17		14		50.00	
500	8		19		13		46.16	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
501	10		20		14		67.15	
502	8		25		17		52.95	
503	10		20		15		53.34	
504	8		20		14		57.15	
505	8		15		18		55.56	
506	15		20		14		75.15	
507	15		25		14		42.86	
508	10		15		15		33.33	
509	8		20		14		57.15	
510	15		20		13		61.54	
511	10		15		13		61.54	
512	8		20		11		54.55	
513	10		25		9		55.56	
514	10		30		10		40.00	
515	8		20		13		61.54	
516	10		20		12		33.33	
517	10		25		11		54.55	
518	8		15		11		63.64	
519	8		20		12		50.00	
520	8		25		11		63.64	
521	8		25		11		54.55	
522	8		20		10		40.00	
523	12		20		14		64.29	
524	10		25		12		50.00	
525	10		20		9		33 34	
526	10		15		11		45.46	
527	8		20		14		57.15	
528	8		25		14		64.29	
529	8		25		16		62.50	
530	10		30		19		63 16	
531	15		25		12		50.00	
532	12		25		14		57.15	
533	10		20		12		50.00	
534	10		20		15		40.00	
535	12		20		11		45.46	
536	8		15		13		53.85	
537	8		25		9		44.45	
538	5		25		9		44.45	
539	8		20		12		50.00	
540	5		25		12		33.33	
541	5		20		15		53 34	
542	8		25		10		40.00	
543	8		20		8		50.00	
544	10		15		13		53.85	
545	10		20		19		63.16	
546	12		25		12		50.00	
547	8		30		11		45.46	
548	10		15		14		64.29	
549	10		15		11		45 46	
550	8		15		13		53.85	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
551	15		20		12		50.00	
552	10		30		18		55.56	
553	10		25		18		50.00	
554	10		30		14		50.00	
555	10		25		14		57.15	
556	10		25		18		61.62	
557	8		20		16		50.00	
558	8		20		16		50.00	
559	12		25		23		39.14	
560	12		30		10		50.00	
561	8		20		21		57.15	
562	18		30		17		58.83	
563	10		25		11		54.55	
564	18		30		12		58 34	
565	12		20		9		55.56	
566	12		20		10		40.00	
567	10		20		12		41.67	
568	10		25		15		40.00	
569	10		20		15		40.00	
570	8		20		12		20.00	
571	15		30		19		57.90	
572	10		25		17		41.18	
573	10		15		18		55.56	
574	10		15		18		50.00	
575	10		15		14		50.00	
576	10		26		17		47.06	
577	12		25		16		56.25	
578	8		20		13		53.85	
579	5		20		11		45.46	
580	8		25		13		46.16	
581	8		20		13		53.85	
582	5		20		13		53.85	
583	5		15		16		43.75	
584	10		20		18		50.00	
585	12		20		13		46.16	
586	12		20		10		40.00	
587	12		10		13		46.16	
588	10		20		11		45.46	
589	5		25		9		22 23	
590	5		20		7		57.15	
591	5		7		15		53.34	
592	12		20		17		47.07	
593	8		25		13		53.85	
594	8		20		16		43.75	
595	10		20		18		25.00	
596	10		30		13		53.84	
597	12		25		16		56.25	
598	8		15		11		54.54	
599	5		10		13		53.85	
600	5		15		16		56.25	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
601	3		26		15		60.00	
602	8		20		11		54.55	
603	10		25		10		50.00	
604	8		30		7		28.58	
605	15		25		17		47.07	
606	10		20		15		40.00	
607	8		25		11		45.46	
608	8		30		11		45.46	
609	10		20		10		30.00	
610	3		20		10		30.00	
611	5		20		11		45.46	
612	8		25		15		60.00	
613	8		30		17		47.07	
614	10		15		7		28.58	
615	12		26		10		20 00	
616	5		20		10		50.00	
617	8		25		11		54.55	
618	12		30		15		40 00	
619	12		15		17		52.94	
620	10		20		15		40.00	
621	10		15		11		45.46	
622	7		10		15		40.00	
623	5		20		10		30.00	
624	8		20		15		40.00	
625	8		15		10		50.00	
626	5		20		11		45.46	
627	8		25		15		40.00	
628	2		15		9		55.56	
629	5		20		13		61.53	
630	8		20		13		53.85	
631	10		25		10		40.00	
632	5		20		12		41.67	
633	5		25		13		53.85	
634	10		25		13		53.85	
635	1		20		12		58 34	
636	5		15		8		50.00	
637	8		20		9		55.56	
638	8		15		11		45.46	
639	5		25		11		45 46	
640	8		30		11		54.55	
641	12		25		11		36.37	
642	8		20		14		35.71	
643	10		20		13		46.16	
644	12		25		14		50.00	
645	8		15		9		55.56	
646	8		20		12		41.67	
647	5		20		13		53.85	
648	8		25		9		55.56	
649	12		20		8		50.00	
650	8		25		13		38.47	

