STUDY ON FIELD AND STORAGE PERFORMANCE IN TERMS OF DISEASES OF SIX BARI ONION VARIETIES

AFIZA KAKON TOMA

DEPARTMENT OF PLANT PATHOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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STUDY ON FIELD AND STORAGE PERFORMANCE IN TERMS OF DISEASES OF SIX BARI ONION VARIETIES

BY

AFIZA KAKON TOMA

Registration No. 19-10235

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Approved by:

....
Dr. M. Salahuddin M. Chowdhury
Professor
Department of Plant Pathology
Sher-e-Bangla Agricultural University
Supervisor

....
Dr. Nazneen Sultana
Professor
Department of Plant Pathology
Sher-e-Bangla Agricultural University
Co-Supervisor

....
Abu Noman Faruq Ahmmed
Professor and Chairman
Department of Plant Pathology
Sher-e-Bangla Agricultural University

Department of Plant Pathology
Sher-e-Bangla Agricultural University

PABX: +88029144270-9
Fax: +88029112649
Web site: www.sau.edu.bd

CERTIFICATE

This is to certify that the thesis entitled, **"STUDY ON FIELD AND STORAGE PERFORMANCE IN TERMS OF DISEASES OF SIX BARI ONION VARIETIES"** *submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE IN PLANT PATHOLOGY** *embodies the results of a piece of bona fide researchwork carried out by* **AFIZA KAKON TOMA** *bearing Registration No.* **19- 10235** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.*

I further certify that such help or sources of information, as have been availed of during the course of this investigation has duly been acknowledged.

Dated:

Place: Dhaka, Bangladesh

Dr. M. Salahuddin M. Chowdhury
Professor
Department of Plant Pathology
Sher-e-Bangla Agricultural University
Dhaka- 1207
Supervisor

DEDICATED

TO

MY BELOVED

PARENTS AND

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Abstract

The experiment was conducted in the field and store house of Spices Research Centre, BARI Shibganj, Bogura, Bangladesh during 2019-2020 to evaluate the field and storage performance of six varieties of BARI Piaz viz., BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, BARI Piaz-4, BARI Piaz-5 and BARI Piaz-6. The field experiment was conducted for producing bulbs and observing the field performance. In the field BARI Piaz-4 showed maximum plant height (50.39-71.50 cm), bulb length (7.57cm), bulb diameter (4.97cm), single bulb weight (71.33g) and yield (36.53t/ha). Where BARI Piaz-5 showed minimum plant height (43.05-58.61 cm), bulb length (4.84cm), bulb diameter (3.91cm), single bulb weight (41.17g) and yield (14.64 t/ha). On the other hand, highest disease incidence of purple blotch (4.19%) and Stemphylium (43.41%) were observed in BARI Piaz-5 where lowest disease incidence of purple blotch (3.49%) and Stemphylium (34.91%) were observed in BARI Piaz-4. After air dried the harvested onion bulbs of six varieties were stored in the store house. Bulbs were stored in a wooden structure under ambient condition. The average air temperature of the store house was 27.19-29.30℃ and humidity 61.63-80.90%. Different storage performances were recorded at an interval of 15 days viz., 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI. Highest number of sprouted bulbs were observed in BARI Piaz-3 at 15, 30, 45, 60, 75and 90 DAI. Where lowest number of sprouted bulbs were observed in BARI Piaz-4. Total percent of sprouted bulbs 8.51%, 38.51%, 46.34%, 14.33%, 29.67% and 15% were observed in V_1, V_2, V_3, V_4, V_5 and V_6 respectively. Highest number of rotten bulbs were observed in BARI Piaz-3 and lowest number of rotten bulbs were observed in BARI Piaz-4. Total percent of rotted bulbs 56.17%, 56.83%, 73.17%, 40.27%, 58.16% and 62.99% were observed in V_1, V_2, V_3, V_4, V_5 and V_6 respectively. At storage, total maximum bulb weight loss 78.70% was observed in BARI Piaz-3 where minimum weight loss 49.42% was observed in BARI Piaz-4. From the study it is found that BARI Piaz-4 performed best than the other varieties at storage. Where BARI Piaz-3 showed lower performance. *Aspergillus niger, Fusarium* sp. and *Penicillium* sp. have been found to cause diseases during postharvest storage condition. In this study, 65% rotten of onion bulbs by *Aspergillus niger,* 20% by *Fusarium* sp., 10% by *Penicillium* sp. and 5% by other pathogens were found.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Onion (*Allium cepa L.*) belongs to the Alliaceae family and is one of the most important spices as well as vegetable crops (Hanelt, 1990). Spices are important constituents of food items. A good number of spices crops are grown in Bangladesh. The major ones are Onion, Garlic, Ginger, Turmeric, Coriander, Chilli etc. Onion has manifold uses; as spices, vegetable, salad, dressing etc. Onion is an indispensable item in every kitchen. The onion is therefore commonly referred to as the "Queen of the Kitchen". Onion contains the lachrymatory principle, a strong antibiotic having fungicidal, bactericidal and nematicidal properties (Purseglove, 1972). Onion due to the presence of a volatile oil 'allyl propyl disulfide'- an organic compound rich in sulfur, is liked for its flavor and pungency. It contains chemical compounds with potential anti-inflammatory, anti-cholesterol, anti-cancer and antioxidant properties, such as quercetin (Slimestad *et al.* 2007). Smith (2003) reported high levels of phytochemicals specially flavonols, which provide colour, texture and taste in onions. It is also of high medicinal value in controlling human and plant diseases (Vohora *et al*. 1973).

The world's leading onion growing countries are China, India, the United States, Holland, Korea, Israel, Japan, Turkey, Syria, Iran, Egypt, Lebanon and Austria (FAO, 2012). China is the largest onion producer in the world with 249.89 lakh metric tons production per year. China and India both produces together more than 50% of world's total onion globally (FAOSTAT, 2019). Major onion producing districts in the country are Rajshahi, Faridpur, Pabna, Meherpur, Kushtia, Magura, Bogura, Rangpur, Thakurgaon, Dinajpur and Jamalpur (Fuad, 2022).

Total onion production area in Bangladesh 1.95 lakh hectares (BBS, 2021). It covers almost 36% of the total areas under spices. It grows extensively during winter season in Bangladesh but at present it also grows in the summer season. The total production of onion in Bangladesh is about 22.69 lakh tons against domestic demand of round 20.6 lakh tons, amount after loss 17.02 lakh tons (BBS, 2021). Officials claimed on recorded that relegating the United States a spot behind, Bangladesh had now emerged as the world's 3rd largest producer of onion after China and India (Ahmed, 2022). It is most widely grown and popular vegetable crop among the *Alliums* as well as cash crops. *Allium* is the onion genus, with 600-920 species, making it one of the largest plant genera in the world. BARI developed 6 onion varieties named as BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, BARI Piaz-4, BARI Piaz-5 and BARI Piaz-6. Among them BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5 are summer variety. BARI Piaz-1, BARI Piaz-4 and BARI Piaz-6 are winter variety.

Onion is highly susceptible to many foliar, bulb and root pathogens which reduces yield and quality (Cramer, 2000). Onion is attacked by 66 diseases including 10 bacterial, 38 fungal, 6 nemic, 3 viral, 1 mycoplasmal, 1 parasitic plant and 7 miscellaneous diseases and disorders (Schwartz and Mohan, 2008; Schwartz, 2010). The major fungal diseases are purple blotch (caused by *Alternaria porri*), damping off (caused by *Pythium* sp., *Phytopthora* sp., *Rhizoctonia solani*, *Fusarium* sp.), downy mildew (*Peronospora destructor*), basal rot (*Fusarium oxysporum* f.sp. *cepae*), Botrytis leaf blight (*Stemphylium vesicarium*); major bacterial diseases are flower stalk and leaf necrosis (*Pantoea agglomerans*); major viral diseases are yellow dwarf (*Onion yellow dwarf virus*) and Irish yellow spot (*Irish yellow spot virus*); nematode diseases are stem and bulb nematode (*Ditylenchus dipsaci*) and root knot nematode (*Meloidogyne incognita*). Among the pathogens some cause diseases at field condition and some cause diseases at storage condition. In Bangladesh onions are attacked by ten diseases caused by various pathogens (Ahmed and Hossain, 1985; Bose and Som, 1986). Among the foliar diseases, purple blotch is one of the most destructive diseases in almost all onion growing countries in the world, which causes heavy loss under field conditions. The low productivity of onion in India is chiefly attributed to prevalence of purple blotch leaf blight and stemphylium leaf blight in almost all the onion cultivated areas of the Northern and Eastern regions (Gupta *et al*., 1996; Suhag and Bhatia, 2006). Purple blotch of onion is noted as a major diseases throughout the world including Bangladesh (Ahmed and Hossain, 1985; Meah and Khan, 1987; Bose and Som, 1986; Castellanos-Linares *et al.*, 1988 and Islam *et al*., 2001).

In the world onion is stored in three conditions viz., cold storage, ambient storage or heat storage and controlled atmosphere storage. In Bangladesh there are two cold storage located at Faridpur and Pabna. BADC stored 200 tons seed onion bulb per cold storage at 0°C temperature. Farmers stored nearly 12-13 lakh tons at normal condition. Due to warm weather condition in Bangladesh, onion is stored at natural temperature and humidity called ambient storage or heat storage (Khan and Rahman, 2020). During storage some losses are encountered due to sprouting, drying and rotting (Currah and

Proctor, 1990). However, the most common factor responsible for loss of onions in storage is from bulb rots (Shehu and Muhammad, 2011). There are many factors responsible for the storage losses of onion. Postharvest diseases are one of them. Onion bulbs rot are caused by micro organisms specially fungi leading to economic loss. About 15 different fungal species are reported responsible for the onion diseases in the storage and transit all over the world for which the loss may go up to 40% (Aiyer, 1980). Fungi are the major causal agents responsible for storage losses (Adongo *et al*., 2015; Ara *et al*., 2008; Kumar *et al*., 2015; Padule *et al*., 1996; Rajapakse and Edirimanna, 2002; Samuel and Ifeanyi, 2015; Shehu and Muhammad, 2011). The most destructive diseases in storage are Blue mould rot (*Penicillium* spp.), Basal rot (*Fusarium moniliforme*), Aspergillus rot (*Aspergillus* spp.) etc. Black mold (Aspergillus niger Van Tieghem) is more prevalent in the tropical region of the country. The disease is more common in Bangladesh wherever onion is stored. *Aspergillus niger* caused black mould disease was reported to be predominant one and causes 30 to 80% loss/spoilage of onion bulb (Quadri *et al*., 1982). Severe incidences of black mould caused by *Aspergillus niger* on onion bulbs in storage have been reported from India (Gupta *et al*., 1991; Maheshwari, 1988), Sudan (Hayden *et al*., 1994,) Israel (Grinstein *et al*., 1992), Egept (Zohri *et al*., 1992), Australia (Salvestrin and Letham, 1994), Taiwan (AVRDC, 1999) and United States (Ceponis, 1986). However, blue mold (Penicillium spp.) is reported to be caused by various species of pathogens on bulbs throughout the world. *Aspergillus niger* infect bulbs at high temperature with high relative humidity while *Penicillium* spp. may destroy bulbs even at low temperature. Infection by *Penicillium* spp. may produce the mycotoxin penitrem A, which has been recently implicated in tremorgenic toxicosis (Overy *et al*., 2005) in man and animals. *Aspergillus niger* has been reported to survive between onion crops as a soil saprophyte in or on bulbs in field or storage and in ubiquitous in nature.

In Bangladesh more than eight varieties are cultivated and stored. Limited work so far seen conducted on field performance and storability of varieties and comparative performance of these variety.

Considering the above stated situations, the present study was undertaken the following objectives:

i. To observe the field performance of six varieties of BARI onion.
ii. To observe the storage performance of onion varieties and identify the causes of loss of onion bulb at storage.
iii. To identify the pathogenic fungi associated with infected bulbs.

CHAPTER II

REVIEW OF LITERATURE

Onion (*Allium cepa L.*) is one of the world's main bulbous vegetable crops and one of the Bangladesh's most important commercial spice crops. The production and storage of bulbs are influenced by various factors. Onion bulb production and storage are greatly influenced by environmental factors, agronomic practices and cultivars (Mondal *et al*., 1986; Mondal *et al.*, 1991). Researcher all over the world has been carrying out their research on field performance and storage performance of different onion varieties. In Bangladesh very few works have been done in this respect. The available information in this connection over the world has been reviewed in this chapter.

2.1 Field works on onion

Wallroth (1833) first reported the association of *Stemphylium* with asparagus (*Asparagus officinalis* L.) and named the genus *Stemphylium*. Cooke and Ellis (1879) for the first time reported the leaf blightof leek (*Allium porrum* L.) in the United States of America and described the causal agent as *Macrosporium porri*. Ajrekar (1921) first reported *Macrosporium* sp. as causal agent of purple leaf blotch (PLB) of onion. Nolla (1927) reported PLB of onion and described the fungus as *Alternaria alli*. He coined the term 'Purple blotch' for the *Alternaria* disease on onion. While Ayyanagar (1928) reported *Alternaria palandui* as causal agent of onion blight.

Angell (1929) described that *Alternaria alli* and *Macrosporium porri* were identical except for theminor variations, which do not warrant species distinction. Further, he also reported that *Macrosporium porri* could cause bulb rot as well as purple coloured foliage lesions and *Alternaria porri* never forms chain of more than two conidia.

Cifferi (1930) reported that the conidiophores arouse singly or in groups and were straight or flexuous, sometimes geniculate, pale to mid brown, up to 120 µm in length with one or several well defined conidial scars. Conidia occurred singly, straight or curved and tapered to a beak that was commonly about the same length or larger than the body of conidium. The conidial length ranged from 100 µm to 300 µm with the broadest part being 15 to 20 µm width having 8-12 transverse and zero to several longitudinal or oblique septa. The beak was flexuous, pale, 2-4 µm thick and tapering.

Wiltshire (1938) proposed the original and modern concept of *Stemphylium*. A leaf spot disease of onion caused by *Stemphylium vesicarium* was first reported from Nasik district of Maharastra. Thirumalachar and Mishra (1953) also reported *Alternaria porri* as the causal agent of PLB of onion.

Thirumalachar *et al.,* (1953) reported about the existence of some varietalresistance and they stated that the fungus *Alternaria porri* (purple blotch) caused severe scorching of some onion varieties at the College of Agriculture, Sabour; but the indigenous red variety had remained uninfected.

Pandotra (1964) reported that PLB symptoms are very prominent on the inflorescence stalks. Bulbs can be infected through neck wounds after harvest causing storage rot. Storage symptoms appear as a dark yellow to wine-red showing spongy rot of outer or inner scales of bulbs. Yield losses to the extent of 20-25 per cent and 92 per cent in Punjab and Maharashtra also have been reported; 44 percent reduction in yield (Bock, 1964).

