2000

An integrated approach to the control of purple blotch of onion seed-crop.

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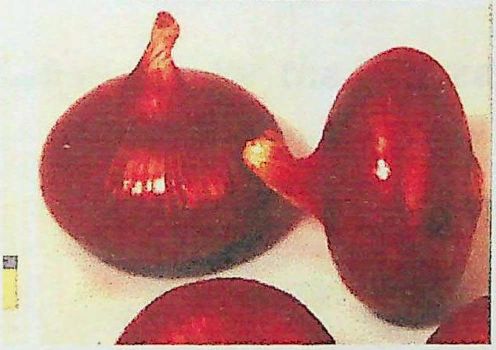

AN INTEGRATED APPROACH TO THE CONTROL OF PURPLE BLOTCH OF ONION SEED-CROP

Thesis

Submitted for the Degree of
Doctor of Philosophy
in
Botany

By

Md. Mozaffar Hossain

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January 2000

Dedicated
to
my parents

DECLARATION

I hereby declare that the whole of the work now submitted as a thesis entitled **"An integrated approach to the control of purple blotch of onion seed-crop"** for the degree of Doctor of Philosophy in Botany of the University of Rajshahi is the results of my own investigation. The thesis has not been concurrently submitted in substance for any other degree.

25.1.200

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CERTIFICATE

This is to certify that the thesis entitled "An integrated approach to the control of purple blotch of onion seed-crop" is an original work done by Mr. Md. Mozaffar Hossain for the degree of Doctor of Philosophy in Botany. The references cited in it have duly been acknowledged. The style and contents of the thesis has been approved and recommended for submission.

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ACKNOWLEDGEMENT

It is a great pleasure and privilege for me to express my deepest sense of gratitude and indebtedness to my supervisor, Dr. M. Shah Alma, Professor, Department of Botany, Rajshahi University for his inspiration, constant guidance and supervision of my research work and help in preparing this thesis. I express my sincere gratitude to Prof. M.A. Jabber Miah for his guidance and suggestion of the thesis work.

I am grateful to Dr. Hamizuddin Ahmed, Ex-Director (Research) and Dr. A.K.M. Amzad Hossain, Ex-Director, Horticulture Research Centre, BARI for their valuable suggestion and constructive criticism throughout the course of this investigation.

I am obliged to BARI authority for the permission to pursue higher studies and allowing me to conduct experiments for this work at BARI campus.

Special thanks and gratefulness to the Director, Horticulture Research Centre, BARI for valuable suggestions, encouragement and various supports for successful completion of this work.

I am indebted to Prof. Asheque Ahmed, Chairman, Department of Botany, Rajshahi University for his encouragement and help.

I am also grateful to the Chief Scientific Officer, Plant Pathology Division, BARI for his suggestion and encouragement for initializing this research work.

Thanks are also due to Chief Scientific Officer of both Pomology Division and Olericulture Division of Horticulture Research Centre, BARI, Gazipur for their cooperation and help.

Special thanks and gratefulness to Dr. M. Shahidul Alam, Assistant Professor, Department of Botany, Rajshahi University for his constant help, encouragement and suggestions.

I gratefully acknowledge FAO-UNDP authority for their partial financial support to carry out research work successfully.

Thanks are also due to my colleagues, friends and field workers of Horticulture Research Centre and Plant Pathology Division, BARI for their sincere cooperation and good wishes during the experimental work in the field.

Thanks to Dr. A.K.M. Anwar Habib, Principal Scientific Officer, Dr. Md. Anwarul Islam, Senior Scientific Officer, Mr. Tapan Kumar Dey, Senior Scientific Officer and Mr. Md. Harunor Rashid, Scientific Officer, BARI, Gazipur for helping in many ways.

I express my sincere thanks to my family members for their patience and encouragement during the course of this study.

Finally, thanks to the Almighty Allah for every success.