Appendix III (B-I) (Contd....)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
651	10		20		15		46.67	
652	8		20		12		50.00	
653	5		25		17		52.95	
654	12		20		16		50.00	
655	10		15		16		43.75	
656	8		15		12		41.67	
657	15		20		10		30.00	
658	10		20		19		57.90	
659	10		25		8		50 00	
660	15		30		14		42.86	
661	10		30		12		20.00	
662	10		20		12		58.34	
663	8		25		12		41.67	
664	8		30		18		55.56	
665	8		30		14		42.86	
666	10		25		20		30.00	
667	10		20		16		50.00	
668	10		20		15		46.67	
669	12		25		12		50.00	
670	12		20		16		50.00	
671	8		20		10		30.00	
672	12		25		19		57 90	
673	8		20		8		50.00	
674	12		15		12		50.00	
675	8		15		12		58.34	
676	5		15		12		50.00	
677	3		20		14		57.15	
678	8		20		11		54.55	
679	10		25		13		53.85	
680	8		20		11		63.64	
681	12		15		6		33.33	
682	5		15		10		50.00	
683	8		20		9		33.34	
684	8		20		17		35.00	
685	10		25		19		52.64	
686	10		30		17		52.95	
687	8		35		14		57.15	
688	8		30		18		44 45	
689	10		25		12		58.33	
690	10		15		12		50.00	
691	8		20		13		53.85	
692	8		20		11		63.64	
693	5		25		10		50.00	
694	8		20		9		33.34	
695	5		15		17		64.70	
696	10		15		19		52.64	
697	5		20		17		52.95	
698	8		20		14		57.15	
699	5		25		12		50 00	
700	5		30		11		54.55	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
701	10		20		22		36.36	
702	10		25		7		28.58	
703	10		20		14		50.00	
704	8		25		14		57.15	
705	10		30		13		61.54	
706	15		25		13		61.54	
707	10		35		15		46.67	
708	8		40		13		38.47	
709	10		25		10		30.00	
710	16		20		16		31.25	
711	18		35		10		30.00	
712	12		20		13		38.47	
713	12		25		15		46.67	
714	12		20		13		61.54	
715	12		25		13		61.54	
716	10		30		14		57.15	
717	10		15		14		50.00	
718	14		35		7		27.58	
719	14		40		22		63.64	
720	8		25		7		27.58	
721	12		20		22		63.64	
722	10		35		14		57.15	
723	14		20		10		30.00	
724	15		25		16		31.25	
725	12		20		10		30.00	
726	10		20		10		40 00	
727	10		20		10		60.00	
728	10		25		11		45.46	
729	8		30		13		46.16	
730	8		25		15		46.67	
731	8		20		9		44.45	
732	10		25		13		53.85	
733	8		20		15		40.00	
734	8		30		13		38.46	
735	8		30		22		45.46	
736	10		25		12		50.00	
737	8		20		14		57.15	
738	8		30		15		40.00	
739	8		20		12		50.00	
740	12		20		10		50.00	
741	10		25		12		41.67	
742	10		30		12		25.00	
743	10		35		10		40.00	
744	10		35		13		53.85	
745	18		30		16		43.75	
746	8		30		6		33.34	
747	10		25		14		50.00	
748	10		20		13		53.85	
749	10		20		14		50.00	
750	8		20		10		40.00	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
751	10		20		11		54.55	
752	10		25		16		43.75	
753	8		20		8		62.50	
754	8		20		17		35.30	
755	8		15		9		33.34	
756	8		20		9		55 56	
757	8		20		10		50.00	
758	8		25		13		46.16	
759	5		15		10		50 00	
760	10		20		10		50.00	
761	10		25		11		54.55	
762	10		20		13		53.85	
763	5		25		7		14.29	
764	10		25		10		50.00	
765	10		30		17		52.95	
766	8		30		10		60 00	
767	8		35		13		38.46	
768	8		30		14		42.86	
769	5		35		11		54 55	
770	12		35		17		47.06	
771	10		25		12		33.33	
772	8		20		12		50.00	
773	8		20		12		41.67	
774	8		20		9		55.56	
775	5		15		17		41.17	
776	10		20		13		46.16	
777	5		15		7		42 86	
778	5		20		10		50.00	
779	8		15		8		37.50	
780	12		20		16		20.00	
781	5		20		10		50.00	
782	5		20		10		40.00	
783	12		25		9		44.45	
784	15		20		16		50.00	
785	5		15		17		58.83	
786	5		25		10		40 00	
787	10		20		11		45.46	
788	10		25		13		46.15	
789	8		25		12		41 67	
790	15		20		12		50.00	
791	10		25		13		53 85	
792	8		25		9		55 56	
793	10		20		16		37 50	
794	15		20		20		35.00	
795	15		15		11		45.46	
796	10		20		6		16.67	
797	10		20		15		40 00	
798	10		15		11		36 37	
799	8		20		13		53 85	
800	15		25		10		40.00	