Simmons (1969) reported that a link between *S. vesicarium* and *P. allii* on onion leaf debris. *A. porri* and *S. vesicarium* often occur in the same PLB lesion and have been shown to beequally pathogenic to onions and leeks, causing a disease complex. He also reported that Asci were bitunicate, cylindrical to club- shaped, measuring 112-168 µm x 20-31 µm (average 131 µm x 26 µm). Ascospores werelight brown, ellipsoidal to ovate, 23-41 µm x 10-18 µm (average 32 µm x 14 µm) and had 3-7 transverse septa. The size of the fruiting bodies and ascospores of *P. allii* on onion leaves and inflorescence stalks were smaller than those on artificial medium.

Raju (1970) described the morphology of *Alternaria porri*. The hypha of *Alternaria porri* (Ellis) Cif. were septate and irregularly branched. The hypha obtained from the diseased lesion and culture medium were of different thickness and measured 3-10 µm and 5-13 µm, respectively. Conidiophores were straight, septate and dark brown bearing conidia singly at the apex. Conidia were beaked, elongated with rounded bases having 3-11 transverse septa and 45-190µm x 10-25 µm in size (Ellis, 1971).

Rao and Pavgi (1975) first reported SLB from India on garlic. Later, it has been recorded on garlic in the United States of America. Similar symptoms were shown on onion. *Stemphylium botryosum* (Singh and Sharma, 1977). *Stemphylium vesicarium* as the causal organism of leaf blight of onion founded by Miller *et al.,* (1978).

Utikar and Padule, (1980) reported that *Alternaria alternata* as the causal agents of

PLB. Qadri *et al.*, (1982) reported that PLB disease is more serious in Kharif (62%) than in Rabi season (38%) and caused total loss in seed yield. Yield losses to the extent of 20-25 per cent and 92 per cent in Punjab and Maharashtra have been reported. Often, the disease is aggravated by prior attack of *Botrytis* or thrips on leaves.

Sandhu *et al*., (1982) reported that none of 102 genotypes they screened was resistant to *Alternaria porri.* However, they could locate 12 genotypes which showed moderate resistance reaction. The genotypes that had flat erect leaves showed moderately resistance reaction whereas all those with curved, drooping leaves were susceptible.

Alves *et al.*, (1983) studied the incidence of purple spot (*Alternaria porri* EII. Cif.) on onion cultivars and hybrids in Manaus, Amazonia. Plants were divided into five classes on the basis of natural infection in the field. Incidence was 30- 50% (class II) in most cases; only the hybrids Px76 having plants in class I (0- 10%).

Miller (1983) reported that PLB causes considerable yield losses in onion production world-wide. The yield losses are mainly through loss of leaf tissue and subsequent reduction in rate of bulb development. The disease incidence and crop losses varied from place to place and season to season. He observed that the older leaves are more susceptible than younger leaves, and young leaves are relatively more susceptible when they emerge close to bulb maturity. Similar lesions are also formed on seed stalks as a result, seeds either do not develop or remain shrivelled. Severely infected foliage cause die back. The disease symptoms first appear only 54-69 days after transplanting (Ariosa and Herrera, 1984).

Ariosa-Terry and Herrera (1986) measured the damage of onion due to purple blotch caused by *Alternaria porri*. The first symptoms appeared 50 days after sowing and disease intensity was the highest at 110 days. White onions were more affected than red onions.

Gupta and Pandey, (1986) found that *Stemphylium* leaf blight (SLB) is prevalent in onion growing areas of India and causes severe losses in northern India. The disease has also been reported on garlic. He also reported that SLB is more severe in Rabi than in Kharif season and causes 90 per cent loss in seed yield.

Dhiman *et al.,* (1986) found that PLB disease causes 62-92 per cent reduction in leaf production. In India, this is one of the severe diseases of onion affecting both bulb and seed crop. Crop losses to the extent of 50-100 per cent have been reported in Canada

(Tolman *et al.*, 1986) and Indonesia (Sastrahiday at, 1995); 59 per cent in bulb yield (Gupta and Pathak, 1988b) and 97 per cent in seed yield (Lakra, 1999).

Gupta and Pathak (1988a) studied 21 indigenous and exotic cultivars screened at 2 locations in India under artificial condition. All the exotic lines except 2 fromthe Sudan were highly resistant to *Alternaria porri* while all the indigenous lines were found susceptible. It is suggested that susceptible cultivars should be replaced by the resistant Pusa Red.

A leaf spot disease of onion caused by *Stemphylium vesicarium* was reported by Patil and Patil (1991). Senthilnathan and Narasimhan, (1992) reported that *Alternaria tenuissima* as causal agents of PLB. SLB has been recorded on garlic in the United States of America, South Africa (Aveling and Naude, 1992; Aveling, 1993), Spain (Basallote *et al.*, 1993), Brazil (Boiteux *et al.*, 1994), and Australia (Suheri and Price, 2000b).

Bhonde *et al.,* (1992) conducted a field trial during 1987-1988 on 8 onion cultivars (Agrifound Light red, Arka Niketan, L-102-1, Nasik Red and Pusa Red,Agrifound Dark Red, Arka Kalyan and Kharif Local). Agrifound Light Red hada good yield and had the highest drymatter content.

Hill (1995) reported that the SLB first appears as elongated, small spindle shaped white flecks, which enlarge and produce sunken purple lesions often surrounded by a yellow to pale brown border. These lesions cause extensive necrosis, resulting in premature drying of leaves and cessation of bulb development.

Miller and Lacy, (1995) found that PLB disease is widely prevalent in almost all onion growing areas especially in warm and humid environments of the globe. Aveling (1998) found that 'Purple blotch' for the *Alternaria* disease on onion. He observed that PLB symptoms on leaf and flower stalk initiate as small, elliptical white lesions, extend to large, sunken purple lesions with concentric dark and light zones. The fungus sporulates heavily in the dark zones while sparsely in the light zones. These blotches may enlarge up to four inches long, on which black fruiting bodies with spore mass appears. Infected leaves are curled and may die.

Sharma (1997) studied onion genotypes grown in Himachal Pradesh, India, for resistance to *Alternaria porri* during 1991-92. He observed those lines IC48059, IC48179, IC39887, IC48025 and ALR resistant.

Srivastava *et al.,* (1999) reported that PLB is an economically important disease of *Allium* sp. world-wide. The disease is less prevalent and less troublesome in the cool temperate parts of the world.

Basallote-Ureba *et al.,* (1999). also observed that the sexual stage of *Stemphylium vesicarium* is reported to be *P. allii* (Rab) Ces. and De Not., which produced pseudothecia on garlic debris in the soil under natural conditions. The pseudothecia were black, globose structures, 100-500 µm diameter, with an apical ostiole.

Suheri and Price (2000) observed that the symptoms of PLB are generally indistinguishable from those of SLB, and the disease is considered to be a complex caused by both pathogens. *Stemphylium vesicarium,* incitant of SLB of onion is considered to initiate the infection, which facilitates subsequent infection of *Alternaria porri* causing PLB and hence, the disease is designated as purple blotch complex (Uddin *et al.,* 2006).

Suheri and Price (2001) reported that during wet season, shallots yield losses to the tune of 60 to 70 per cent had occurred in Australia due to high incidence and severity of PLB.

Simmons (2007) found that *Alternaria porri* is a haploid fungus which belongs to the phylum Ascomycota, class Dothideomycetes, order Pleosporales and family Pleosporaceae. There is no report of occurrence of sexual state of the fungus.

Chethana *et al*., (2011) conducted the screening of onion genotypes for purple blotch under field condition of onion revealed that, the genotype Arka Kalyan was found moderately resistant while the genotypes viz., Rampur Rose, Agrifound Rose, Arka Pragati, Arka Niketan, Arka Pitamber and Arka Bindu were found moderately susceptible to purple blotch of onion.

Kumar *et al.,* (2012) conducted an experiment in the Department of PlantPathology, Bihar Agricultural College, Sabour to locate the sources of resistanceof *Alternaria porri*. 45 days old seedlings were inoculated by spraying the spore suspension (1 × 106 spores/ml) of *Alternaria porri*. Seedlings in pots were subjected to humid chamber for about 24 hours before and after inoculation. Thevariety Arka Kalyan appeared most resistant recording the least disease intensity (5.53 percent only), although being statistically *at par* with Arka Niketan and Agri. Foundation Dark Red recording 6.36 percent and 6.33 percent disease intensity.

Mohsin *et al*., (2016) reported that twenty seven isotates of *Alternaria porri* were isolated from diseased leaf samples collected from different onion growing regions of Bangladesh and characterized for cultural, morphological and pathogenic variability. *A. porri* colony colour ranged between light to dark olivaceous and grayish white with irregular, regular with concentric ring and regular without concentric ring shape. Margin of colonies were entire, irregulaer and wavy with effuse, fluffy and velvety texture. Isolates impregnated media with color ranged between grey to brown on the reverse of the plates.

Bal *et al.,* (2019) studied the 23 genotypes of onion were screened against purpleblotch disease where none of the genotypes were found to be immune. Five genotypes viz., Akola Safed, Arka Niketan, Punjab Naroya, Arka Lalima, Arka Kirtiman exhibited resistance to this disease. Eight genotypes viz., BhimaSubhra, Arka Bheem, PRO-6, Bhima Raj, Kalyanpur Red Round, L-28, Bhima Dark Red, Bhima Shakti were found to be moderately resistant with 11-20% leafarea infected. A total of ten genotypes were grouped under moderate susceptiblecategory (21-40% leaf area infected).

Mansha *et al.,* (2019) studied the potential of 25 onion genotypes were evaluatedagainst purple blotch and their yield response during two years (2014–15) under field conditions. Five varieties (Phulkara, Sunset, Ceylon, TI-172, XP-Red) showed resistant response while Desi Red, Early Red, Robina, Dark Red and Mirpurkhas exhibited moderately resistant response. VRIO-6, VRIO-1, VRIO- 4, Red Nasik and Desi Black were found moderately susceptible against the disease. VRIO-9, Pak-10321, Fsd Red, Pusa Red and Red Imposta gave susceptible response, while VRIO-3, VRIO-5, VRIO-8, VRIO-7 and VRIO-2 exhibited highly susceptible response.

2.2 Storage works on onion

Hayden *et al.,* (1994) reported that the virtual absence of soil and air-borne inocula of *Aspergillus niger* and of naturally contamination of healthy onion seeds with *Aspergillus niger* resulted in increased incidence of black mould in the field and stored bulbs.

Nandasana *et al*., (1998) stated that the post-harvest losses in onion can be as high as 40-50% due to weight loss, sprouting and rotting.

Visser (1999) carried out experiments to investigate the varietal susceptibility of 11 onion cultivers to *Fusarium oxysporum* fsp. *Cepae* (in the field, at harvesting and after storage). None were found resistant.

Gruszecki and Tendaj (2000) examined weight losses of onion bulbs during longterm storage in a common store. Onions obtained from sets comared with onions from transplants and seeds were characterized by significantly higher susceptibility to disease. Disease problems were more likely when onions were stored after mid-march.

Kozakiewicz (2000) reported that *Aspergillus niger* is commonly isolated from seeds of spices, onions and garlic. On plants it causes black mould disease of onion bulbs and garlic. Serious losses are occurring in post-harvest decay of onion bulbs.

Vinod *et al*., (2000) evaluated the storage quality of bulb of onion cultivars under room temperature. Observations on rotting, sprouting and total weight loss were recorded at 30 day interval. Results indicated that bulb rotting, sprouting and weight loss increased with increasing storage duration.

Joon Taek *et al*., (2001) examined post-harvest decay of onion bulbs in storage. Bulb rot incidence was unexpectedly high and onion bulbs with 1^{st} quitly grade were rotten most severely by 51%, followed by 32% for 2^{nd} and 21% for 3^{rd} grades. This indicates that larger bulbus had higher incidences of bulb rots. Major pathogens associated with basal and neck rots were *Fusarium oxysporum* and *Aspergillus* sp. or *Botrytis alli,* respectively of which basal rot was most prevalent and damaging during storage.

Nagerabi and Ahmed (2001) investigated the biology of black mould (*Aspergillus niger*) on two local onion cultivers. Natural seed contamination and artificial infection of onion seeds with spore suspension of *Aspergillus niger* reduced seed germination, reduced emergence and distorted seedlings growth, presumably due to the toxic metabolites secreted by the fungus.

Gurkina (2002) reported that the most dangerous diseases for onions are *Fusarium* bulb rot (*Fusarium* spp.) and White rot (*Sclerotium cepivorum*).

Krawiec (2002) stated that the weight losses and total storage losses, i.e. complete drying occurs on onion bulbs of various sizes stored onion at 0-1 and 18-20℃ temperature. Bulbs stored at 18-21℃ had higher bulb rots (27.1%) and weight losses (35.9%) than those stored at 0-1℃. The smaller bulbs had greater weight losses than the larger ones, regardless of storage temperature and cultivar. The smaller bulbs completely dried up and some sprouting was observed.

Satish *et al.,* (2002) stated that onions with or without foliages subjected to sun and artificial curing before storage on a concrete floor covered with paper sheets under ambient conditions. They also stated that water loss, sprout loss and disease loss were the major storage loss variables responsible for onion losses during storage.

Srinivasn *et al.,* (2002) found *Aspergillus niger* (black mould) in onion during storage. Market survey for the assessment of spoilage caused by the fungus recorded a loss of 2.9% to 12.09%. bulb rotting was noticed when the storage temperature was between 30 and 40°C and the relative humidity was above 80%. *Aspergillus niger* and *Aspergillus flavus* were isolated from infected onions.

Afek and Orenstein (2003) conducted a study to investigate the effect of Hydrogen Pheroxide Plus (HPP) and curing on the storage decay, (caused by *Aspergillus niger*) life and quality of onion cultivars. The treatments were applied on onion cultivers and stored for 5 months at 22°C and 60% relative humidity. Hydrogen Pheroxide Plus (HPP) and curing treatments reduced onion decay during storage.

Nagerabi and Ahmed (2003) tested the courses of pre and post harvest epidemiological studies on bulbs contaminated by *Aspergillus niger*. *Aspergillus niger* spores, either seed borne. Soil borne or air borne, were avirulent to the healthy onion plants. The fungus heavily contaminated the dead onion tissues, mainly the dead leaves followed by dry scales, dead roots and to a lesser extent, bulb necks, preferring the red skinned cultivar to the white one. The initial spores carried from a naturally contaminated field soil on the dead tissues could germinated and produce massive numbers of new spores on bulbs stored at average climatic conditions (23-39±°C, under 29-93% relative humidity).

Patil *et al*., (2003) screened eight dark red onion genotypes and 3 control cultivars during 3 months of storage. Only marketable onions subjected to post-harvest treatments are used. After 3 months, mean total losses of 15.98% were recorded, including 13.18% physiological losses were recorded only during the third month of storage.

Surviliene (2003) reported that the fungi colonizing onion bulbs under field conditions which later caused storage decay. Fungi had been isolated from bulbs and later in stored at 2-4°C for 4 and 7 months. Among them *Penicillium* spp.is more prevalent. The most frequent onion diseases during storage were *Fusarium* bulb rot (*Fusarium* spp.), blue mould (*Penicillium* spp) black mould rot (*Aspergillus niger).* Mixed rots of onion bulbs were predominant. Losses ranged from 3.98% to 13.15% in storage.