(Md. Mozaffar Hossain)

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ACRONYMS, ABBREVIATIONS AND SYMBOLS

a.m.	= Antimeridium	Mn	= Manganese
a.i.	= Active ingredient	MP	= Muriate of potash
B	= Boron	mt	= Metric tonnes
^{o}C	= Degree celsius	N	= Nitrogen
cv.	= Cultivar	P	= Phosphorus
cm	= Centimetre	PDI	= Per cent Disease Index
Cu	= Copper	pH	= A symbol for the degree of acidity or alkalinity of a solution
CODEX	= Coefficient of disease index	RH	= Relative humidity
DAP	= Days after planting	P_2O_5	= Phosphorus penta-oxide
D	= Date of planting	ppm	= Parts per million
DMRT	= Duncan's Multiple Range Test	RCBD	= Randomized Complete Block Design
EC	= Emulsifiable concentrate		
FYM	= Farm yard manure	S	= Sulphur
g	= Gramme	t	= Ton
µg	= Microgramme	temp.	= Temperature
ha	= Hectare	V	= Variety
K	= Potassium	WP	= Wettable powder
K_2O	= Potassium oxide	Zn	= Zinc
meq	= Milliequivalent	/	= Per
Mo	= Molybdenum	%	= Per cent

CHAPTER 1

INTRODUCTION

Onion (*Allium cepa* L.) is an important and widely used spice of Bangladesh. It is also used as vegetable all over the world. In Bangladesh, the greater districts of Faridpur, Pabna, Rajshahi, Dinajpur, Jessore, Dhaka and Comilla are the major onion growing areas. Its present production is around 1,48,000 mt against the requirement of one million ton estimated on a modest requirement of 25 g/capita/day (Hossain and Islam, 1993). The local cultivars namely, Taherpuri, Jhitka, Salta, Kalasnagari and Faridpur bhati are mainly grown in the country (Rahim and Siddique, 1991).

The crop suffers from many diseases (Meah and Khan, 1987; Ahmed and Hossain, 1985; Munoz *et al.*, 1984). Among them purple blotch caused by *Alternaria porri* (Ellis) Cif. is noted as the major disease in many onion growing countries including Bangladesh (Castellanos-Linares *et al.*, 1988; Rahman *et al.*, 1988; Meah and Khan, 1987; Bose and Som, 1986; Ahmed and Hossain, 1985; Munoz *et al.*, 1984; Ashrafuzzaman, 1977). Ahmed and Goyal (1988) mentioned that purple blotch, incited by *A. porri*, is a major problem of onion (*Allium cepa*) in India.

The disease is a serious problem for seed production in tropical countries like Bangladesh (Rahman *et al.*, 1988; Anonymous, 1985). Initially symptoms appear on leaves or seed stalk as small water-soaked lesion that quickly develops white centres. As lesions enlarge, they become zonate and brown to purple, and are surrounded by a yellow zone. The lesion extends upward and downward for some distance. In moist weather, the surface of the lesion may be covered with brown to dark grey fruiting structures of the fungus. A few large lesions have formed in a leaf or seed stalk, which may coalesce and girdle the leaf or seed stalk and tissues distal to the lesions will die (Schwartz and Mohan, 1994).

Purple blotch of onion causes breaking of floral stalks and thus the seed production is seriously affected. Damage of foliage and breaking of floral stalks due to the disease resulting in failure of seed production are common (Munoz *et al.,* 1984; Ashrafuzzaman and Ahmed, 1976). The infected seed stalks break at the point where the lesion is developed (Singh, 1987). Under favourable environmental conditions for the disease complete failure of the crop may take place if appropriate control measures are not followed (Sharma, 1986). Bulb and seed yields of onions cv. 'Nasik Red' were significantly reduced as a result of purple blotch caused by *A. porri* (Gupta and Pathak, 1988). About 20 to 25% losses in seed yield has been recorded in India (Thind and Jhooty, 1982) and 41-44% in Bangladesh (Hossain *et al.,* 1993).

Two onion cultivars, Taherpuri and Faridpur bhati are widely grown in Bangladesh but both of them are susceptible to purple blotch (Rahman *et al.,* 1988). The cultivation area of onion and its rate of production per unit area in Bangladesh are gradually decreasing due to this disease (Anonymous, 1992). As a result Bangladesh has to import a large quantity of onion every year to fulfil the national demand in exchange of foreign currency.