Appendix III (B-I) (Contd....)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
801	12		25		12		41.67	
802	8		20		11		45.46	
803	8		20		11		54.55	
804	15		15		13		42.16	
805	10		20		12		50 00	
806	8		25		7		57.14	
807	12		20		10		60.00	
808	8		20		15		66.66	
809	5		20		9		55.55	
810	5		20		9		55.56	
811	5		25		10		50.00	
812	5		20		10		60.00	
813	8		25		9		55 55	
814	5		20		10		50.00	
815	12		30		9		55.55	
816	8		25		11		54.55	
817	15		35		8		62.50	
818	10		20		10		60.00	
819	8		30		13		61.54	
820	5		20		11		54 55	
821	8		35		11		54.54	
822	5		40		13		53.85	
823	10		30		10		50.00	
824	5		25		11		63 63	
825	10		20		13		53.85	
826	8		25		19		57.89	
827	10		30		15		60.00	
828	10		25		16		56.25	
829	8		30		9		11.11	
830	5		20		13		61.54	
831	15		20		18		55.55	
832	8		25		15		53.33	
833	5		30		13		55.55	
834	8		30		12		33.33	
835	8		20		10		50.00	
836	5		30		15		66.67	
837	12		20		6		66.66	
838	8		25		15		53.34	
839	5		35		11		54.55	
840	15		20		10		40.00	
841	10		25		15		33 33	
842	8		20		13		61.54	
843	12		20		13		46.16	
844	10		35		7		57.15	
845	10		40		10		30.00	
846	8		25		15		53.34	
847	12		30		10		40.00	
848	10		30		15		53.34	
849	5		35		16		50.00	
850	8		25		16		43.75	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
851	8		20		20		50.00	
852	8		25		11		36.37	
853	10		30		15		40.00	
854	8		25		19		52.64	
855	5		50		9		55.56	
856	5		15		5		20.00	
857	8		20		20		25.00	
858	5		25		14		50.00	
859	8		35		14		50.00	
860	5		30		17		52.95	
861	5		35		15		40.00	
862	5		30		13		23.07	
863	10		50		9		11 11	
864	5		45		11		18.18	
865	5		70		9		11.11	
866	8		30		10		40.00	
867	5		35		18		44.45	
868	8		40		21		52.39	
869	10		25		7		57.15	
870	8		35		11		36.37	
871	8		30		14		57.15	
872	8		25		15		33.33	
873	12		35		17		64.71	
874	12		30		10		40.00	
875	8		25		17		29.41	
876	8		20		12		58.34	
877	10		25		7		42.86	
878	10		30		11		63.64	
879	8		25		11		45.46	
880	8		50		10		40 00	
881	8		15		10		30.00	
882	5		20		13		53.85	
883	10		25		9		55.56	
884	8		35		11		54.55	
885	8		30		6		33.34	
886	10		35		10		45.00	
887	8		30		11		36.37	
888	12		50		17		58.83	
889	5		45		12		58.34	
890	8		70		12		25 00	
891	12		30		10		60.00	
892	8		35		23		43.48	
893	10		40		12		58.34	
894	15		25		11		54.55	
895	8		35		16		56.25	
896	8		30		19		47.37	
897	10		25		17		58.83	
898	10		35		11		45.46	
899	8		30		14		64.29	
900	15		25		20		35 00	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
901	12		20		14		28.58	
902	10		25		9		22.23	
903	15		30		17		64.71	
904	10		25		11		36.36	
905	8		20		16		68.75	
906	15		15		14		31.25	
907	10		20		8		62.50	
908	10		30		13		46.16	
909	8		35		17		41.18	
910	10		25		14		35.71	
911	10		25		14		50 00	
912	8		30		12		50.00	
913	15		35		18		55.56	
914	10		15		7		42.86	
915	10		20		11		45.46	
916	10		30		11		45.46	
917	5		35		12		58.34	
918	10		35		14		57.15	
919	12		40		13		46.16	
920	15		20		13		46.16	
921	12		20		17		41.18	
922	10		30		14		35.71	
923	15		25		11		63.64	
924	10		20		13		46.16	
925	8		25		14		50.00	
926	8		20		13		30.77	
927	8		25		10		20.00	
928	10		25		14		28.58	
929	10		30		15		33.34	
930	8		35		11		36.37	
931	10		25		18		22.23	
932	8		30		13		30.77	
933	10		30		14		33.72	
934	5		25		10		30.00	
935	8		40		7		57.15	
936	8		25		10		50.00	
937	5		35		12		41.67	
938	8		30		13		61.54	
939	10		25		10		20.00	
940	8		20		10		50.00	
941	10		25		19		57.90	
942	8		20		16		56 25	
943	12		40		19		42.11	
944	18		25		15		53.34	
945	8		20		17		58.83	
946	8		30		19		57.90	
947	10		35		12		58.34	
948	10		40		11		9.09	
949	8		20		13		30 77	
950	10		25		10		50 00	

Appendix III (B-I) (Contd….)

Sr. No.	PDI of PB 60 DAT		PDI of PB 90 DAT		No. of leaves/ plant		Per cent No. of disease affected leaves/plant	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
951	12		35		18		22.23	
952	12		35		13		30.77	
953	8		20		14		35.72	
954	8		25		11		36.37	
955	12		35		12		41 67	
956	8		40		15		60.00	
957	8		20		12		58 34	
958	18		20		15		53.34	
959	5		35		11		63.64	
960	10		20		14		50.00	
961	15		20		14		57.15	
962	8		25		15		33.33	
963	5		20		9		58.56	
964	10		50		10		10.00	
965	10		30		17		58.83	
966	15		35		15		33 33	
967	15		20		18		50.00	
968	8		50		12		66.67	
969	8		35		16		62.50	
970	10		30		17		58.83	
971	8		25		14		50.00	
972	10		35		20		55 00	
973	12		30		16		56.25	
974	12		30		11		36.37	
975	12		35		12		41.67	
976	10		20		11		18.19	
977	8		25		15		33.34	
978	8		25		14		28.58	
979	12		30		12		50 00	
980	8		15		11		36.37	
981	12		20		17		29.42	
982	10		70		7		14.28	
983	8		20		12		33.34	
984	12		40		18		33.34	
985	8		20		15		33.34	
986	10		25		18		33.34	
987	10		30		20		20.00	
988	8		20		12		33.34	
989	8		25		13		46.16	
990	8		20		14		42 86	
991	10		30		13		53 85	
992	10		80		15		53.54	
993	10		70		9		12.50	
994	8		20		10		30.00	
995	10		30		11		54.55	
996	10		20		22		40.91	
997	8		25		12		33.34	
998	8		25		18		33 34	
999	12		15		15		33.34	
1000	8		20		18		33.44	