Chaugule *et al*., (2004) conducted a survey at field and market in Maharashtra, Gujrat, Orissa, Tamil nadu, Karnataka, Rajasthan and Andhra Pradesh of India to assess post-harvest losses in onion. The highest percentage of unmarketable bulbs was recorded in Karnataka (13.8%), followed by Tamil nadu (12.0%). The highest percentage of loss due to drying was recorded in Andhra Pradesh (5.4%), followed by Gujrat (4.25%), where as the highest percentage of loss due to spoilage was recorded in Tamil nadu (5.0%), followed by Karnataka (3.4%).

Gruszecki (2004) stored bulbs of onion cultivers were under ambient conditions and found that bulb size had no significant effects on the marketable yield, and sprouting and rotting of the bulbs during storage, however smaller bulbs recorded the higher weight loss.

Tyson and Fullerton (2004) stated that *Aspergillus niger* is the cause of black mould of onion, which is primarily a post-harvest disease. The highest levels of soil-borne *Aspergillus niger* occurred in fields that had not been recently rotated out of onions. Levels of soil-borne *Aspergillus niger* were correlated with black mould incidence in bulbs stored at high temperature and high humidity, but not in bulbs stored at ambient temperature and high humidity.

Velez *et al*., (2004) attempted to isolate and identify fungi associated with the onion. Fungi were isolated from bulbs that showed typical disease symptoms. *Aspergillus niger* was the fungus most frequently isolated from bulbs and seeds. *Penicillium* also isolated from onion bulbs.

Wright and Triggs (2004) observed the effects of cultural practices during and after harvest of onion (*Allium cepa*) on bulb quality and incidence of storage rots (caused by several species of bacteria) and fungal moulds (including *Aspergillus niger* and *Penicillium* spp.) under both ambient and refrigerated simulated shipping. They observed that refrigeration reduced the severity of surface moulds of onion.

Ahmed *et al*., (2005) conduct a study on assessment of post-harvest losses on the bulbs of two onion cultivars. Significant differences were found in the mean values of dry matter, weight loss, rotting and total losses in the bulbs of cultivers. Total losses 58.48% were recorded in one cultivar and 0-17.38 were recorded in the other cultivar at three month of storage.

Tariq *et al*., (2005) conducted a study on assessment of post-harvest losses on the bulbs of two onion cultivers (Swart-1 and Afghan White) (temp. 20°C min. and 30°C max.). Significant differences were found in weight loss, rotting, sprouting and total losses in the bulbs of two cultivers. Maximum sprouting (99.0%) and total losses (58.48%) were recorded in swat-1 cultiver at 3rd month of storage. In afghan white, rotting increased from 0-17.38% during 3 months storage period. Maximum weight loss was 14.93% at 3rd month of storage in swat-1 cultiver while 9.42% was in afghan white at the 2nd month of storage.

Gutierrez and Cramer (2005) stated that Fusarium basal rot (FBR), caused by *Fusarium oxysporum* is a soil borne fungal disease that affects bulb onions. Short day onion cultivers that are resistant to FBR are lacking. To screen fall-sown onion germplasm for FBR resistance using a mature bulb field screening at harvest and after 4 weeks in storage. The experiment was conducted for 2 years, and in storage each year, 26 fall-sown onion lines were grown in a field known to produce a high incidence of Fusarium basal rot infected bulbs. When all the bulbs in a plot were mature, the basal parts of 20 bulbs were cut transversely and each plate was rated for diseases severity on scale of one (no diseased tissue) to nine (70% or more diseased). Bulbs were stored and re-rated at 2 and 4 weeks after harvested. Disease severity and incidence were higher in the first year than in the second year.

Visser *et al*., (2006) stated that *Fusarium* basal rot of onion, caused by *Fusarium oxysporum* Esp. *cepae*, is a steadily increasing problem. Financial losses confronted with *Fusarium* basal rot is substantial, due to yield reduction and high storage costs.

Raju and Nail (2006) stated that *Aspergillus niger* and *Penicillium* spp. are the predominant fungal pathogens associated with storage diseases of onion causing black mould, respectively. The disease incidence increased with increase with duration of storage irrespective of the treatments.

Chope *et al.,* (2007) used controlled atmosphere (CA) storage to increase the storage life of onions in their study. Removal of bulbs from controlled atmosphere storage resulted in an immediate increase in the respiration rate (measured in air), which then reverted to a lower rate following subsequent storage under air conditions for 21 days. In some cultivers, this could be sufficient to trigger the onset of sprouting and thus account for the detrimental effect of controlled atmosphere storage on shelf-life. Delaying the start of CA storage of onions on some cultivers suppress their sprouting.

Morgen *et al*., (2007) concluded a storage experiments with commercial onion cultivers with significant differences in quercetin glucoside content. But neither nitrogen fertilizer level nor lifting time had more than minor effect at start of strong or after 3 or 5 months of storage. After 5 months of storage, sprouting was recorded during a shelf-life period of 9 weeks at room temperature. Early lifting resulted in onions with low sprouting and good storage abilities without negative effects on quercetin glucoside content.

Ara *et al.,* (2008) reported that five different fungi were repeatedly isolated and identified by PDA plate incubation method from four local varieties of onion namely Taherpuri, Faridpuri, Kalashnagari, Zitka and one Indianvariety. These fungi were *Aspergillus niger*, *A. flavus*, *Penicillium* spp. *Fusarium oxysporum* and *F. moniliformie*. Fungal diseases viz. black mould, blue mould rot and *Fusarium* bulb rot are serious problem of onion bulb and loss due to these diseases may be minimized by taking measures in the field, during transit and in storage so that bulbs are not injured.

2.3 Comparative works on onion

Das (2010) reported that at seedling stage in net house no disease incidence of white blotch of onion (Stemphylium vesicarium) were recorded in case of BARI Piaz-3, Indian big and Indian small. The lowest disease incidence and highest yield also recorded in BARI Piaz-3, Indian big and Indian small among nine onion cultivers viz. BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, Thakurgong local, Faridpur local, Manikgong local, Indian big, Indian small and Taherpuri. BARI Piaz-1 showed lower performance in respect of all parameters.

Kibria (2010) reported that BARI Piaz-3 gave lowest disease incidence and highest yield (12.67 t/ha) against purple blotch of onion (*Alternaria porri*) among nine onion cultivers viz., BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, Thakurgong local, Faridpur local, Manikgong local, Indian big, Indian small and Taherpuri. In case of disease reaction 8.00% observed in BARI Piaz-3 and was graded as resistant.

Khalequzzaman (2018) reported that black mould rot caused by *Aspergillus niger* is often responsible for severe damage to onions during storage. He also observed that there was no effects of fungicides on rotted and sprouted bulbs of all varieties of onion for whole storage periods. Summer varieties viz. BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5 showed around 50% rotted and sprouted bulbs at 20-25 days after initiation. But winter varieties viz. BARI Piaz-1 and BARI Piaz-4 showed around 50% rotted and sprouted bulbs at 130 DAI. Among the winter varieties, BARI Piaz-4 was more stable to BARI Piaz-1.

CHAPTER III

MATERIALS AND METHODS

The details of the materials and methods of this research work are described in this chapter under the following headings and sub-headings.

3.1 Experimental sites

The experiment was conducted in the field and store house of Spices Research Centre, BARI, Shibganj, Bogura, Bangladesh. The experimental field is located at the 24°51N latitude and 89°22E longitude with an elevation of 20 meter from sea level.

3.2 Experimental period

The experiments were carried out during the rabi season from November, 2019 to March, 2020. Seeds were sown on 7th November, 2019 and were harvested on 25-30 March, 2020.

3.3 Soil type

The soil of the experimental site belongs to the Ageo-ecological region of "Level Barind Tract" (AEZ No. 25). The predominant soil texture is sandy loam. The P^H of the top soils ranges from 6.20 to 6.23. The soil in general fertile and rich in Iron, Phosphrous and Manganize. The information about the soil of experimental site is given (Appendix- ii).

3.4 Weather

The monthly mean of daily maximum, minimum and average air temperature, relative humidity, monthly and total rainfall at the experimental site during the period of the study have been collected from Bangladesh Meteorological Department, Bogura and presented in (Appendix-iii).

3.5 Land Preparation

The experimental field was ploughed with power tiller drawn rotovator. After ploughing the field, it was left to nature for 10 days for sun and nature to work upon. Subsequent cross ploughing was done followed by laddering to make the land level. Then the soil clods were broken by a wooden hammer and all weeds, stubbles and residues were removed from the field.

3.6 Application of Fertilizers

Manure/Fertilizers	Dose hectare^{-1}
Well decomposed cow dung	5.0 ton
Urea	120 kg
Triple supper phosphate (TSP)	40 kg
Muriate of potash (MP)	75 kg
Gypsum	30 kg

The entire amount of cow dung P and ½ of N and K were applied during final land preparation. The rest N and K was applied in two equal splits as top dress at 25 and 50 days after transplanting (DAP).

3.7 Experimental design and layout

The experimental plots were arranged in Randomized Complete Block Design (RCBD) with three replications. The experiment details were given bellow:

Number of plot : 18

Plot size : 2.5 m×1.5 m

Block to block distance : 1.0 m

Plot to boundary distance : 0.5 m

Plot to plot distance (Length wise) : 0.5 m

Plot to plot distance (breath wise) : 0.5 m

Plant to plant spacing : 10cm

Row to row spacing : 15cm

Total field size : 131.25 m^2

3.8 Name of varieties

Six varieties were used here, all were BARI developed varieties.

V1= BARI Piaz-1

V2= BARI Piaz-2

V3= BARI Piaz-3

V4= BARI Piaz-4

V5= BARI Piaz-5 and

V6= BARI Piaz-6

Among these varieties, BARI Piaz-1, BARI Piaz-4 and BARI Piaz-6 were winter variety and BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5 were summer variety.

3.9 Collection of onion seeds and sowing date

Seeds were collected from Spices Research Centre, BARI, Shibganj, Bogura, Bangladesh. Seeds were sown on 7th November, 2019.

3.10 Planting date of onion seedling

Uniform seedlings were planted in the experimental plot in 19th December, 2019.

3.11 Seedling transplanting

35 days age seedling were planted. The healthy seedling were selected for planting in experimental plots. The seedling were planted maintaining row to row distance 15 cm and plant to plant distance 10 cm. The seedling were planted, as per design and spacing.

BARI Piaz-1

BARI Piaz-2

BARI Piaz-3

BARI Piaz-4

BARI Piaz-5

BARI Piaz-6

Plate: 1. Plantation of six BARI onion varieties at SRC, Shibganj, Bogura

3.12 Intercultural operations

3.12.1 Irrigation

Irrigation was given as per requirement of the land with regular intervals. First irrigation was given after 7 days of sowing of seeds and contained up to harvesting of crop. Irrigation was generally followed the each weeding of the crops.

3.12.2 Weeding and mulching

Weeding and mulching were done when required to keep the crop free from weeds, for better soil aeration and conserve soil moisture. The common weeds were *Cynodon dactylon L.* (Durba grass), *Cyperus rotundus L.* (Mutha) etc. Weeding was done carefully keeping the delicate plants undisturbed.

3.12.3 Insecticide

Admire (0.05%) was sprayed three times at interval 10 days. It was applied 10 to 30 days after transplanting for controlling thrips. Other intercultural operations were done to maintain the normal hygienic condition of crop in the field.

3.12.4 Fungicides

Fungicides were used as routine agronomical practice to protect from diseases. Rovral 50 WP (0.2%), Dithane M-45 (0.45%) were sprayed 3 times at interval 10 days. Fungicides solution were prepared by taking 2gm of Rovral 50 WP and Dithane M-45 fungicides, then mixed with one liter sterile water for optimum concentration.

3.13 Tagging and data collection

A label attached to the onion plant or stuck in the soil near the base of the plant that was given information about variety of the following onion plant.

3.14 Collection of diseased leaf samples

Onion leaves having typical leaf spot symptoms (Plate 2) were collected from field of Spices Research Centre, BARI, Shibganj, Bogura. The diseased leaves were cut from the plants and put into an envelope. Then the envelop of each collection sample were taken to the Plant Pathology laboratory, Spices

Research Centre, BARI, Shibganj, Bogura for isolation.

3.15 Isolation and identification of pathogens

The disease infested leaves of onion plants were collected and kept in ploythene bags and tagged. The samples were taken to the laboratory. Then slides were prepared from the diseased samples, observed under microscop and identified the pathogen according to CMI Description.

A. BARI Piaz-1

B. BARI Piaz-2

C. BARI Piaz-3

D. BARI Piaz-4

E. BARI Piaz-5

F. BARI Piaz-6

Plate 2. Leaf samples showing typical symptom of purple blotch and stemphylium diseases (A, B, C, D, E and F)

3.16 Harvesting

The crop was harvested 97-102 days after transplanting when the maximum number of plants showed the sign of maturity by drying out most of the leaves and collapsed at the neck of the tops.

3.17 Collection of data

The following parameters were considered for data collection.

- Disease incidence (%)
- Sprouting (%)
- Rotting (%)
- Physiological losses in weight (%)
- Black mould (%)
- Fusarium rot (%)
- Blue mould (%)

3.18 Procedure of data collection

3.18.1 Number of leaf /plant

Number of leaf /plant was counted from randomly selected 10 plants from each plot at different dates as scheduled.

3.18.2 Number of infected leaf/ plant of different varieties

Number of infected leaf/ plant were recorded and used for calculation of diseased incidence.

3.18.3 Disease incidence

For calculation of disease incidence every plant was counted in the field and also counted the infected plants then expressed in percentage. The disease incidence of onion was calculated by the following formula. (Manandhar, 2016)

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Number of total plants observed}} \times 100$$

3.18.4 Plant height (cm)

The average height of the longest plant at physiological maturity was measured in cm from the ten randomly taken plants in the three central rows.

3.18.5 Leaf number per plant

The total number of healthy leaves were counted from the ten randomly taken plants from middle three central rows at physiological maturity.

3.18.6 Bulb length (cm)

Bulb length was measured from the harvested bulbs. It was measured at the basal end point from the bottom scar of the bulb to the tip point of the bulb using scale in cm.

3.18.7 Bulb diameter (cm)

Bulb diameter was measured from randomly taken five bulbs at the widest point in the middle portion of the bulb using scale in cm.

3.18.8 Average bulb weight plant^{-1}

The average mature bulb weight per plant was recorded after weighting ten bulbs produced in the three central rows and dividing by the number of plants.

3.18.9 Total yield per hectare

Total bulb yield of plants grown in three central rows was measured after bulbs were cured or exposed for ten days to sunlight. The yields obtained from plots were converted to hectare base.