Temperature, humidity and host nutrition play an important role for infection of onion by *A. porri* (Gupta *et al.*, 1993; Everts, 1990; Lacy, 1990; Mondal *et al.*, 1989; Khare and Nema, 1981). Many workers tried to find out suitable control measures of the disease, like cultivation of resistant variety, manipulation of date of planting, management of fertilizers, bulb size, protective spray of fungicides, etc. (Srivastava *et al.*, 1991; Banks and Edgington, 1989; Mishra *et al.*, 1989; Mondal *et al.*, 1989; Yazawa, 1989; Abd-Elrazik *et al.*, 1988; Gupta and Pathak, 1988; Gupta and Pathak, 1987; Martinez-Reyes *et al.*, 1987; Miller *et al.*, 1986; Sharma, 1986; Vishwakarma, 1986; Gupta *et al.*, 1981; Sandhu *et al.*, 1981). In Bangladesh, report on attempts for successful production of onion seed is scanty (Rahim and Siddique, 1991; Rahman *et al.*, 1988). Ashrafuzzaman and Ahmed (1976) tested some foliar fungicides against the disease. Little information is available in Bangladesh on the benefit of use of fertilizer, time of planting and protective spraying on onion seed production (Rahim and Siddique, 1991; Bokshi *et al.*, 1989). The study was therefore, undertaken to assess the effects of integrated approach using standard size of bulb, NPKS fertilizers, micronutrients, time of planting and protective sprays on control of onion purple blotch and yield of onion seed.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Occurrence of Purple Blotch and Loss in Seed Yield of onion

Purple blotch of onion caused by *A. porri* (Ellis) Cif. is a major disease under tropical conditions. The disease is a limiting factor for bulb and seed production. Gupta *et al.* (1991) reported that purple blotch of onion is an important, widespread disease and is prevalent in almost all the onion-growing areas of India. According to them the characteristic feature of the disease are the small, whitish, sunken lesions with purple centres which rapidly enlarge and eventually girdle the leaf or seed stalk of onion. Usually the affected leaves or seed stalks fall down and die within 3 or 4 weeks if the environment favours the disease. Ahmed and Hossain (1985) recorded purple blotch of onion from all onion growing regions of Bangladesh. Ashrafuzzaman and Ahmed (1976) reported that the damage of foliage and breaking of floral stalks due to the disease resulting in failure of seed production are common. Hossain *et al.* (1993) reported 41-44% loss of seed crop in Bangladesh. Under favourable environmental conditions for the disease complete failure of onion seed crop takes place and there is no pod formation and seed set (Sharma, 1986). The disease causes 20-25 per cent loss in seed yield in India (Thind and Jhooty, 1982).

Srivastava *et al.* (1994) reported the high incidence (2.5-87.8%) of purple blotch (*A. porri*) in both the kharif and rabi onions, when high humidity prevailed, during the 5 years of the survey (1988-93).

In India the most serious diseases, which can result in 100% crop losses were reported by Daljeet *et al.* (1992) as purple blotch (*A. porri*), *Stemphylium vesicarium, Peronospora destructor* and *Botrytis* spp., as well as the insect pest *Thrips tabaci.*

In addition to purple blotch (*A. porri*) which usually occurs in the Indian Punjab, stalk rot (*Sclerotinia sclerotiorum*) has recently been recorded, and blight and blotch (*S. botryosum* [*Pleospora tarda*]) and downy mildew (*Peronospora destructor*) are now causing major losses of the onion seed crop reported by Sharma *et al.* (1992).

Among the factors reducing yield and limiting the production of onion seed in Cuba were breaking of floral stalks due to injuries caused by *A. porri* was reported by Munoz-de-Con *et al.* (1986).

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

Rao and Pavgi (1975) recorded another serious pathogen, *S. vasicarium* causing Stemphylium blight, which confined to leaves and inflorescence stalks. Brar *et al.* (1991) reported that *S. botryosum* grows over the downy mildew lesions and transformed them into large elliptical dark brown depressed spots. Bisht and Thomas (1992) in India did Work on varietal screening of garlic against Stemphylium blight. They found out some resistant garlic lines against the disease.