Appendix III (B-II). Observations of M_4 red onion bulb crop

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
1	7.4	7.0	6.5	6.4	1.13	1.09	1.9	2.2	136	149	13.0	13.0
2	8.5	8.0	5.8	6.0	1.46	1.33	2.0	1.3	113	73	13.0	13.2
3	8.5	6.4	5.6	5.1	1.51	0.90	1.6	1.6	143	75	12.0	12.0
4	6.0	7.6	5.3	5.7	1.13	1.33	1.5	1.3	148	84	11.0	14.8
5	6.5	6.7	6.2	5.3	1.04	1.26	1.2	2.0	187	108	11.0	12.6
6	6.5	7.3	5.7	5.6	1.14	1.30	1.5	2.5	182	104	13.0	11.0
7	7.7	6.4	5.6	6.0	1.37	1.06	2.5	1.9	88	126	13.0	12.2
8	7.0	5.4	5.6	4.5	1.25	1.20	2.5	1.3	77	70	11.6	13.0
9	2.9	5.8	5.1	6.1	0.56	0.95	3.4	1.0	114	82	12.2	12.2
10	4.0	6.0	5.5	5.0	0.72	1.20	3.0	1.9	41	86	13.0	11.4
11	8.1		6.5		1.24		2.0		287		14.0	
12	9.5		6.0		1.58		1.4		138		11.0	
13	7.3		6.4		1.14		2.5		127		12.4	
14	7.2		6.0		1.20		1.9		77		12.2	
15	7.3		5.8		1.25		2.0		198		14.0	
16	6.5		5.5		1.18		1.4		65		13.0	
17	5.8		5.5		1.05		2.0		126		12.0	
18	5.5		6.0		0.91		3.1		84		12.0	
19	5.6		5.2		1.07		1.2		133		12.0	
20	5.5		5.2		1.05		2.5		93		11.0	
21	7.5		6.1		1.22		2.1		120		11.0	
22	7.8		6.1		1.27		2.6		129		13.4	
23	5.9		5.2		1.13		2.1		66		15.0	
24	7.7		6.4		1.20		1.5		172		14.0	
25	6.9		6.0		1.15		2.0		92		14.2	
26	6.7		6.5		1.03		2.2		144		15.0	
27	6.4		6.0		1.06		2.1		161		14.4	
28	7.0		5.0		1.10		2.2		89		14.0	
29	5.5		5.2		1.05		2.5		118		13.0	
30	4.0		5.0		0.80		1.9		47		12.0	
31	4.0		5.5		0.57		2.4		86		14.0	
32	7.2		6.5		1.10		1.9		120		13.0	
33	7.3		5.5		1.32		0.9		121		15.0	
34	6.1		5.2		1.10		2.0		41		14.0	
35	6.6		5.7		1.15		1.5		98		14.0	
36	6.5		6.0		1.08		2.0		132		14.4	
37	6.5		5.5		1.18		1.5		90		13.0	
38	7.0		5.5		1.27		1.5		131		14.0	
39	7.0		5.9		1.18		1.6		44		11.0	
40	8.0		6.0		0.85		2.0		91		12.0	
41	7.0		6.5		1.07		2.5		72		13.0	
42	6.5		6.0		1.08		1.5		148		13.2	
43	5.4		5.1		1.05		1.7		118		11.0	
44	6.5		5.1		1.27		2.5		119		12.0	
45	4.5		5.0		0.90		1.9		93		13.0	
46	5.5		5.0		1.10		1.6		70		14.0	
47	5.1		6.0		0.85		2.4		175		12.0	
48	5.3		4.5		1.17		1.9		64		13.0	
49	7.5		6.5		1.15		1.3		103		14.4	
50	7.0		6.5		1.07		2.1		80		14.0	