3.18.10 Storage of the harvested onion

The experiment was initiated at ambient store house of Spices Research Centre, BARI, Shibganj, Bogura, on April 16, 2020. The storage condition of the store house was farmer level condition. The average air temperature of the store house was 27.19-29.30℃ and humidity 61.63-80.90%. Onion bulbs of the six varieties were air dried 10 days before storage. 200 bulbs of each varieties were stored in a wooden structure under ambient condition.

3.18.10.1 Different Data collection at storage

Different data were recorded on number of sprouted bulb, rotted bulb and weight loss of bulb. Associated fungal development on six varieties of stored onion were observed at 15 days interval.

3.18.10.2 Sprouting percentage

Samples of 30 bulbs were randomly taken from each variety for determining the sprouting percentage on stipulated days after storage, the bulbs showing a sprout were separated from the lot and weight on an electronic balance. The sprouting percentage, which indicated the weight of the bulbs sprouted on 15, 30, 45, 60, 75, 90, 105, 120, 135, 150 and 165 DAS was calculated by using the formula of Soomro *et al*., (2016).

$$\text{Sprouting percentage} = \frac{\text{Weight of the sprouted bulbs}}{\text{Initial weight of bulbs}} \times 100$$

3.18.10.3 Rotting percentage

Samples of 30 bulbs were randomly taken from each variety for determining the weight of the rotted bulbs at the end of 15, 30, 45, 60, 75, 90, 105, 120, 135, 150 and 165 DAS was recorded under each variety under storage condition and the rotting percentage was calculated by using the formula of Jamali *et al*., (2012).

$$\text{Rotting percentage} = \frac{\text{Weight of the rotted bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

3.18.10.4 Weight loss (%)

Weight loss was determined using samples of 30 bulbs were randomly taken from each variety. The difference in weight of the bulbs at the beginning and mid of each month was recorded on 15, 30, 45, 60, 75, 90, 105, 120, 135, 150 and 165 DAS using an digital electric balance and expressed as percent WL using the formula of Soomro *et al*., (2016).

$$\text{PWL (\%)} = \frac{\text{Initial weight-weight, day after storage}}{\text{Weight, day after storage}} \times 100$$

3.18.10.5 Incidence of black mould

The incidence of black mould was recorded at fortnightly at interval up to 150 days. The incidence of black mould was expressed as percentage of bulbs affected out of 30 bulbs by using the formula of Jamali *et al*., (2012).

$$\text{Black mould (\%)} = \frac{\text{Number of affected bulbs}}{\text{Total number of bulbs}} \times 100$$

3.18.10.6 Incidence of Fusarium rot

The incidence of Fusarium rot was recorded at fortnightly at interval up to 150 days. The incidence of Fusarium rot was expressed as percentage of bulbs affected out of 30 bulbs by using the formula of Jamali *et al*., (2012).

$$\text{Fusarium rot (\%)} = \frac{\text{Number of affected bulbs}}{\text{Total number of bulbs}} \times 100$$

3.18.10.7 Incidence of blue mould

The incidence of blue mould was recorded at fortnightly at interval up to 150 days. The incidence of blue mould was expressed as percentage of bulbs affected out of 30 bulbs by using the formula of Jamali *et al*., (2012).

$$\text{Blue mould (\%)} = \frac{\text{Number of affected bulbs}}{\text{Total number of bulbs}} \times 100$$

3.19 Isolation technique

The rotten bulbs were taken to the plant pathology laboratory, Spices Research Centre, BARI, Shibganj, Bogura for isolation.

3.19.1 Examination of rotten onion

Onion bulbs which were not entirely rotten but expressing disease symptoms were selected for isolation. The selected diseased onion bulb was washed thoroughly to remove soil and sand particals. The infected onion bulb was cut into pieces 5mm in length with the help of sharp scalpel in such way that each of the cut pieces contained a part of the diseased area along with healthy tissues. These inocula were then placed on the filter paper to remove excess water. Half of the inocula pieces were subjected to surface sterilization by dipping for 5 seconds in 1:1000 $Hgcl_2$ solutions. Surface sterilized inocula were then thoroughly (3 times) washed with sterile water and dried on sterile filter paper.

Isolation of various pathogens were done following Ara *et al*., (2008).

a) By blotter incubation method/ Tissue planting method of isolation followed by light microscopy

b) By growing on acidified Potato Dextrose Ager (PDA) medium (for fungi)

Identification of associated microorganism was followed by microscopy (stereo binocular and/or compound light microscop)

a. Blotter incubation method

Sterilized petri dishes were used. Three layers of sterile filter papers (Whatman No.1) were moistured by dipping them in sterile water and were placed on the bottom of each petri dish. The diseased samples were rinsed properly with distilled water. The diseased bulb portions were then cut into small pieces along with some healthy tissues and then placed on the moist blotter. The plated petri dishes were then labled and kept on the laboratory desk for incubation at room temperature (22℃±2℃) for the growth and sporulation of fungi. The sprouting fungi which grew on the wet blotters were identified under the stereoscopic microscop.

A **B** **C**

Plate 3. Tissue planting on blotter paper (A, B, C)

b. Incubation on Potato Dextrose Ager (PDA) medium

The diseased bulbs were washed first in tap-water to remove dusts or other inert matters attached to the surface of the bulbs.

Prepared inocula were placed (4+1) aseptically in the petri-dishes containing acidified PDA (2 drops of 50% lactic acid) media. The petri dishes were incubated at room temperature (22℃±2℃) for seven days. The plates were examined daily starting from the third day after planting for any fungal growth on the media around the inocula. The fungi thus growing out from the inocula were transferred to fresh culture plates from where sub-cultures were made into PDA plates for pure culture and identification of the organisms through light microscop.

3.19.2 Identification of fungi

Each diseased onion sample (with petri-dish) was observed under a stereomicroscope at 10X and 25X magnifications in order to record the fungi. Most of the associated microorganisms were detected by observing their growth characters on the incubated diseased onion on PDA following the keys outlined by Barnett (1965). During experiment period, identified fungi were kept on PDA media. After growth in the culture all the fungi were again isolated on fresh PDA medium to get pure culture. This culture media characterized by visual observation and fungi were identified basal on cultural characteristics and microscopic view. For confirmed identification of fungi, temporary slides were prepared from the fungal colony and observed under a compound microscope, and identified with the help of keys suggested by Booth (1971) and Ellis (1971).

3.20 Statistical analysis

The collected data on various parameters under different experiments were statistically analyzed using the programe R-studio to find out the significance of the treatment's effects. The means for all the treatments were calculated, and analysis of variance for all the characteristics were performed by the F test. The significance of difference between the pair of means was evaluated by the Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS

The present study was conducted to find the field and storage performance of six varieties of BARI Piaz. The results obtained from the study have been described in this chapter. The results and the analysis of data for different growth parameter of onion, different yield and yield parameter, effect of disease reaction on varieties, culture of purple blotch and stemphylum, performance of onion varieties sprouted and % sprouted bulbs during storage condition, performance of onion varieties rotted and % rotted bulbs during storage condition, weight losses of onion varieties at different date, pathogens causing rote of onion bulbs at storage. All the data have been presented in table (1-8), Figure-1 and Plate (4-7).

4.1 Field performance of six onion varieties of BARI Piaz

4.1.1. Growth parameters of six varieties of onion under field condition

Plant height

Significant variation observed in plant height among different varieties. Maximum plant height was achieved 45 days after planting. Then at 60 DAP and 75 DAP it was decreased. At 45 DAP the highest plant height (71.50cm) was observed in V_4 (BARI Piaz-4) followed by V_2 (68.50cm), V_1 (67.33cm) and V_3 (66.50cm) on the other hand, the lowest plant height (58.61cm) was observed in V_5 (BARI Piaz-5) followed by V_6 (64.00cm).

Number of leaves per plant

The number of leaves per plant varied significantly among the varieties. (Table.1) Highest number of leaves per plant was observed in 60 days after planting. Then at 75 DAP it was decreased due to leaf senescence period. Maximum number of leaves per plant (8.96) was observed in V_2 (BARI Piaz-2) followed by V_5 (8.80), V_1 (8.17). On the other hand, minimum leaves per plant (6.45) was observed in V_6 (BARI Piaz-6) followed by V_3 (7.00) and V_4 (7.33).

Table 1. Growth parameters of six varieties of onion under field condition

Varieties	Plant height (cm)					No. of leaves/plant				
	15 DAP	**30 DAP**	**45 DAP**	**60 DAP ****	**75 DAP ****	**15 DAP**	**30 DAP**	**45 DAP**	**60 DAP**	**75 DAP**
V1	46.94 ab	59.72 abc	67.33 ab	40.66b	17.89c	5.11ab	7.33 ab	7.72bc	8.17 abc	2.80 bc
V2	48.77 ab	63.44 ab	68.50 ab	48.11a	33.28a	5.45a	8.06 a	8.83bc	8.96 a	3.93 ab
V3	48.22 ab	61.77 ab	66.50 ab	31.11a	30.47a	4.78bcd	6.88 bc	8.72 ab	7.00 cd	5.06 a
V4	50.39 a	65.22 a	71.50 a	43.61b	25.00bc	4.89bc	6.39 cd	7.39 c	7.33 bcd	2.28 c
V5	43.05 b	53.11 c	58.61 c	43.00b	29.23ab	4.6cd	6.59 bc	7.66 c	8.80 ab	3.43 bc
V6	46.72 ab	57.33 bc	64.00 bc	41.28b	20.28c	4.39d	5.67 d	6.94 c	6.45 d	2.55 c
CV %	7.60	6.88	5.34	4.83	15.11	5.12	7.42	7.31	7.29	20.41
Level of significance	**NS**	*****	*****	******	******	******	******	*****	*****	******
LSD (0.05)	**6.55**	**6.98**	**6.42**	**3.92**	**7.29**	**0.45**	**0.92**	**1.05**	**1.54**	**1.24**

V_1: BARI Piaz-1, V_2: BARI Piaz-2, V_3: BARI Piaz-3, V_4: BARI Piaz-4, V_5: BARI Piaz-5, V_6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting

****** Decreased due to senescenc

4.1.2. Yield and yield parameters of six varieties of onion under field condition

Single bulb weight

There was significant variation in weight of bulbs due to different varieties of onion (Table-2). The finding showed that the highest fresh weight of a single bulb (71.33g) was found in V_4 (BARI Piaz-4) against the average fresh weight (19.93g) of a local single bulb. The lowest fresh weight of a single bulb (41.17g) was found in V_5 (BARI Piaz-5).

Single bulb length

Bulb length was varied in different varieties of onion (Table-2).The highest bulb length (7.57cm) was found in V_4 (BARI Piaz-4) against the average bulb length (3.18cm) of a local single bulb. The lowest bulb length (4.84cm) was found in V_5 (BARI Piaz-5) which was significantly different from all the other varieties.

Bulb diameter

Significant variation was observed in bulb diameter of onion among the varieties. (Table-2). At harvesting, the maximum bulb diameter (4.97cm) was obtained from V_4 (BARI Piaz-4) against the average bulb diameter (2.22cm) of a local single bulb. On the other hand the minimum bulb diameter (3.91cm) was recorded from V_5 (BARI Piaz-5). These results indicated that varietal variation played a role on getting proper vegetative as well as maximum bulb diameter of onion.

Yield per plot

Significant variation was remarked on yield per plot due to different varieties of onion (Table-2).The height yield per plot (13.70kg) was found in V_4 (BARI Piaz-4). On the other hand, lowest yield per plot (5.5kg) was found in V_5 (BARI Piaz-5) which was significantly different from others varieties.

Table 2. Yield and yield parameters of six varieties of onion under field condition

Varieties	Single bulb weight (g)	Bulb length (cm)	Bulb diameter (cm)	Yield /plot (kg)
V1	49.22b	5.94b	4.66ab	12.04a
V2	45.00b	5.74b	4.57ab	7.00bc
V3	42.28b	5.87b	4.39abc	7.27b
V4	71.33a	7.57a	4.97a	13.70a
V5	41.17b	4.84c	3.91c	5.5c
V6	42.72b	6.06b	4.14bc	6.23bc
CV %	10.25	5.27	7.98	10.91
Level of significance	**	**	**	**
LSD (0.05)	9.07	0.58	0.64	1.71

V1: BARI Piaz-1, V_2: BARI Piaz-2, V_3: BARI Piaz-3, V_4: BARI Piaz-4, V_5: BARI Piaz-5, V_6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting

Yield (t/ha)

Yield ton per hectare was significantly influenced by different cultivar of onion (Graph-1). In the Graph-1 the highest yield (36.53t/ha) was found in V_4 (BARI Piaz-4) which is statistically similar to BARI Piaz-1 (32.09 t/ha). Where the lowest yield (14.64t/ha) was found in V_5 (BARI Piaz-5) followed by BARI Piaz-6 (16.62 t/ha), BARI Piaz-2 (18.66t/ha) and BARI Piaz-3 (19.38t/ha). So, in the field condition performance of V_4 (BARI Piaz-4) was better than the other five varieties.

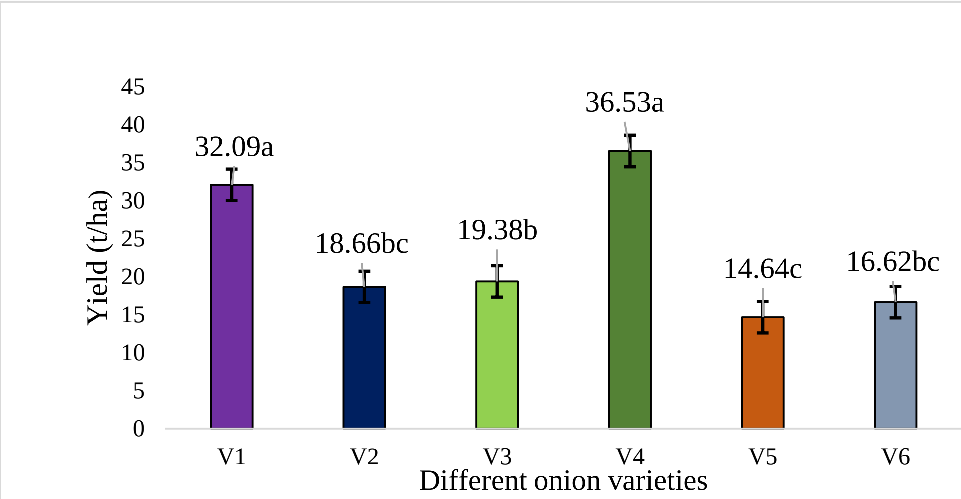


Figure 1. Bulb yield of different onion varieties (t/ha)

4.1.3. Prevalence of diseases on six varieties of BARI Piaz

Higher (4.19%) disease incidence of purple blotch found in V_5 (BARI Piaz-5) which is statistically similar to BARI Piaz-6 (3.87%). Where lower (3.49%) disease incidence of purple blotch found in V_4 (BARI Piaz-4), followed by BARI Piaz-1 (3.63%), BARI Piaz-3 (3.63%) and BARI Piaz-2 (3.73%) which are statistically similar (table 3).