Shi and Kuang (1991) studied the biological characteristics of *S. botryosum,* causing onion leaf blight. The optimum temperature for conidial germination and hyphal growth of the fungus was 25°C. The pH ranged for growth was 3 to 11 and conidial formation was inhibited by light. The best medium for sporulation was PDA supplemented with 0.5% $MgSO_4$ and 0.5% $CaCO_3$. Tomaz and Lima (1988) reported from Portugal 80-85% losses caused by a disease (*S. vesicarium*) affecting leaves and inflorescence stalks.

Miller *et al.* (1978) reported Stemphylium blight of onion in South Texas, a previously unrecognized disease of onion caused significant damage during 1976, both alone and with *A. porri*. Lesions were nondelinated, light yellow to brown, water-soaked and from 1 cm in length to the entire leaf, compared with the purple lesions of *A. porri.* Isolations from light yellow areas of lesion invariably yielded *S. vesicarium*. Density of spores ($244/cm^2$) and lesions were greater on the southeast side of leaves facing the prevailing wind, whereas fewer spores ($14/cm^2$) were observed on the opposite green side of the leaf. Inoculations with *S. vesicarium* on the short day onion cultivars, White Granex, Ben Shamen and New Mexico Yellow Grano produced lesions identical to those in the field.

Shishkoff and Lorbeer (1989) isolated *S. vesicarium* from lesions on leaves of onion plants. In controlled inoculations the fungus caused lesions on leaves of all ages of onion plants, especially on older leaves. Rubbing leaves of greenhouse-grown onion plants with bleached, non-absorbent cotton to damage the cuticle increased the number of lesions/leaf.

2.2 Weather Conditions for the Development of the Disease

Everts and Lacy (1996) studied the factors influencing infection of onion leaves by *A. porri* and subsequent lesion expansion. Conidia deposited on onion leaves formed one to several germination tubes and appressoria and often penetrated at more than one locus under conditions favorable for infection. After 3 h in the dew chamber at 24°C following inoculation of onion leaves, 73% of conidia had germinated and 5% had formed appressoria. Infection hyphae were not observed until 6 h following inoculation, at which time 2% of conidia had formed infection hyphae and 0.5% of conidia had caused visible lesions. Length of dew period was significantly positively correlated with lesion numbers but not with lesion size. There were two types of lesions: expanding and nonexpanding (flecks of less than or equal to 2 mm in diameter). Expanding lesions resulted even when plants inoculated with dry conidia of *A. porri* were incubated in a growth chamber under conditions not conducive to infection for 4 days prior to being placed in a dew chamber for 24 h under conditions conducive to infection, indicating that conidia survived well under these conditions.

The intensity and dynamics of *A. porri* conidial germination were studied by Rodriguez *et al.* (1994) in Cuba with 5, 10, 15, 20, 25, 30, 35, 37.5 and 40°C and RH 76-100%. Conidia developed at 5-37.5°C, with an optimum temperature of 30°C. Germination started within 1 h of incubation at 20-35° and in 4 h 50% of the conidia had germinated. The minimum threshold for RH at 20°C was between 76-78%.

Formation of conidia by *A. porri* was examined under variable dew duration and controlled relative humidity (RH) by Evert and Lacy (1990). Viable conidia produced on lesions increased from 26% after 9 hr of dew to 72, 91, 93, 96, and 96% after 12, 15, 18, 21, and 38 hr of dew, respectively. Conidia formed during dew duration of 12 hr caused flecks when used to inoculate healthy plants, and those formed during dew duration of 16 hr caused typical lesions. Conidia were formed at all RHs tested (75-100%); numbers were very low at 75-85% RH but increased with increasing RH. Conidia formed on lesions on senescent leaves when incubated in dew at 25°C. They formed repeatedly (up to eight cycles) on lesions exposed to alternating low (35-50%) and high (100%) RH in a dew chamber at 25°C.