Appendix III (B-II) (Contd…)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
51	6.1		6.0		1.10		2.2		102		14.0	
52	5.5		5.8		0.94		2.6		82		14.4	
53	5.9		5.5		1.07		2.2		80		14.0	
54	6 5		6.0		1.08		1.9		84		15.4	
55	5.0		5.0		1.00		1.7		111		14.0	
56	5.5		6.4		0.85		2.5		66		13.8	
57	5.1		5.2		0 98		2.1		139		13.0	
58	5.1		4.5		1.13		2.7		92		11.0	
59	5.5		5.5		1.00		2.0		108		14 0	
60	6.0		4.5		1.33		2.2		91		12.0	
61	6.0		5.6		1.07		1.5		126		11.0	
62	7 5		6.0		1.25		2.1		100		12.0	
63	6.3		4.5		1 40		1.7		111		13.0	
64	6.0		5.0		1.20		1.9		92		15.0	
65	7.0		5 8		1.20		1.8		50		11.4	
66	6.0		5.0		1.20		1.9		115		14.4	
67	7.0		5.6		1.25		1.5		60		13.0	
68	7.5		6.0		1.25		2.1		58		14.0	
69	6.0		4.5		1.33		1.7		26		13.0	
70	6.0		5.0		1.20		1.9		126		10.0	
71	7 0		5.5		1.27		2.1		157		13.0	
72	7.0		6.9		1.10		2 0		114		13.4	
73	6.0		4.8		1.25		1.6		77		15.0	
74	5.5		5.3		1.03		2.2		123		12.0	
75	5.1		4.5		1.13		2.1		160		14.0	
76	5.0		4.0		1.25		2.3		146		16.0	
77	8.0		6.0		1.33		1.6		84		14.0	
78	4.0		3.0		1.33		2.1		154		11.0	
79	5.0		4.5		1 11		2.3		140		14.0	
80	4 1		3.5		1 17		1.3		83		12.0	
81	5.5		5.5		1.00		1.6		86		15.0	
82	5.6		6.1		0.91		1.6		61		13.0	
83	7.2		5.8		1.24		2.2		153		15.0	
84	7.6		6.5		1.16		1.3		104		13.0	
85	4.0		3.8		1.05		1.2		57		14.0	
86	6.0		6.3		0.95		1.3		88		12.0	
87	5.1		5.0		1.02		1.0		57		14.0	
88	6.2		5.5		1.12		0 9		192		14 4	
89	5.6		5.3		1.05		1.1		91		11.0	
90	4 1		3.5		1.17		1.3		122		15.0	
91	6.5		5.0		1.08		1.9		179		14.0	
92	6.1		6.3		0.96		1.1		112		14.8	
93	6.0		5.5		1.09		1.4		88		13.0	
94	8.1		6.4		1.26		1.6		141		14.0	
95	6.0		6 3		0.95		1.0		131		14.4	
96	6 0		5.1		1.17		1.6		103		16.0	
97	5 5		5.5		1.00		1.7		106		15.0	
98	5.6		4.9		1.14		1.8		114		14.2	
99	6 5		6 0		1 08		1 1		92		12.0	
100	4.2		4.1		1.02		1 5		126		14.0	

Appendix III (B-II) (Contd…)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
101	7.0		5.4		1.29		1.6		135		13.0	
102	6.9		5.5		1.25		1.6		152		12.0	
103	7.3		6.0		1.21		1.7		110		14.0	
104	7.0		5.5		1.27		1.8		132		12.0	
105	7.0		5.5		1.27		1.9		94		15.0	
106	7.0		5.0		1.40		1.8		125		14.0	
107	6.0		5.7		1.05		1.3		141		14.0	
108	6.3		5.1		1.23		1.0		114		13.0	
109	6.0		4.5		1.33		1.0		113		14.0	
110	5.0		4.1		1.21		1.4		97		12.8	
111	5.7		4.0		1.42		1.2		86		14.0	
112	6.0		5.0		1.20		1.0		145		13.0	
113	6.5		3.5		1.85		2.2		107		13.0	
114	8.0		5.0		1.60		2.0		96		13.8	
115	5.1		4.0		1.27		1.5		80		15.0	
116	4.9		3.5		1.40		1.5		91		14.0	
117	6.5		4.0		1.62		1.3		103		15.0	
118	6.4		5.0		1.28		1.1		80		14.0	
119	6.0		4.5		1.33		1.0		76		14.0	
120	5.9		3.9		1.51		1.1		122		13.0	
121	7.0		5.0		1.40		1.6		103		11.0	
122	6.0		4.0		1.50		2.0		102		15.0	
123	6.0		4.1		1.46		1.6		77		12.0	
124	6.5		5.5		1.18		2.0		137		12.0	
125	6.0		4.1		1.46		1.6		83		12.8	
126	6.8		5.5		1.23		1.3		126		13.0	
127	5.7		4.5		1.26		1.6		129		13.2	
128	7.0		4.5		1.55		1.3		94		12.0	
129	5.9		5.5		1.07		1.6		93		11.0	
130	5.5		4.5		1.22		1.0		113		14.0	
131	5.4		4.8		1.12		1.1		86		13.8	
132	4.9		3.9		1.25		1.3		69		13.0	
133	6.5		5.0		1.30		2.0		106		12.8	
134	5.1		4.0		1.27		1.2		98		13.0	
135	4.5		4.0		1.12		1.9		101		14.0	
136	5.4		4.5		1.20		1.0		77		13.0	
137	5.5		4.5		1.22		1.6		89		12.2	
138	4.1		5.5		0.74		0.9		47		13.0	
139	5.0		4.0		1.25		1.0		49		14.0	
140	4.2		4.3		0.97		1.0		49		12.0	
141	5.0		4.3		1.16		1.2		91		15.0	
142	4.5		3.8		1.18		2.5		34		14.0	
143	4.1		3.5		1.17		1.5		154		14.0	
144	7.5		6.3		1.19		2.1		65		13.4	
145	4.9		4.2		1.02		1.6		96		13.0	
146	6.0		5.8		1.03		1.0		106		12.0	
147	6.0		4.8		1.25		2.2		61		15.0	
148	5.5		5.5		1.00		1.1		56		14.0	
149	5.8		4.5		1.28		0.9		54		14.0	
150	5.2		4.5		1.20		1.9		47		11.0	