Similarly, higher (43.41%) disease incidence of stemphylium found in V_5 (BARI Piaz-5) which is statistically similar to BARI Piaz-6 (41.56%) and BARI Piaz-2 (40.63%). On the other hand, lower (34.91%) disease incidence of stemphylium found in V_4 (BARI Piaz-4) followed by BARI Piaz-1 (37.85%) and BARI Piaz-3 (38.75%).

As the disease incidence (%) of purple blotch and stem phylum was higher in V_5 (BARI Piaz-5) so the yield of V_5 (BARI Piaz-5) was lower.

Table 3. Prevalence of diseases on six varieties of BARI Piaz

Varieties	Disease incidence (%)	
	Purple blotch	Stemphylium
V1	3.63bc	37.85bc
V2	3.73bc	40.63ab
V3	3.63bc	38.75abc
V4	3.49c	34.91c
V5	4.19a	43.41a
V6	3.87ab	41.56ab
CV%	4.97	6.95
Level of significance	*	*
LSD (0.05)	**0.339**	**4.99**

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting

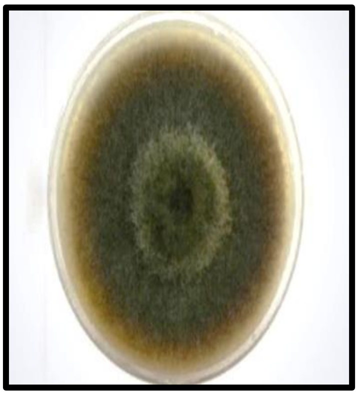
A

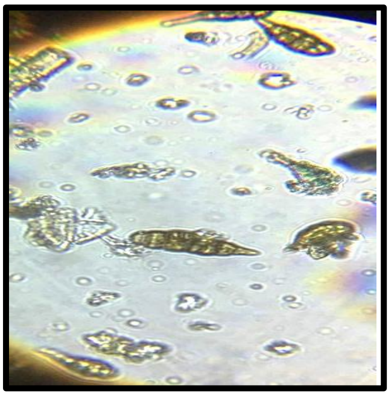
B

C

D

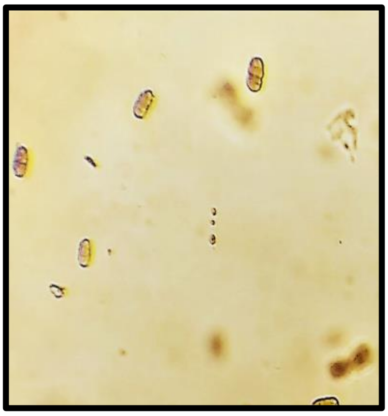
Plate 4. Diseased plants showing symptoms purple blotch (A, B) and stemphylium (C, D)





A. ***Alternaria porri***

B. ***Alternaria porri*** **(40X)**



C.***Stemphylium vesicarium***

D.***Stemphylium vesicarium*** **(40X)**

Plate 5. ***Alternaria porri*** **(A, B) and** ***Stemphylium vesicarium*** **(C, D)**

4.2. Storage performance of six varieties of BARI Piaz

200 number of bulbs from each variety (BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, BARI Piaz-4, BARI Piaz-5 and BARI Piaz-6) were stored in a wooden rake under ambient condition. Different storage performance of each variety was recorded at an interval of 15 days viz., 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI.

4.2.1. Effect of storage condition on no. of sprouted bulbs of onion varieties

Significant variation was observed in sprouting of onion bulbs among the varieties at storage condition. At 15 DAI maximum number of sprouted bulbs (39.33) was observed in V_3 (BARI Piaz-3) and minimum number of sprouted bulbs (0.33) was observed in V_4 (BARI Piaz-4), (table 4). From V_3 (BARI Piaz-3), highest number of sprouted bulbs were observed in 15, 30, 45, 60, 75 and 90 DAI. From V_4 (BARI Piaz-4) minimum number of sprouted bulbs were observed in 15, 30, 45, 60, 75 and 90 DAI. Then the number of sprouting bulbs increases in V_4 (BARI Piaz-4). At 105, 120, 135 and 150 DAI maximum no. of sprouted bulbs were observed in V_4 (BARI Piaz-4). Total number of sprouted bulbs 17.01, 77.01, 92.67, 28.66, 59.33 and 30 were observed in $V_{1,}$ $V_{2,}$ $V_{3,}$ $V_{4,}$ V_5 and V_6 respectively.

4.2.2. Effect of storage condition on % of sprouted bulbs of onion varieties

At 15 DAI maximum percent of sprouted bulbs (32.71%) was observed in V_3 (BARI Piaz-3) and minimum percent of sprouted bulbs (1.30%) was observed in V_4 (BARI Piaz-4) (table 4). From V_3 (BARI Piaz-3), highest number of sprouted bulbs were observed in 15, 30, 45, 60, 75 and 90 DAI by 32.71%, 27.27%, 26.06%, 3.43%, 1.47% and 3.85% which is followed by V_2 (BARI Piaz-2). From V_4 (BARI Piaz-4) minimum number sprouted bulbs 1.30%, 0.00%, 6.02%, 0.87%, 0.72% and 0.95% were observed in 15, 30, 45, 60, 75 and 90 DAI which is followed by V_1 (BARI Piaz-1). Then the percent of sprouting bulb increases in V_4 (BARI Piaz-4) at 105, 120, 135 and 150 DAI. Total % of sprouted bulbs 8.51%, 38.51%, 46.34%, 14.33%, 29.67% and 15% were were observed in $V_{1,}$ $V_{2,}$ $V_{3,}$ $V_{4,}$ V_5 and V_6 respectively.

Table 4. Effect of storage condition on number of sprouted bulbs and % of sprouted bulbs of onion varieties

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	No. of Sprouted bulbs at 15 DAI	% Sprouted bulbs at 15 DAI	No. of Sprouted bulbs at 30 DAI	% Sprouted bulbs at 30 DAI	No. of Sprouted bulbs at 45 DAI	% Sprouted bulbs at 45 DAI	No. of Sprouted bulbs at 60 DAI	% Sprouted bulbs at 60 DAI
V_1= BARI Piaz-1	6.20b	200	0.67d	2.61de	0.67d	1.86c	3.33d	7.65e	1.67b	0.90d
V_2= BARI Piaz-2	6.60b	200	37.00b	29.29b	21.67b	26.76a	5.67c	20.86b	4.67a	3.20b
V_3= BARI Piaz-3	6.70b	200	39.33a	32.71a	24.67a	27.27a	14.67a	26.06 a	5.00a	3.43a
V_4= BARI Piaz-4	10.97a	200	0.33d	1.30 e	0.00d	0.00d	3.33d	6.02f	1.67b	0.87d
V_5= BARI Piaz-5	7.10b	200	16.33c	17.16 c	10.00c	12.00b	14.67a	17.01c	5.00a	2.17c
V_6= BARI Piaz-6	6.77b	200	1.33d	4.26d	1.67d	3.09c	6.67c	10.76d	2.67b	0.96d
CV %	6.90	1.42	5.65	9.37	10.34	7.23	11.42	5.04	18.1	5.90
Level of significance	**	NS	**	**	**	**	**	**	**	**
LSD (0.05)	0.93	5.2	1.63	2.48	1.84	1.60	1.58	1,35	1.13	0.21

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI=Days after initiation

Table 4. Effect of storage condition on number of sprouted bulbs and % of sprouted bulbs of onion varieties (continued)

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	No. of Sprouted bulbs at 75 DAI	% Sprouted bulbs at 75 DAI	No. of Sprouted bulbs at 90 DAI	% Sprouted bulbs at 90 DAI	No. of Sprouted bulbs at 105 DAI	% Sprouted bulbs at 105 DAI	No. of Sprouted bulbs at 120 DAI	% Sprouted bulbs at 120 DAI
V_1= BARI Piaze-1	6.20b	200	1.67a	0.73d	3.00bc	1.49c	1.67b	1.05c	0.00d	0.00c
V_2= BARI Piaze-2	6.60b	200	1.00b	1.13b	3.00bc	2.76b	2.00b	2.34a	0.00d	0.00c
V_3= BARI Piaze-3	6.70b	200	1.67a	1.47a	5.33a	3.85a	1.33b	1.54b	0.00d	0.00c
V_4= BARI Piaze-4	10.97a	200	1.00b	0.72 d	2.33c	0.95d	3.67a	2.36a	6.67a	2.28c
V_5= BARI Piaze-5	7.10b	200	1.00b	0.78cd	3.00bc	1.73c	3.33a	2.31a	2.00c	2.23c
V_6= BARI Piaze-6	6.77b	200	1.33ab	0.88c	4.33ab	1.55c	3.33a	2.07a	2.67b	1.68b
CV %	6.90	1.42	23.33	6.31	21.02	11.95	18.44	10.00	9.23	5.87
Level of significance	**	NS	**	*	**	**	**	**	**	**
LSD (0.05)	0.93	5.2	0.54	0.11	1.33	0.45	0.86	0.35	0.32	0.11

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI=Days after initiation

Table 4. Effect of storage condition on no. of sprouted bulbs and % of sprouted bulbs of onion varieties (continued)

Varieties	Initial Wt. of Bulb (kg) at	Initial No. of Bulb	No. of Sprouted bulbs at 135 DAI	% Sprouted bulbs at 135 DAI	No. of Sprouted bulbs at 150 DAI	% Sprouted bulbs at 150 DAI	Total No. of Sprouted bulbs	Total % Sprouted bulbs
V_1= BARI Piaz-1	6.20b	200	2.33c	1.97d	2.00a	1.80 c	17.01	8.51
V_2= BARI Piaz-2	6.60b	200	0.00d	0.00e	2.00a	3.02 b	77.01	38.51
V_3= BARI Piaz-3	6.70b	200	0.00d	0.00e	0.67c	1.22d	92.67	46.34
V_4= BARI Piaz-4	10.97a	200	7.33a	2.56c	2.33a	1.55 cd	28.66	14.33
V_5= BARI Piaz-5	7.10b	200	2.67c	3.47a	1.33b	3.77a	59.33	29.67
V_6= BARI Piaz-6	6.77b	200	5.33b	3.14b	0.67c	0.70 e	30	15
CV %	6.90	1.42	9.64	6.71	14.59	12.12	-	-
Level of significance	**	NS	**	**	**	**	-	-
LSD (0.05)	0.93	5.2	0.52	0.23	0.39	0.44	-	-

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% levelof probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI=Days after initiation

4.2.3. Effect of storage condition on number of rotted bulbs of onion varieties

Summer varieties of onion (BARI Piaz-2, BARI Piaz-3, and BARI Piaz-5) contain more moisture than the winter varieties of onion (BARI Piaz-1, BAR Piaz-4, and BARI Piaz-6) which is vulnerable for pathogenic infection at storage condition. Maximum number of rotted bulbs were observed in V_3 (BARI Piaz-3) at 15, 30, 45, 60, 75 and 90 DAI where minimum number of rotted bulbs were observed in V_4 (BARI Piaz-4) at15, 30, 45, 60, 75 and 90 DAI. But at 150 DAI (8.33) maximum number of rotted bulbs was observed in V_4 (BARI Piaz-4). Total number of rotted bulbs 112.34, 113.66, 146.34, 80.54, 116.32 and 125.97 were observed in $V_{1,}$ $V_{2,}$ $V_{3,}$ $V_{4,}$ V_5 and V_6 respectively. Among the winter varieties of onion (BARI Piaz-1, BARI Piaz-4, BARI Piaz-6) V_4 (BARI Piaz-4) was more stable than the others (table 5).

4.2.4. Effect of storage condition on % of rotted bulbs of onion varieties

At 15 DAI maximum number of percent rotted bulbs (4.94%) was observed in V_3 (BARI Piaz-3) and minimum number of percent rotted bulbs (1.04%) was observed in V_4 (BARI Piaz-4) (table 5). From V_3 (BARI Piaz-3), highest number of percent rotted bulbs 4.94%, 3.92%, 47.98%, 36.84%, 4.42% and 4.08% were observed in 15, 30, 45, 60, 75 and 90 DAI which is followed by V_2 (BARI Piaz-2). From V_4 (BARI Piaz-4) minimum number of percent rotted bulbs 1.04%, 0.75%, 10.94%, 10.20%, 2.26% and 1.68% were observed in 15, 30, 45, 60, 75 and 90 DAI which is followed by V_1 (BARI Piaz-1). Then the percent of rotting bulb increases in V_4 (BARI Piaz-4) at 105, 120, 135 and 150 DAI. Total % of rotted bulbs 56.17%, 56.83%, 73.17%, 40.27% 58.16% and 62.99% were observed in $V_{1,}$ $V_{2,}$ $V_{3,}$ $V_{4,}$ V_5 and V_6 respectively.

Table 5. Effect of storage condition on number of rotted bulbs and % of rotted bulbs of onion varieties

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	No. of Rotted bulbs at 15 DAI	% Rotted bulbs at 15 DAI	No. of Rotted bulbs at 30 DAI	% Rotted bulbs at 30 DAI	No. of Rotted bulbs at 45 DAI	% Rotted bulbs at 45 DAI	No. of Rotted bulbs at 60 DAI	% Rotted bulbs at 60 DAI
V_1= BARI Piaz-1	6.20b	200	6.67c	1.85 c	4.00d	1.37 c	9.67d	12.87 e	14.00b	23.21c
V_2= BARI Piaz-2	6.60b	200	17.33b	3.44b	13.67b	3.86 a	25.67c	37.89 b	13.33b	32.60b
V_3= BARI Piaz-3	6.70b	200	32.00a	4.94a	17.00a	3.92 a	33.00a	47.98 a	24.67a	36.84a
V_4= BARI Piaz-4	10.97a	200	2.33d	1.04 d	5.33d	0.75 d	7.33d	10.94 e	5.33c	10.20e
V_5= BARI Piaz-5	7.10b	200	9.00c	2.25 c	8.67c	2.28 b	29.33b	30.25 c	12.00b	19.34d
V_6= BARI Piaz-6	6.77b	200	7.33c	1.96 c	8.33c	2.11 b	23.67c	22.44 d	12.3 b	20.89cd
CV %	6.90	1.42	18.86	9.94	13.86	12.68	7.60	7.1	16.41	5.36
Level of significance	**	NS	**	**	**	**	**	**	**	**
LSD (0.05)	0.93	5.2	4.26	0.47	2.39	0.55	2.96	3.50	4.06	2.33

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI = Days after initiation

Table 5. Effect of storage condition on number of rotted bulbs and % of rotted bulbs of onion varieties (continued)