Gupta and Pathak (1986) mentioned that sixty-day-old onion plants (cv. Nasik Red) were most susceptible to the purple blotch pathogen (*A. porri*). Inoculated plants to high RH (100%) for 120 hours resulted in maximum disease severity and shortest incubation period.

Attack by *T. tabaci* predisposed plants to infection by *A. porr*i and severe purple blotch occurred on plants in which the insects were uncontrolled reported by Thind and Jhooty (1982).

Khare and Nema (1981) studied on purple blotch of onion-sporulation on host and dispersal of conidia. Maximum sporulation of *A. porri* in the field was at 8 a.m. and most occurred immediately after the rains. In the laboratory sporulation was best at 22°C and 90% RH. Most conidia were trapped at 12 noon and at least at 8 a.m. (mean temp. >18 °C).

A. porri and *S. botryosum* were repotted by Wu (1979) to be seed-borne which reduced germination in onion. The occurrence of *A. porri* was not affected by irrigation as reported by Dematte *et al.* (1976).

2.3 Time of Planting and Bulb Size

Sidhu *et al.* (1994) produced 1100 kg/ha seed of Punjab Naroya variety using medium to large bulbs. In Sri Lanka Yazawa (1990) suggested from a preliminary trial that decreasing the plant spacing, shading of the roof, use of jungle bees as pollinators and the selection of fully mature bulbs as mother bulbs could improve seed yield.

Gupta and Pathak (1987) reported from India that three summer ploughings reduced the disease severity by 72%, with 24.4-29.8% higher bulb yield, compared with unploughed plots. The early sown crop had lower disease index and higher bulb yield, compared with the crop sown later than 15 September as reported by Munoz *et al.* (1986) studied on the effects on seed production of various factors including cultivar, bulb storage temperature and duration, planting date and bulb diameter. They reported that the seed yields of 300-400 kg/ha obtained from bulbs of cv. Red Creole stored for 70-120 days at 3-12°C prior to planting out in the cooler months of October and November. Seed yields increased with bulb diameter. Bulb losses during storage and losses due to *A. porri* infection of the flowering seed stalks were high.

Sandhu *et al.* (1983) studied the incidence of *A. porri*. Onions grown for seed (cv. unspecified), the incidence of *A. porri* was appreciably higher (85.3%) in plants grown from sets than in those grown from seeds (29.5%). Disease incidence was higher in closely spaced plants (45 X 30 cm) than in those spaced at 60 X 45 cm. The early sown crop (1 November) was always more susceptible to *A. porri* than the late sown crop (1 December).

Effect of nitrogen, plant spacing and size of mother bulb on growth and yield of seed crop of onion (*A. cepa* L.) were studied by Pall and Padda (1972). Onions were grown for seed from mother bulbs weighing 20, 35 or 50 g, spaced at 20, 35 or 50 cm and given 20, 40 or 60 kg/ha N. The seed yield was greatest when 50 g bulbs were used at the closest spacing with N at 40 kg/ha. The treatments did not influence seed weight or the number of days from planting to the breaking of seed stalk or to flower initiation. However, the number of days from planting to 50% flowering was least with the largest bulbs. N applications checked the incidence of purple blotch disease.

2.4 Onion Variety

Intensity of *A. porri* infection was recorded by Bhangale and Joi (1985) on 74 cultivars of onion grown under field conditions. No resistant cultivars were observed, but Gujarat and 1003 were classed as moderately susceptible to the disease.

Alves (1983) studied the incidence of purple spot (*A. porri* Ell. 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 III) in most cases, only the hybrid Px76 having plants in class I (0-10%).

Padule and Utikar (1982) tested 32 onion cultivars under field conditions against purple blotch and recorded all the cultivars to be susceptible.