Appendix III (B-II) (Contd…)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
151	6.3		5.7		1.10		1.3		85		13.0	
152	5.5		3.5		1.28		1.2		82		14.0	
153	5.8		4.5		1.28		2.0		53		13.0	
154	6.2		4.7		1.31		2.1		63		14.0	
155	5.0		4.2		1.19		0.9		79		11.0	
156	5.0		3.5		1.42		1.5		72		13.0	
157	5.5		4.0		1.37		1.7		104		14.0	
158	5.1		5.1		1.00		1.6		50		15.0	
159	4.5		6.5		0.69		2.5		76		11.0	
160	5.7		4.1		1.39		1.1		89		12.0	
161	5.8		4.0		1.45		1.3		76		11.0	
162	6.5		5.5		1.18		1.7		51		12.2	
163	5.2		4.2		1.23		2.0		101		13.0	
164	6.3		3.0		2.10		1.9		56		12.0	
165	6.0		4.7		1.27		2.1		49		14.0	
166	6.5		6.0		1.08		1.0		117		11.0	
167	4.2		3.5		1.20		1.1		89		13.2	
168	4.5		3.8		1.18		2.0		119		11.0	
169	4.0		4.5		0.88		1.1		81		13.0	
170	6.2		4.0		1.55		1.7		89		11.2	
171	6.0		5.1		1.17		2.1		125		12.0	
172	3.2		3.2		1.00		1.6		96		13.0	
173	5.9		4.0		1.47		2.1		77		13.4	
174	3.4		4.1		0.82		1.5		75		13.0	
175	4.8		4.2		1.14		1.3		105		12.0	
176	6.3		5.3		1.18		0.9		107		11.0	
177	4.9		4.8		1.02		2.0		91		13.0	
178	5.7		4.0		1.42		0.4		108		11.0	
179	6.7		6.1		1.09		2.4		35		11.0	
180	5.5		4.5		1.22		0.5		16		12.0	
181	6.7		5.1		1.31		1.9		84		9.0	
182	8.0		6.0		1.33		2.5		93		11.0	
183	6.3		5.1		1.23		2.4		139		13.0	
184	7.3		5.5		1.32		1.3		115		13.0	
185	9.3		7.4		1.25		1.6		177		14.0	
186	7.6		6.5		1.16		2.5		210		12.2	
187	7.8		6.9		1.13		3.0		176		14.0	
188	5.9		5.1		1.15		1.6		193		14.4	
189	8.0		5.4		1.48		1.3		110		13.0	
190	6.2		4.1		1.51		2.1		178		13.2	
191	6.0		5.2		1.15		1.6		105		11.4	
192	5.8		4.5		1.28		3.2		143		12.0	
193	6.5		4.9		1.32		1.3		113		15.0	
194	6.5		5.5		1.18		1.9		112		11.0	
195	6.0		5.1		1.17		2.4		188		11.0	
196	7.4		6.7		1.11		2.5		125		11.4	
197	5.7		6.6		1.01		1.5		68		14.0	
198	6.0		5.2		1.15		2.6		105		13.0	
199	5.8		4.5		1.28		3.2		105		11.0	
200	6.5		4.9		1.32		1.3		143		12.2	

Appendix III (B-II) (Contd…)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
201	5.4		4.5		1.20		1.1		70		12.0	
202	7.5		6.0		1.25		2.4		181		11.0	
203	6.4		5.4		1.18		2.0		125		13.0	
204	6.9		6.7		1.02		1.6		103		15.0	
205	5.8		5.1		1.13		2.0		112		12.2	
206	7.0		5.1		1.37		2.2		123		12.8	
207	7.0		6.5		1.07		2.6		99		12.0	
208	5.1		4.5		1.13		1.3		125		13.0	
209	5.5		5.1		1.07		3.3		110		10.0	
210	5.0		4.5		1.11		2.0		129		11.6	
211	8.0		6.7		1.19		1.6		144		14.0	
212	5.0		4.0		1.25		2.0		74		13.0	
213	5.1		4.0		1.27		1.3		186		14.0	
214	5.0		4.6		1.08		2.0		82		11.0	
215	4.8		4.4		1.09		2.2		65		12.0	
216	5.5		4.6		1.19		1.9		70		14.4	
217	7.7		5.6		1.37		2.3		49		13.0	
218	4.1		3.5		1.11		1.5		41		14.0	
219	5.0		4.0		1.25		2.0		83		13.0	
220	5.4		4.5		1.20		1.6		56		13.2	
221	5.1		4.0		1.27		2.0		138		11.0	
222	6.4		5.0		1.28		1.3		129		14.0	
223	7.3		6.0		1.21		1.0		73		13.0	
224	6.4		5.0		1.28		2.2		143		14.0	
225	7.0		6.0		1.16		1.9		88		11.0	
226	5.0		3.5		1.42		1.9		127		13.0	
227	7.5		5.3		1.41		1.3		52		14.4	
228	7.0		5.1		1.37		2.0		127		12.0	
229	6.4		4.6		1.39		1.3		50		15.0	
230	7.0		6.0		1.16		1.2		109		11.0	
231	6.0		5.0		1.20		2.0		134		13.0	
232	6.0		5.0		1.20		2.6		91		13.0	
233	6.1		4.7		1.29		2.3		92		14.0	
234	5.2		5.7		0.94		2.2		95		14.4	
235	6.0		5.2		1.15		1.6		87		12.0	
236	6.0		4.5		1.33		1.5		103		14.2	
237	6.1		4.7		1.29		2.0		105		12.8	
238	5.2		5.5		0.94		2.6		134		12.2	
239	6.0		5.4		1.33		2.1		92		12.4	
240	6.0		5.0		1.20		2.2		95		13.2	
241	6.4		5.9		1.08		1.6		118		13.0	
242	6.1		4.9		1.24		2.1		107		14.2	
243	4.0		5.0		0.80		1.3		93		12.8	
244	6.7		4.5		1.48		1.6		58		10.0	
245	5.5		5.3		1.03		1.7		37		12.0	
246	6.4		5.9		1.08		2.1		91		13.2	
247	6.1		4.9		1.24		2.4		103		13.0	
248	4.0		5.0		0.80		1.6		107		12.8	
249	5.5		5.3		1.03		1.2		95		12.4	
250	6.4		5.9		1.08		1.1		87		12.0	