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	No. of Rotted bulbs at 75 DAI	% Rotted bulbs at 75 DAI	No. of Rotted bulbs at 90 DAI	% Rotted bulbs at 90 DAI	No. of Rotted bulbs at 105 DAI	% Rotted bulbs at 105 DAI	No. of Rotted bulbs at 120 DAI	% Rotted bulbs at 120 DAI
V_1= BARI Piaz-1	6.20b	200	12.00b	2.96b	7.00b	2.41c	27.00a	52.84a	10.00b	6.66a
V_2= BARI Piaz-2	6.60b	200	10.00b	4.40a	6.33b	3.29b	16.67bc	30.69d	4.33d	3.39c
V_3= BARI Piaz-3	6.70b	200	16.00a	4.42a	8.67a	4.08a	11.67c	16.01e	2.00e	5.73b
V_4= BARI Piaz-4	10.97a	200	5.67c	2.26b	3.33d	1.68d	12.67c	36.14cd	8.33c	3.56c
V_5= BARI Piaz-5	7.10b	200	9.00b	3.97a	4.33cd	2.75bc	21.33b	44.36b	13.33a	3.21c
V_6= BARI Piaz-6	6.77b	200	11.00b	2.91b	4.67c	2.49c	31.00a	38.34bc	13.00a	3.36c
CV %	6.90	1.42	16.29	11.28	9.92	11.92	14.52	10.89	6.61	9.82
Level of significance	**	NS	**	**	**	**	**	**	**	**
LSD (0.05)	0.93	5.2	3.14	0.72	1.03	0.60	5.30	7.21	1.48	0.77

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI=Days after initiation

Table 5. Effect of storage condition on number of rotted bulbs and % of rotted bulbs of onion varieties (continued)

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	No. of Rotten bulbs at 135 DAI	% Rotten bulbs at 135 DAI	No. of Rotten bulbs at 150 DAI	% Rotten bulbs at 150 DAI	Total No. of Rotten bulbs	Total % Rotten bulbs
V_1= BARI Piaze-1	6.20 b	200	15.00a	27.16ab	7.00a	18.13b	112.34	56.17
V_2= BARI Piaze-2	6.60 b	200	3.33d	24.86b	3.00c	29.06a	113.66	56.83
V_3= BARI Piaze-3	6.70 b	200	0.00e	7.14d	1.33d	11.34c	146.34	73.17
V_4= BARI Piaze-4	10.97 a	200	6.67c	13.89c	8.33a	16.33b	80.54	40.27
V_5= BARI Piaze-5	7.10 b	200	5.00cd	27.93a	4.33bc	30.51a	116.32	58.16
V_6= BARI Piaze-6	6.77 b	200	10.00b	25.21b	4.67b	18.11b	125.97	62.99
CV %	6.90	1.42	14.23	6.51	16.06	7.93	-	-
Level of significance	**	NS	**	**	**	**	-	-
LSD (0.05)	0.93	5.2	1.73	2.49	1.39	2.97	-	-

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI = Days after initiation

4.2.5. Weight losses of onion varieties at different storage period

Different varieties of onion significantly influenced the weight loss at storage condition. On the basis of weight loss at storage condition V_4 (BARI Piaz-4) showed best performance followed by BARI Piaz-1, BARI Piaz-6, BARI Piaz-5 BARI Piaz-2 and BARI Piaz-3 at different days after initiation. At 15 DAI the result showed that BARI Piaz-4 performed best (10.56%) at storage followed by BARI Piaz-1 (16.26%), BARI Piaz-6 (12.11%), BARI Piaz-5 (22.66%), BARI Piaz-2 (31.53%) and lowest was found in BARI Piaz-3 (40.53%). Similar trend of result were found at 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI. The result showed that increasing the days the weight loss of onion bulb at storage gradually increased. Total % of bulb weight loss 64.79%, 71.80%, 78.70%, 49.42% 77.34% and 65.30% were observed in $V_{1,}$ $V_{2,}$ $V_{3,}$ $V_{4,}$ V_5 and V_6 respectively.

As V_3 (BARI Piaz-3) performed more sprouting at storage condition (table 4) so, maximum weight losses of onion bulb was observed in V_3 (BARI Piaz-3). V_3 (BARI Piaz-3) showed maximum weight loss at 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI (table 6). On the other hand, minimum weight loss was observed in V_4 (BARI Piaz-4) as it performed lower sprouting at storage condition.

Table 6. Weight losses of onion varieties at different storage period

Varieties	Initial Wt. of Bulb (kg)	Initial No. of Bulb	Bulb weight loss % at 15 DAI	Bulb weight loss % at 30 DAI	Bulb weight loss % at 45 DAI	Bulb weight loss % at 60 DAI	Bulb weight loss % at 75 DAI	Bulb weight loss % at 90 DAI
V_1= BARI Piaz-1	6.20 b	200	16.26 d	19.39 cd	32.20 c	37.91 c	42.46 c	44.79 c
V_2= BARI Piaz-2	6.60 b	200	31.53 b	38.47 a	49.83 b	63.60 a	68.00 a	66.95 a
V_3= BARI Piaz-3	6.70 b	200	40.53 a	41.61 a	60.10 a	66.15 a	69.61 a	69.75 a
V_4= BARI Piaz-4	10.97 a	200	10.56 e	15.45 d	23.92 d	28.07 d	31.12 d	30.13 d
V_5= BARI Piaz-5	7.10 b	200	22.66 c	28.50 b	44.85 b	52.70 b	55.29 b	58.47 b
V_6= BARI Piaz-6	6.77 b	200	12.11 e	20.51 c	32.33 c	41.69 c	45.09 c	48.30 c
CV (%)	6.90	1.4	6.17	8.68	7.6	11.07	6.18	6.71
Level of significance	**	NS	**	**	**	**	**	**
LSD (0.05)	0.93	5.1	2.50	4.32	5.65	9.74	5.84	6.47

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI=Days after initiation

Table 6. Weight losses of onion varieties at different storage period (continued)

Varieties	Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	Bulb weight loss % at 105 DAI	Bulb weight loss % at 120 DAI	Bulb weight loss % at 135DAI	Bulb weight loss % at 150 DAI	Total Bulb weight loss %
V_1= BARI Piaz-1	6.20 b	200	49.69 c	57.04 b	60.56 b	62.07 b	64.79 c
V_2= BARI Piaz-2	6.60 b	200	74.11 a	75.29 a	75.59 a	75.89 a	71.80 b
V_3= BARI Piaz-3	6.70 b	200	75.18 a	76.64 a	76.75 a	77.87 a	78.70 a
V_4= BARI Piaz-4	10.97 a	200	33.62 d	41.57 c	46.60 c	48.72 c	49.42 d
V_5= BARI Piaz-5	7.10 b	200	65.10 b	70.92 a	75.07 a	76.98 a	77.34 a
V_6= BARI Piaz-6	6.77 b	200	53.80 c	57.45 b	61.21 b	63.11 b	65.30 c
CV (%)	6.90	1.4	6.57	8.0	3.88	7.84	3.44
Level of significance	**	NS	**	**	**	**	**
LSD (0.05)	0.93	5.1	7.00	9.2	4.64	9.62	4.26

V1: BARI Piaz-1, V2: BARI Piaz-2, V3: BARI Piaz-3, V4: BARI Piaz-4, V5: BARI Piaz-5, V6: BARI Piaz-6, * Significant at 0.05% level of probability, ** Significant at 0.01% level of probability, NS = Not Significant, DAP= Days after planting, DAI = Days after initiation

4.3.1. Percentage frequency of the fungal isolates from storage onion bulbs

The percentage frequency of the fungi from infected onion bulbs are presented in Table 7. From the (Table 7) *Aspergillus niger* occurred with most frequency (65%) followed by *Fusarium* sp. (20%), *Penicillium* sp. (10%) and others (5%).

Table 7. Percentage frequency of occurrences on infected onion bulbs at storage condition

Fungi	% Frequency
Aspergillus niger	65.00
Fusarium sp.	20.00
Penicillium sp.	10.00
Others	05.00

4.3.2. Identification of storage diseases of infected onion bulbs

The diseases were identified by visual observations and investigations and the name of identified diseases were presented in Table 8. The identified spoilage postharvest diseases were Black mold, Blue mold, Fusarium rot of onion bulb and others.

Table 8. Storage onion fungal diseases and their causal organisms

Fungal diseases	Causal organism
Black mold	*Aspergillus niger*
Blue mold	*Penicillium* sp.
Basal rot	*Fusarium* sp.

4.3.3. Cultural and microscopic characteristics of identified fungi

a. Cultural and microscopic characteristics of *Aspergillus niger*

The fungus colonies on PDA exhibit whitish mycelia growth. At later stage, the colonies turned into blackish velvety appearance (Plate 6.A).

***Aspergillus niger*:** Colorless conidiophores were observed under the microscope. Conidial heads of the organism were globose and dark brown in color (Plate 6.B)

b. Cultural and microscopic characteristics of *Fusarium* sp.

The fungus colonies on PDA exhibit fluffy, pinkish mycelium around with whitish mycelium (Plate.6.C)

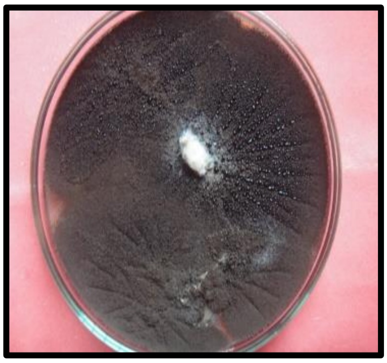
***Fusarium* sp.**: Macro conidia observed under microscope were relatively wide, straight and stout, gradually curved and pointed towards the end. Apical cell morphology was found blunt and rounded. Basal cell morphology was found straight to almost cylindrical. 3 to 5 septation was present which was observed under microscope. Larger sized conidia were present (Plate 6.D).

The smaller sized conidia were present. 1 to 2 septation present, oval, ellipsoid and fusiform. Aerial mycelium was false headed (Plate 6.D).

c. Cultural and microscopic characteristics of *Penicillium* sp.

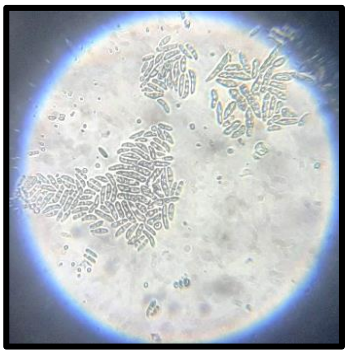
The fungus on PDA media exhibit prolific production of colonies with filamentous, cottony, velvety, flat or woolly in texture (Plate 6.E)

***Penicillium* sp.**: From a specialized conidiogeny, chains of single celled conidia (Ameroconidia) were produced in basipetal succession called a phialide (Plate 6. F).



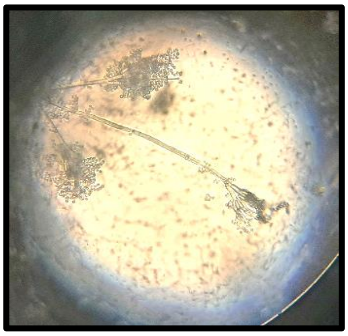
A. ***Aspergillus niger***

B. ***Aspergillus niger***
(40X)



C. ***Fusarium*** **sp.**

D. ***Fusarium*** **sp.**
(40X)



E. ***Penicillium*** **sp.**

F. ***Penicillium*** **sp.**
(40X)

Plate 6. Cultural (A, C, E) and microscopic view (B, D, F) of identified fungi


BARI Piaz-1 **BARI Piaz-2**


BARI Piaz-3 **BARI Piaz-4**


BARI Piaz-5 **BARI Piaz-6**

Plate 7. Storage quality loss of six varieties of BARI onion

CHAPTER V
DISCUSSION

In the present study both winter (BARI Piaz-1, BARI Piaz-4 and BARI Piaz-6) and summer (BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5) varieties were cultivated in robi season and their field performances in terms of plant height, no. of leaves per plant, single bulb weight, single bulb length, bulb diameter, yield per plot, prevalence of diseases on six varieties of BARI Piaz were observed. After harvesting bulbs of six varieties were air dried and then stored in a store house under ambient condition. Bulbs of varieties were kept in a wooden structure to observe the storage performance of six varieties of BARI Piaz, effect of storage condition on number of sprouted bulbs, % of sprouted bulbs, number of rotted bulbs, % of rotted bulbs, weight losses of onion bulb at different storage period and identification of fungus from infected onion bulbs. To assign summer (BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5) varieties were included in the research only evaluate the performance in rabi season.

In the field experiment, V_4 (BARI Piaz-4) showed maximum plant height (50.39-71.50 cm), bulb length (7.57 cm), bulb diameter (4.97cm), single bulb weight (71.33g) and yield (36.53 t/ha) against the actual average plant height (50-60 cm), average single bulb weight (60-70g) and average yield (17-22 t/ha) of BARI Piaz-4. On the other hand, V_5 (BARI Piaz-5) showed minimum plant height (43.05-58.61 cm), bulb length (4.84 cm), bulb diameter (3.91cm), single bulb weight (41.17g) and yield (14.64 t/ha) against the actual average plant height (45-55 cm), average single bulb weight (55-70g) and average yield (18-20 t/ha) of BARI Piaz-5. This variation occurred may be due to change of weather condition or due to cultivated summer variety in winter season. The results obtained from the present study are similar with the findings of Zedan (2011), Gopakkli and Sharanappa (2014). The variation in the total yield among onion varieties was possibly due to bulb size and adaption to growth conditions (Ddamulira, *et al.,* 2019). Earlier findings by (Nasreen, *et al.,* 2007) also emphasized the contribution of bulb size in enhancing onion total yield. The result were in line with findings of (Gonzalez, *et al*., 2000; Som, 2014) who reported that various onion cultivers of the same species grown in the same environment give different yields as the performance of a cultivar mostly depend on the interaction of genetic make up of parental lines from which they are derived.

Initial symptoms of purple blotch disease appear in the form of small, whitish, sunken lesions on the leaves and flower stalks. Later on, water soaked large zonate lesions of purplish red color surrounded by yellowish pale brown border was found. On the other hand, stemphylium first appears as elongated, small spindle shaped white flecks, which enlarge and produce sunken purple lesions often surrounded by a yellow to pale brown border. These lesions cause extensive necrosis and finally drying of younger leaves. The above symptoms and progress of the diseases have been reported by different workers (Aveling, 1998; Miller, 1983; Suheri and Price, 2001). Hill (1995) and Basallote-Ureba *et al*. (1999) found that SLB lesions cause extensive necrosis, resulting in premature drying of leaves and cessation of bulb development.

Isolation and identification of pathogen were made from typical leaf symptoms by tissue planting method following Hasan, (2008). *Alternaria porri* and *Stemphylium vesicarium* had fluffy growth on potato dextrose agar. Mycelia of *Alternaria porri* had effuse, fluffy and velvety growth having grey to brown color. The findings are similar with Mohsin *et al*. (2016). They used 27 isolates of *Alternaria porri* those were isolated from diseased leaf samples collected from different onion growing regions of Bangladesh. They found colony color varied from light to dark olivaceous green with greyish white. The results are in agreement with Pusz (2009) who found that the colonies of *Alternaria alternata* isolated from *Amaranthus retroflexus* varied from light grey to dark gray. Isolates of *Alternaria porri* produced light to deep brown color and straight or curved shape conidia with horizontal and longitudinal septation. The findings are similar with Mohsin *et al*. (2016). The colony of *Stemphylium vesicarium* appeared light grey to dirty white at early stage then it turned greenish brown to brownish gray. The colony was found fluffy with filiform margin. The results are similar with Yadav *et al*. (2017). They found that the colony growth of *Stemphylium vesicarium* appeared light grey to dirty white after 3 days of incubation, which finally turned turned greenish brown to brownish gray and colony was found fluffy, umbonate to raise with filiform margin which is same as Chowdhury (2013). Chowdhury *et al.* (2015) also found that colonies of *Stemphylium vesicarium* showed deep grey to whitish, greenish brown to dirty white, light grey to whitish, deep greenish white, light grey and dirty white to greenish color from frontal view on PDA.