Appendix III (B-II) (Contd...)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
251	6.0		5.0		1.20		1.5		91		11.0	
252	5.5		4.9		1.12		1.0		81		12.4	
253	4.5		3.5		1.28		1.6		84		13.0	
254	4.1		6.3		0.65		1.5		104		12.8	
255	5.5		4.5		1.22		1.3		58		13.2	
256	5.5		4.0		1.37		2.4		105		10.8	
257	6.5		6.0		1.08		2.4		59		12.0	
258	6.0		5.0		1.20		1.0		50		14.0	
259	5.9		5.5		1.07		1.5		80		14.4	
260	5.5		5.0		1.10		2.1		47		13.0	
261	6.1		5.1		1.19		1.5		97		13.0	
262	5.5		4.5		1.22		1.3		111		12.4	
263	7.0		4.7		1.48		0.7		124		12.0	
264	6.8		7.5		0.90		1.5		136		11.0	
265	5.0		6.9		0.72		1.0		73		12.0	
266	5.1		4.0		1.27		2.4		107		12.2	
267	6.0		6.0		1.00		2.0		105		11.0	
268	3.2		4.1		0.78		2.1		72		12.0	
269	5.0		5.5		0.90		2.4		34		13.0	
270	3.0		4.1		0.73		1.9		39		14.0	
271	7.0		5.1		1.37		2.0		123		14.2	
272	3.6		5.4		0.66		2.0		95		14.0	
273	7.0		7.0		1.00		3.2		95		13.0	
274	5.0		6.0		0.83		2.4		162		12.0	
275	6.0		4.5		1.33		1.5		67		14.4	
276	5.0		5.0		1.00		2.1		152		12.2	
277	4.5		6.5		0.69		2.0		145		14.0	
278	7.0		5.4		1.29		1.9		31		13.0	
279	6.4		4.2		1.52		2.1		123		12.2	
280	7.0		5.4		1.29		2.5		95		14.0	
281	5.1		4.7		1.08		2.0		65		13.0	
282	7.6		5.6		1.35		2.1		158		11.0	
283	5.5		5.1		1.07		3.0		67		15.0	
284	4.9		3.5		1.40		2.1		67		13.0	
285	6.6		6.1		1.08		2.2		95		11.0	
286	6.0		5.0		1.20		2.0		67		12.0	
287	4.5		3.5		1.28		2.0		160		14.0	
288	5.7		5.6		1.01		2.3		95		13.0	
289	7.0		5.1		1.47		2.1		67		11.0	
290	6.7		5.1		1.32		2.2		158		12.0	
291	5.5		4.5		1.22		2.5		81		12.0	
292	6.0		5.4		1.11		2.4		92		14.0	
293	7.0		7.5		0.93		3.0		68		13.4	
294	5.4		5.4		1.00		2.9		77		13.0	
295	7.1		5.7		1.24		2.4		88		12.0	
296	4.9		6.0		0.81		2.9		148		14.2	
297	5.2		5.0		1.01		2.0		93		15.0	
298	6.0		4.5		1.33		2.7		90		14.4	
299	6.0		5.1		1.17		2.0		19		11.0	
300	5.4		4.5		1.20		2.6		147		12.4	

Appendix III (B-II) (Contd...)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
301	6.4		5.1		1.25		2.5		122		13.0	
302	7.0		6.7		1.04		2.1		84		9.0	
303	5.6		5.1		1.09		2.3		110		13.4	
304	7.0		5.1		1.37		2.6		74		11.0	
305	6.0		5.5		1.09		2.1		64		13.4	
306	6.4		5.1		1.25		3.1		64		8.0	
307	6.0		5.4		1.11		3.0		137		11.0	
308	7.1		5.1		1.39		3.0		159		13.0	
309	6.2		5.7		1.08		2.5		112		13.0	
310	4.5		6.0		0.75		2.0		120		12.0	
311	5.0		4.5		1.11		1.3		118		15.0	
312	6.0		5.4		1.11		2.0		69		13.8	
313	5.7		5.1		1.11		2.2		98		13.0	
314	7.0		5.3		1.32		2.4		97		14.0	
315	6.4		4.5		1.42		1.9		110		13.0	
316	5.8		5.0		1.16		1.6		61		12.2	
317	5.1		3.9		1.30		2.4		30		13.2	
318	6.0		4.5		1.33		2.4		82		14.0	
319	5.1		5.5		0.92		1.6		69		12.0	
320	6.4		5.0		1.28		2.0		41		12.2	
321	5.0		6.0		0.83		2.0		74		14.0	
322	5.5		5.0		1.10		3.0		70		13.0	
323	6.4		5.1		1.25		2.0		91		13.6	
324	6.0		5.5		1.09		2.4		62		13.4	
325	5.0		4.2		1.19		1.5		69		14.6	
326	5.9		5.6		1.05		2.1		37		14.4	
327	5.5		5.4		1.10		1.6		126		13.2	
328	7.0		5.5		1.27		1.1		13		12.0	
329	5.4		5.1		1.05		1.5		88		11.0	
330	4.0		3.5		1.14		2.0		102		13.0	
331	5.6		5.5		1.01		1.5		132		13.0	
332	5.1		4.0		1.27		3.0		121		12.6	
333	7.0		6.0		1.16		0.9		67		12.8	
334	5.0		5.3		0.94		1.4		106		12.0	
335	7.0		5.5		1.27		2.4		69		14.0	
336	5.4		4.9		1.10		0.8		106		12.8	
337	6.4		4.5		1.42		1.6		81		13.0	
338	6.5		6.2		1.44		1.3		69		14.0	
339	6.4		4.8		1.33		1.0		50		13.0	
340	5.0		4.5		1.11		1.7		48		12.0	
341	7.0		5.5		1.27		2.5		100		10.0	
342	6.5		6.0		1.08		2.7		94		13.0	
343	7.3		6.0		1.21		2.0		85		15.0	
344	4.5		4.0		1.12		2.2		138		13.8	
345	6.0		6.2		0.96		2.1		128		14.2	
346	7.0		5.0		1.40		2.3		76		13.0	
347	5.8		5.7		1.01		1.7		73		15.0	
348	6.0		5.3		1.13		1.5		68		13.2	
349	6.5		5.8		1.12		1.0		94		15.0	
350	5.5		3.8		1.44		1.3		119		13.0	

Appendix III (B-II) (Contd...)

Sr. No.	Equatorial diameter (cm)		Polar diameter (cm)		Bulb shape index		Neck thickness (cm)		Bulb weight (g)		TSS (%)	
	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control	Irradiated	Control
351	6.5		5.4		1.20		2.5		158		13.0	
352	7.0		5.4		1.29		2.4		133		12.0	
353	6.5		5.5		1.18		2.0		57		12.6	
354	6.5		5.0		1.30		3.0		112		14.0	
355	5.4		4.5		1.20		2.9		76		10.6	
356	5.1		4.5		1.13		2.0		117		13.0	
357	7.0		5.1		1.37		2.4		121		11.0	
358	5.5		6.5		0.84		2.5		129		10.0	
359	5.0		4.5		1.11		2.4		71		11.0	
360	7.0		5.0		1.40		2.2		84		12.0	
361	7.0		5.5		1.27		2.0		109		14.0	
362	6.9		5.7		1.21		2.4		190		13.0	
363	6.9		6.4		1.27		2.0		88		12.0	
364	6.0		5.4		1.11		3.1		126		14.4	
365	6.7		4.5		1.48		2.5		125		10.0	
366	6.5		6.2		1.04		2.0		74		14.0	
367	7.4		5.2		1.42		1.6		90		13.0	
368	5.4		5.5		0.98		1.5		66		11.0	
369	6.0		4.5		1.33		1.6		43		12.0	
370	5.6		5.2		1.07		2.2		104		13.0	
371	6.0		5.4		1.11		2.0		63		13.0	
372	6.1		5.5		1.10		3.5		77		13.0	
373	6.2		5.0		1.24		1.5		136		12.0	
374	8.3		5.7		1.45		2.5		101		12.0	
375	6.5		6.0		1.08		1.9		136		13.2	
376	6.0		4.5		1.33		1.5		96		13.4	
377	5.1		4.5		1.13		1.3		98		14.0	
378	7.3		6.3		1.15		2.0		122		14.4	
379	5.1		4.5		1.13		1.9		89		12.0	
380	5.5		5.4		1.01		1.3		64		12.0	
381	6.4		5.6		1.14		2.1		112		12.0	
382	6.4		5.0		1.28		2.4		88		13.0	
383	6.2		5.0		1.24		2.2		118		13.4	
384	6.4		5.4		1.18		2.3		128		12.0	
385	5.0		6.4		0.78		2.0		57		11.0	
386	3.3		2.6		1.26		1.7		112		13.0	
387	5.7		4.5		1.26		1.7		88		13.6	
388	5.5		5.5		1.00		2.3		46		12.0	
389	7.0		5.5		1.27		2.1		61		11.0	
390	5.0		5.3		0.94		1.3		33		14.4	
391	7.0		5.4		1.29		1.9		101		14.0	
392	4.8		4.0		1.20		2.0		53		13.0	
393	4.0		5.0		0.80		1.0		77		13.4	
394	5.5		4.7		1.17		2.1		98		12.0	
395	5.4		5.6		0.96		1.6		93		14.0	
396	6.5		6.0		1.08		1.6		98		11.0	
397	6.0		6.1		0.98		1.7		88		13.2	
398	6.6		5.4		1.22		2.1		42		14.0	
399	5.0		5.3		0.94		1.0		41		13.6	
400	5.0		4.0		1.25		1.8		75		11.0	

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Vita

9. VITA

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of

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in

HORTICULTURE

2005

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