Minimum disease incidence of purple blotch (3.49%) and stemphylium (34.31%) was recorded from V_4 (BARI Piaz-4). Where the maximum purple blotch (4.19%) and stemphylium (43.41%) from V_5 (BARI Piaz-5). Because of summer variety and thinner skin or may be due to weather condition BARI Piaz-5 was more susceptible for disease development. So, field performance of BARI Piaz-4 (winter) is better than the other varieties. BARI Piaz-5 (in case of winter season) shows lowest performance in the field condition. The study is agreement with Yadav (2013); he recorded the incidence of onion purple blotch (PLB) ranging from 11.29 to 63.73% in Navsari district of Gujrat over two Rabi seasons. Gupta *et al*. (1994) recorded severe PLB incidence (5.00 to 96.50%) in important onion growing areas of the country. The results are in agreement with Patil and Patil (1991) worked in six districts of Maharastra where onion is growing on commercial scale incidences of 51.11, 51.52, 41.64, 36.50, 51.09 and 30.27%, respectively. Many workers reported the fungal pathogens from the infected onion leaves, including purple blotch caused by *Alternaria porri* (Alves *et al.,* 1982; Schwartzet *et al*., 2007). Stemphylium leaf blight by *Stemphylium vesicarium* (Gupta *et al*., 1986; Hassan *et al*., 2007; Misawa and Myasuka, 2012).

In the storage experiment, maximum no. of sprouted and percent sprouted bulbs were observed in V_3 (BARI Piaz-3) at 15, 30, 45, 60, 75 and 90 DAI where minimum no. of sprouted and percent sprouted bulbs were observed in V_4 (BARI Piaz-4). At 105 DAI the no. of sprouting bulbs were increased in V_4 (BARI Piaz-4). In the study, BARI Piaz-4 performed best than the other varieties and BARI Piaz-3 showed least performance at storage. BARI Piaz-3 started sprouting earlier due to more moisture content in the bulb than the other varieties. More moisture content during the period of storage caused sprouting of onion bulbs that leads fungal growth and finally spoilage of onion occurred. Similar result was found by Khalaquzzaman (2018). He found that summer varieties viz., BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5 showed around 50% rotted and sprouted bulbs at 20-25 DAI. But winter varieties viz., BARI Piaz-1 and BARI Piaz-4 showed around 50% rotted and sprouted at 130 DAI. Among the winter varieties, BARI Piaz-4 was more stable to BARI Piaz-1. Bhagyawant *et al.,* (2016) found that the variation in percent sprout among onion varieties tested was probably due to the fact that sprouting is a normal physiological change in stored bulbs that develops reproductive shoots, however this change depends on storage conditions and cultivars.

Maximum no. of rotted and percent rotted bulbs were found in V_3 (BARI Piaz-3) and minimum no. of rotted and percent rotted bulbs were found in V_4 (BARI Piaz-4) at storage. Pathogens were responsible for rotten bulbs. More moisture content and thinner skin of BARI Piaz-3 was vulnerable for pathogenic infection. Weather condition at storage also responsible for pathogenic infection. Patel *et al.,* (2013) found the similar result. They found that the high humidity during the period of storage caused germination that leads fungal growth and finally spoilage of onion occurred. Visser (1999) published that injury to the bulb incurred before or during storage and this was the key factor in storage disease development causing storage loss. This corresponds to the earlier findings of Biswas *et al*., (2004) who reported that storage losses were significantly influenced by storage duration, cultivar, storage condition and interaction between storage condition and cultivar (Ko *et al*., 2002).

At 15 DAI BARI Piaz-4 performed best (10.56%) weight loss at storage followed by BARI Piaz-1 (16.26%), BARI Piaz-6 (12.11%), BARI Piaz-5 (22.66%), BARI Piaz-2 (31.53%) and lowest result showed in BARI Piaz-3 (40.53%). Similar trend of result were found in 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI. The result showed that increasing the days, the weight loss of onion bulbs at storage gradually increased. The losses may be due to the moisture loss during respiration of onion bulbs. Sprouting of onion bulbs and pathogenic infection were also responsible for weight loss of onion bulbs at storage. In the present study, it is found that BARI Piaz-4 performed best than the other varieties at storage. The results are similar with Patel *et al*., (2013) found that traditionally storage (bulk storage) the loss of onion was recorded as 4.13%, 3.93%, 5.37%, 7.53%, 4.84% and 3.16% respectively in month of May, June, July, August, September and October.

Aspergillus niger, *Fusarium* sp., *Penicillium* sp. were isolated and identified from the rotten onion bulbs by PDA plate incubation method. In the storage condition, 65% bulbs were rotted by *Aspergillus niger* 20% by *Fusarium* sp. 10% by *Penicillium* sp. and 5% by other pathogens. Similar results were found by Jidda *et al*., (2016). They found that fungal pathogens associated with rotten Monguno Red onions bulbs 60% by *Aspergillus niger,* 20% by *Fusarium* sp., 17% by *Candida tropicalis* and 3% by *Sacchamyces cerevisiae*. Four fungal genera and five species namely *Aspergillus niger, Aspergillus flavus*, *Penicillium* sp., *Rhizopus stolonifer* and *Fusarium oxysporum* were isolated from infected onion bulbs by Adongo *et al*., (2015). They found that *Aspergillus niger* recorded the highest frequency of isolation (35.0%), followed by *Penicillium* sp. (27.0%), then R. *stolonifer* (14.5%) and *Fusarium oxysporum* (14.5%) with *Aspergillus flavus* recording the least (9.0%). Black mold was the most predominant disease in both the dry and wet seasons. The result of this present study indicate that the fungal diseases (Black mold, Blue mold rot and *Fusarium* bulb rot) are serious problem of onion bulb in Bangladesh during storage. Same result was found by Ara, *et al.,* (2008). Five different fungi were isolated and identified by PDA plate incubation method. These fungi were *Aspergillus niger, Aspergillus flavus, Penicillium* spp. *Fusarium moniliforme,* and *Fusarium oxysporum. Aspergillus niger* and *Penicillium* sp. were isolated from the rotten onion bulbs (Govintharaj and Vijayakumar, 2019). Khalequzzaman (2018) also identified *Aspergillus niger* as storage fungi in onion bulbs of his experiment. He found that black mold rot caused by *Aspergillus niger* is often responsible for severe damage to onions during storage. Clusters of black spores of *Aspergillus niger* generally form along veins and on or between the outer papery scales of onion bulbs (Rao and Rajasab, 1992). Infected tissue of onion bulbs initially has a water-soaked appearance, later gradually dry and shrivel (Sinclair and Letham, 1996). Black mold caused by *Aspergillus niger* in onion can occasionally be seen in the field at harvest, it is a post-harvest disease and can cause extensive losses in storage under tropical conditions (Tyson and Fullerton, 2004).

The colony of *Aspergillus niger* on PDA exhibit whitish mycelia growth then it turned into blackish velvety appearance. Colorless conidiophores, globose and dark brown conidial head were produced by *Aspergillus niger*. *Fusarium* sp. produced fluffy, pinkish mycelium around with whitish mycelium. It produced wide, straight and stout, gradually curved and pointed towards the end with 3 to 5 septation macro conidia. Oval, ellipsoid, fusiform with 1 to 2 septation micro conidia were produced by *Fusarium* sp. The colony of *Penicillium* sp. exhibit prolific production of colonies with filamentous, cottony, vulvety, flat or wooly in texture. Chains of single celled conidia (Ameroconidia) were produced in basipetal succession called a phialide. Same cultural characters were reported by Vaijayanthi and Vijayakumar (2019); Ara, *et al.,* (2008).

The results of this present study indicate that the storage condition, onion varieties and fungal diseases were influenced in loses of onion bulb in storage. Proper storage condition, careful harvesting, protection of bulb from sunburn, provision of adequate ventilation and regular examination during storage will minimize the loses of onion bulb.

CHAPTER VI

SUMMARY AND CONCLUSION

Allium, a large genus containing more than five hundred species belongs to the family Alliaceae. Onion *(Allium cepa*) is one of the oldest crops, known to mankind and consumers worldwide. It is a popular pungent herb which has been used for culinary and medicinal purposes. Two types onion produces in Bangladesh namely winter (BARI Piaz-1, BARI Piaz-4 and BARI Piaz-6) and summer (BARI Piaz-2, BARI Piaz-3 and BARI Piaz-5) variety. Generally huge amount of onion bulb grows in rabi season (October-March) under winter variety in Bangladesh. During kharif season (February-October) a little amount of summer onion produces due to lack of improve technology and also climatic change as well as lower shelf life. Farmers of Bangladesh shows negative attitude to produce summer onion due to lower shelf life.

The experiments were done to evaluate the field performance of six varieties of BARI Piaz and it's storage performance. In this experiment different agronomical activities were observed, diseased leaf samples were collected and pathogens were isolated and identified on PDA media in the laboratory. Purple blotch caused by *Alternaria porri*, and stemphylium caused by *Stemphylium vasicarium* were destructive disease of onion in the field of Spices Research Centre, BARI Shibganj, Bogura, Bangladesh. After air dried the harvested onion bulbs of six varieties were kept in the store house of Spices Research Centre, BARI Shibganj, Bogura, in a wooden structure under ambient condition. The average air temperature of the store house was 27.19-29.30℃. Data were recorded on number of sprouted bulbs, rotted bulbs and weight loss of bulbs were observed at 15 days interval. Associated fungus were isolated and identified on PDA media from the rotten bulbs. The experiment was divided in three split and laid out in RCBD with three replications and six varieties.

The present investigations showed that in the field BARI Piaz-4 showed maximum plant height (50.39-71.50 cm), bulb length (7.57cm), bulb diameter (4.97cm), single bulb weight (71.33g) and yield (36.53t/ha). Where BARI Piaz-5 showed minimum plant height (43.05-58.61 cm), bulb length (4.84cm), bulb diameter (3.91cm), single bulb weight (41.17g) and yield (14.64 t/ha). On the other hand, highest disease incidence of purple blotch (4.19%) and stemphylium (43.41%) was recorded from BARI Piaz-5. On the other hand the lowest disease incidence of purple blotch (3.49%)

and stemphylium (34.91%) was recorded from BARI Piaz-4.

From the field experiment it was summarized that BARI Piaz-5 variety was most susceptible to both purple blotch and stemphylium diseases may be due to weather condition. Where BARI Piaz-4 variety was least susceptible compared to other varieties. As the disease incidence was low at BARI Piaz-4 so maximum yield was recorded from here.

In the storage, different storage performances were recorded at an interval of 15 days viz., 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 DAI. Highest no. of sprouted (1.67-39.33) and percent sprouted (1.47-32.71%) bulbs were observed in BARI Piaz-3 at 15, 30, 45, 60, 75 and 90 DAI. Where lowest no. of sprouted (0.00-3.33) and percent sprouted (0.00-6.02%) bulbs were observed in BARI Piaz-4. After 105 DAI no. of sprouting and percent sprouting bulb increases in BARI Piaz-4. Highest no. of rotted (0.00-33.00) and percent rotted (1.49-47.98%) bulbs were observed in BARI Piaz-3 and lowest no. of rotted (2.33-12.67) and percent rotted (0.75-36.14%) bulbs were observed in BARI Piaz-4. At storage maximum weight loss (40.53-77.87%) were observed in BARI Piaz-3 where minimum weight loss (10.56-48.72%) were observed in BARI Piaz-4. These losses may be due to the moisture loss during respiration. From the study it is found that BARI Piaz-4 performed best than the other varieties at storage. Where BARI Piaz-3 showed lower performance.

The present study revealed that different diseases are known to occur on onion bulbs at storage. Fungi are the most common factor responsible for rotten of onion bulbs and loss of onion at storage. *Aspergillus niger, Fusarium* sp. and *Penicillium* sp. have been found to cause diseases during postharvest storage condition. In the study, 65% rotten of onion bulbs by *Aspergillus niger,* 20% by *Fusarium* sp.*,* 10% by *Penicillium* sp. and 5% by other pathogens were found. These pathogens lead to enormous loss of the onion bulbs not only it terms of quantity but also reduce it’s economic value. Some of these fungi are capable of producing mycotoxins which are hazardous to the health of consumers. Therefore, attention is required for the disease, thereby increasing the economic yield of the produce. This will ensure substantial contribution of the spices to food supply and national economy.

From the above study it was concluded that-

i. In terms of yield and disease reaction BARI Piaz-4 performed best than the other varieties where BARI Piaz-5 showed lowest performance in the field. Because of summer variety and thinner skin or may be due to weather condition BARI Piaz-5 was more susceptible for disease development and yield was low.
ii. In the storage BARI Piaz-4 performed best than the other varieties where BARI Piaz-3 showed lowest performance. Because BARI Piaz-3 contain more moisture than the other (winter and summer) varieties during storage which caused sprouting and leads to fungal growth and finally spoilage of onion occurred. These were responsible for weight loss of onion bulbs.
iii. Three fungi were isolated from the infected bulbs. They were *Aspergillus niger, Fusarium* sp. and *Penicillium* sp.

CHAPTER VII

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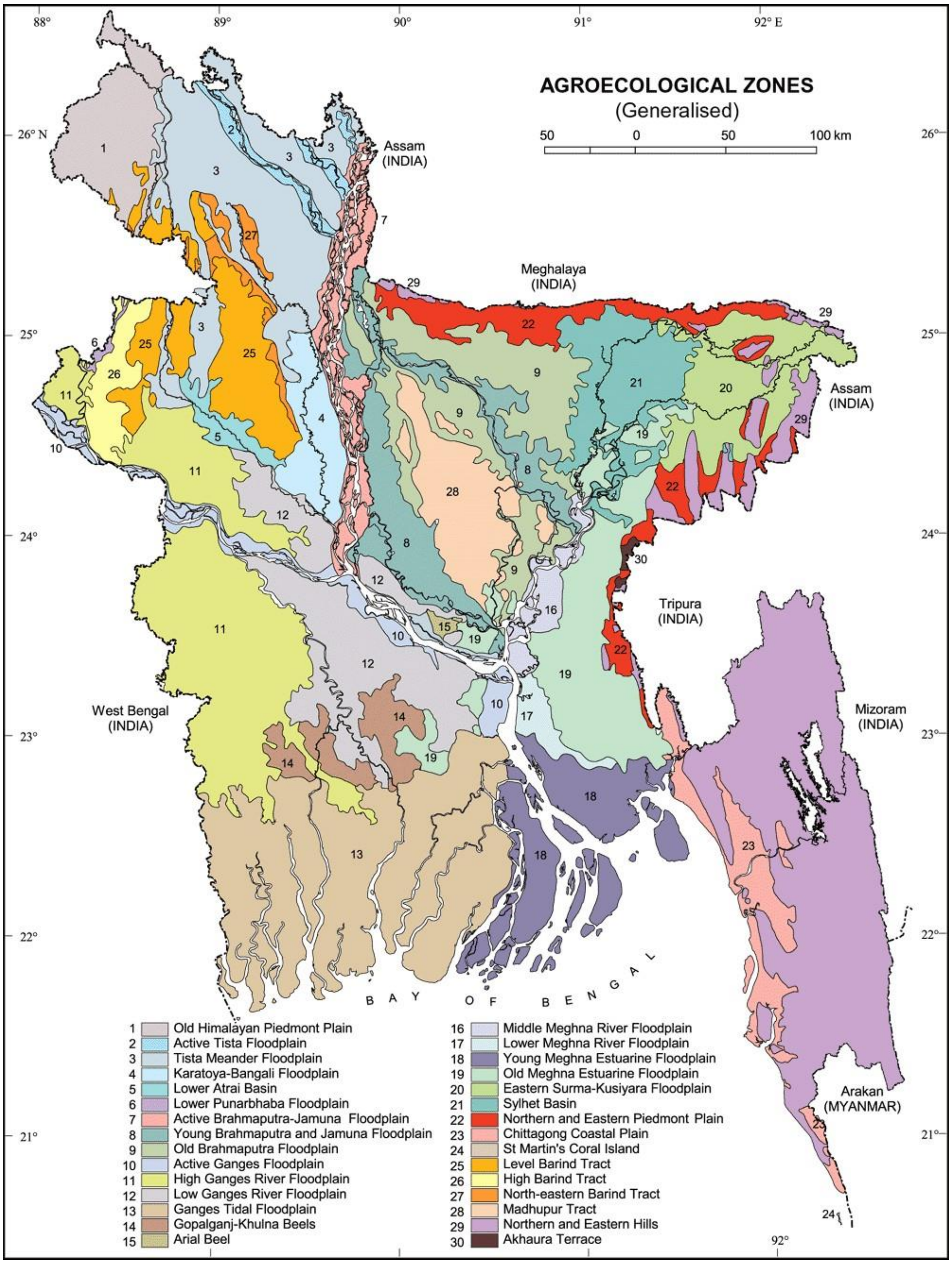
CHAPTER VIII

APPENDICES

Appendix I: Experimental location in the map of Agro-Ecological Zones of Bangladesh



Appendix II. Some important physical and chemical characteristics of the soil
Soil was collected from the plot of SRC, Shibgonj, Bogura where the experiment were conducted during 2019-2020.

A. Physical properties of initial soil of the experimental plot

Particle size distribution	Value
Sand (%)	61.09
Silt (%)	24.56
Clay (%)	14.35
Textural class	Sandy Loam
Bulk density (g/cm^3)	1.33
Particle density (g/cm^3)	2.18
Total porosity (%)	38.99
Field capacity (%)	29.29

B. Chemical properties of initial and post-harvest soil of the experimental site

Soil characteristics	Analytical value (Initial soil)		Analytical value (Soil after harvest)		Critical levels
	Value	Interpretation	Value	Interpretation	
Soil p^H	6.23	Neutral	6.20	Neutral	-
Organic matter (%)	1.49	Medium	1.17	Medium	C:N= 10:1
Total N (%)	0.08	Medium	0.06	Medium	0.12
Available P (µg/g soil)	77.96	Medium	38.67	Optimum	7.0
Exchangeable K (meq/100g soil)	0.17	Low	0.23	Low	0.12
Available S (µg/g soil)	8.26	Low	29.33	Medium	10.0
Available Zn (µg/g soil)	1.61	Low	1.53	Low	0.6
Available Boron (µg/g soil)	0.48	Low	0.07	Medium	0.2

Soil characteristics	Analytical value (Initial soil)		Analytical value (Soil after harvest)		Critical levels
	Value	Interpretation	Value	Interpretation	
Available Cu (µg/g soil)	2.51	Very high	2.07	Very high	0.2
Available Fe (µg/g soil)	129.51	Very high	122.17	Very high	4.0
Available Mn (µg/g soil)	25.21	Very high	23.07	Very high	1.0
Exchangeable Ca (meq/100g soil)	4.61	Optimum	4.19	Optimum	2.0
Exchangeable Mg (meq/100g soil)	1.63	Medium	1.47	Low	0.5

Source: Soil Science Division, BARI, Joydebpur

Appendix III. Minimum and maximum air temperature, rainfall and relative humidity during the experimentation period in 2019-2020

Years	Months	Air temperature (°C)			Rainfall (mm)	Relative humidity (%)
		Max.	Min.	Ave.		
2019	January	26.77	12.61	19.69	0.00	61.42
	February	27.70	15.46	21.58	1.11	58.04
	March	31.10	19.58	25.34	0.42	49.00
	April	32.55	23.11	27.83	1.67	65.80
	May	33.78	25.22	29.5	5.19	69.48
	June	33.61	26.32	29.96	11.50	74.63
	July	32.74	26.75	29.74	14.52	77.45
	August	34.04	27.58	30.81	3.32	75.90
	September	32.35	26.53	29.44	10.70	83.73

Years	Months	Air temperature (°C)			Rainfall (mm)	Relative humidity (%)
		Max.	Min.	Ave.		
2019	October	31.34	23.63	27.48	12.90	82.32
	November	30.81	19.83	25.32	0.03	80.73
	December	24.84	17.83	21.33	0.00	82.52
2020	January	23.56	12.81	18.18	0.07	81.39
	February	26.78	17.43	22.10	0.07	62.93
	March	30.70	19.65	25.18	0.90	53.74
	April	32.16	22.22	27.19	3.23	61.63
	May	32.60	23.93	27.41	18.90	73.71
	June	33.40	26.61	30.00	14.53	78.30
	July	32.35	27.04	29.70	15.65	78.23
	August	33.65	27.53	30.59	5.35	75.74
	September	32.52	26.96	29.74	10.70	83.73
	October	32.80	25.80	29.30	5.19	80.90
	November	30.56	21.89	22.27	0.00	68.07
	December	24.88	13.98	19.43	0.00	76.19

Appendix-IV: Some abbreviations and symbols used in the body of the thesis

Abbreviations	Full word
%	Percent
t	Ton
cm	Centi-meter
g	Gram
hr.	Hour
kg	kilogram
Kg/ha	Kilograms per hectare
m	Meter
m^2	Square meter
etc.	Etcetera
No.	Number
et al.	and others
PDA	Potato dextrose agar
CV%	Percentage of coefficient of variation
DAP	Days After Planting
°C	Degree Celsius
Viz.	Namely
NS	Not significant
t/ha	ton per hectare
LSD	Least Significant Difference
DAI	Days After Initiation
BBS	Bangladesh Bureau of Statistics
BARI	Bangladesh Agricultural Research Institute
FAO	Food and Agricultural Organization
ANOVA	Analysis of variance
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy

Abbreviations	Full word
Rep.	Replication
Res.	Research
RCBD	Randomized complete block design
SRC	Spices Research Centre
Sci.	Science
Univ.	University
J.	Journal
V	Variety
MT	Metric ton
PLB	Purple leaf blotch
SLB	Stemphylium leaf blight
PWL	Percent Weight Loss
Hort.	Horticulture
Pathol.	Pathology
$Hgcl_2$	Mercuric chloride
Dis.	Disease
Mycol.	Mycology
Inst.	Institute
Dev.	Development
Intl.	International
Biol.	Biology
Dept.	Department
Veg.	Vegetable
Nat.	National
BAU	Bangladesh Agricultural University
Prot.	Protection
Edu.	Education
Bull.	Bulletin
Phytochemi.	Phytochemical
Pharmaco.	Pharmacology
Govt.	Government

Abbreviations	**Full word**
Bot.	Botany
Spp.	Species
df.	Degree of freedom
Tech.	Technology
IJPSS	International Journal of Plant & Soil Science
AVRDC	Asian Vegetable Research an Development Center
CMI	Culture and Media Institute

Appendix V. ANOVA for the performance of varieties growth parameter of onion

Source of variance	Degree of freedom	Mean sum square									
		Plant height (cm) at different DAP					No. of leaves/plant at different DAP				
		15	30	45	60	75	15	30	45	60	75
Block	2	0.9375	1.414	5.323	2.263	7.896	0.01995	2.02156	1.68158	3.14040	0.5357
Treatment	5	18.6387	58.105 **	58.239 *	50.843 **	130.317 **	0.41984 **	0.13957 **	0.02347 *	0.32327 *	3.207 **
Error	10	17.6467	4.816	12.458	4.647	16.071	0.06213	0.25585	0.33169	0.71851	0.4657

Appendix VI. ANOVA for the performance of varieties yield, yield parameters and disease reaction on varieties of onion

Source of variance	Degree of freedom	Mean sum square						
		Single bulb weight (g)	Bulb length (cm)	Bulb diameter (cm)	Yield plot (kg)	Yield (t/ha)	Purple blotch (%)	Stem phylum (%)
Block	2	20.44	0.11435	0.04954	1.588	11.397	0.10032	5.8335
Treatment	5	395.90**	2.34214**	0.43570 *	34.420**	244.962**	0.18121*	27.1424*
Error	10	24.85	0.10014	0.12522	0.885	6.237	0.03489	7.5514

Appendix VIIa. ANOVA for the performance of onion varieties no. of sprouted bulbs during storage condition (2019-2020)

Source of variance	Degree of freedom	Mean sum square							
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	No. of sprouted bulbs at different DAP					
				16	32	48	64	80	96
Block	2	0.0439	8.0779	0.67	0.22	0.889	2.3889	0.05556	0.5
Treatment	5	9.4689**	8.0779	1008.63**	364.49**	66.189**	7.9556**	0.32222 **	3.7**
Error	10	0.2606	8.0779	0.80	1.02	0.756	0.3889	0.58889	1.9

Appendix VIIa. ANOVA for the performance of onion varieties no. of sprouted bulbs during storage condition (Contd.)

Source of variance	Degree of freedom	Mean sum square						
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	No. of sprouted bulbs at different DAP				
				112	128	144	160	176
Block	2	0.0439	8.0779	0.05556	0.2222	0.6667	0.50000	0.3889
Treatment	5	9.4689**	8.0779	3.02222 **	20.4889**	23.0333**	1.56667**	5.8222**
Error	10	0.2606	8.0779	0.52222	0.2889	0.4000	0.36667	0.4556

Appendix VIIb. ANOVA for the performance of onion varieties % sprouted bulbs during storage condition (2019-2020)

Source of variance	Degree of freedom	Mean sum square							
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	% of sprouted bulbs at different DAP					
				16	32	48	64	80	96
Block	2	0.0439	8.0779	0.99	0.30	0.729	0.0234	0.004739	0.0483
Treatment	5	9.4689**	8.0779	586.63 **	469.26 **	187.639**	4.2302**	0.266899**	3.3691**
Error	10	0.2606	8.0779	1.86	0.78	0.552	0.0129	0.003592	0.0603

Appendix VIIb. ANOVA for the performance of onion varieties % sprouted bulbs during storage condition (Contd.)

Source of variance	Degree of freedom	Mean sum square						
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	% of sprouted bulbs at different DAP				
				112	128	144	160	176
Block	2	0.0439	8.0779	0.07069	0.0019	0.0138	0.0138	0.0741
Treatment	5	9.4689**	8.0779	0.86351**	3.9694**	6.9962**	6.9962 **	3.6796 **
Error	10	0.2606	8.0779	0.03793	0.0037	0.0156	0.0156	0.0560

Appendix VIIIa. ANOVA for the performance of onion varieties no. of rotted bulbs during storage condition (2019-2020)

Source of variance	Degree of freedom	Mean sum square							
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	No. of rotted bulbs at different DAP					
				16	32	48	64	80	96
Block	2	0.0439	8.0779	2.89	8.167	5.72	16.056	13.389	8.3889
Treatment	5	9.4689**	8.0779	347.96**	73.967**	333.82**	117.122**	36.356**	11.6556 **
Error	10	0.2606	8.0779	5.49	10.833	21.79	16.256	23.389	7.4556

Appendix VIIIa. ANOVA for the performance of onion varieties no. of rotted bulbs during storage condition (Contd.)

Source of variance	Degree of freedom	Mean sum square						
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	No. of rotted bulbs at different DAP				
				112	128	144	160	176
Block	2	0.0439	8.0779	0.889	0.667	83.333	0.3889	0.7222
Treatment	5	9.4689**	8.0779	183.656 **	63.300**	0.167**	19.6889**	12.9889**
Error	10	0.2606	8.0779	8.489	0.667	0.900	0.5889	0.1222

Appendix VIIIb. ANOVA for the performance of onion varieties % rotted bulbs during storage condition (2019-2020)

Source of variance	Degree of freedom	Mean sum square							
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	% of rotted bulbs at different DAP					
				16	32	48	64	80	96
Block	2	0.0439	8.0779	0.0031	0.0865	3.18	0.017	0.35554	0.01771
Treatment	5	9.4689**	8.0779	5.8163**	4.9931**	628.71**	276.682**	2.42533**	2.02678**
Error	10	0.2606	8.0779	0.0659	0.0915	3.69	0.601	0.15479	0.10995

Appendix VIIIb. ANOVA for the performance of onion varieties % rotted bulbs during storage condition (Contd.)

Source of variance	Degree of freedom	Mean sum square						
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	% of rotted bulbs at different DAP				
				112	128	144	160	176
Block	2	0.0439	8.0779	7.88	0.0496	2.274	2.188	0.33502
Treatment	5	9.4689**	8.0779	471.47**	6.6214**	216.797**	171.545**	1.40589**
Error	10	0.2606	8.0779	15.73	0.1799	1.878	2.668	0.09367

Appendix IX. ANOVA for the bulb weight loss % of different onion varieties at different dates in storage condition (2019-2020)

Source of variance	Degree of freedom	Mean sum square							
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	Bulb weight loss % at different DAP					
				16	32	48	64	80	96
Block	2	0.0439	8.0779	0.17	19.09	29.91	9.35	19.33	4.96
Treatment	5	9.4689**	8.0779	417.36**	347.89**	540.46**	679.69**	691.04**	670.49**
Error	10	0.2606	8.0779	1.89	5.63	9.64	28.67	10.32	12.67

Appendix IX. ANOVA for the bulb weight loss % of different onion varieties at different dates in storage condition (Contd.)

Source of variance	Degree of freedom	Mean sum square						
		Initial Wt. of Bulb (kg) at 16.4.20	Initial No. of Bulb at 16.4.20	Bulb weight loss % at different DAP				
				112	128	144	160	176
Block	2	0.0439	8.0779	6.10	23.64	11.95	1.64	14.60
Treatment	5	9.4689**	8.0779	770.60**	555.26**	420.14**	401.47**	347.34**
Error	10	0.2606	8.0779	14.84	25.54	6.51	27.96	5.48