2.5 Effect of NPK and Micronutrient on the Incidence of Purple Blotch of Onion

The recovery of nitrogen (N) by a crop and its subsequent use for production can potentially be increased by the split application of N was reported by DeVisser (1998). The significance of this strategy for onions was tested in seven field experiments on Dutch clay soils. An experimental recommendation system consisting of split N application accounting for soil mineral N by replenishing the soil mineral N with fertilizer N up to a crop stage-dependent threshold value, was compared with the pre-sowing fixed N rate. N splitting did not affect the estimated N loss during the growing season, the residual N in soil or the apparent recovery rate of the N applied. However, these variables were significantly influenced by the total N rate, which indicated that N loss to the environment could only be decreased by either lowering the fixed N rate before sowing or lowering the threshold values of the experimental recommendation system.

Pandey *et al.* (1994) reported that the cultivation of onion in Rajasthan has been hampered by lack of quality seed. Seed production of onion (cv. Agrifound Dark Red) was carried out at Jaipur during the kharif season. The plants were spaced at 45 X 30, 60 X 30 or 60 X 45 cm, and given 4 rates of nitrogen (zero, 40, 80 or 120 kg N/ha), split equally into basal and top dressings. The closest spacing gave the highest seed yield, but the umbel size, and incidence of purple blotch and thrips was not affected by the plant spacing. Both 80 and 120 kg N/ha gave significantly higher yields than the lower fertilizer rates, but the higher N rates resulted in significantly larger umbels and less incidence of thrips. The incidence of purple blotch was unaffected by N application.

Bhargava and Singh (1992) worked on the effect of nitrogenous fertilizers and trace elements on the severity of Alternaria blight of bottle gourd. The incidence of blight (*A.. cucumerina*) on bottle gourd increased with the amount of nitrogen fertilizer applied to the soil. The maximum disease intensity (58.7%) was recorded after N application as urea at 100 kg N/ha. Lower doses of urea fertilizer also induced higher disease intensities than the other forms of N fertilizer assessed (ammonium sulfate and calcium ammonium nitrate). Foliar sprays with 2.5 or 25 ppm Cu, B or Zn significantly reduced disease intensity, while 25 ppm Fe and Mn were phytotoxic. Zn and Cu provided good disease control at each concentration tested (25, 2.5 and 0.25 ppm) compared with an untreated control.

Mohit and Singh (1991) reported that high N applications without P or K resulted in severe infection by *A. alternata* on aubergine in a field trial, while high P and K helped to decrease incidence. High P and K, separately or together, reduced the disease under varying levels of N.

Hillocks and Chinodya (1989) found out the relationship between Alternaria leaf spot (*A. macrospora*) and potassium deficiency causing premature defoliation of cotton in Zimbabwe. The observed that severe leaf spotting developed only on plants already showing deficiency symptoms. Defoliation was delayed or reduced by either the application of potassium fertilizer or by fungicide sprays, but significant yield increases required both fertilizer and fungicide.

Mondal *et al.* (1989) reported from Bangladesh that higher doses of N (150 or 200 kg urea/ha) in combination with higher doses of P (triple superphosphate) and with 80 kg muriate of potash/ha in onion increased the number of leaves and seed stalks/plant and reduced the number of diseased (*A. porri*) inflorescence stalks and infected umbels, increasing yields by up to 234% over the controls.

Dabash *et al.* (1985) reported the influence fertilizers on the reduction of white rot disease of onion. In a pot experiments, the application of urea alone at 336 kg/fed., or with P and K at 336, 84 and 168 kg/fed., significantly decreased white rot (*S. cepivorum*) incidence of onion. Ammonium sulphate at 672 kg, or with P and K at 672, 168 and 84 kg, also decreased incidence. Soil treatment with trace elements had varying effects on disease incidence. Zn alone followed by Mn each at 0.16 kg/fed reduced severity while Cu singly or in combination with ferrous sulphate, Zn and Mn increased incidence. The total count of fungi greatly increased in the rhizosphere after Mn treatment.

Khare and Nema (1982) studied environment of spore germiantion of *A. porri*. The germination *in vitro* was 100% within 4 h at 22°C, while on onion a maximum was recorded within 6 h at 25°C. RH 100% was optimum for germination both *in vivo* and *in vitro*. Increasing concentration of sucrose inhibited germination. Spore germination on leaves decreased with increasing N supplied to the host, while the reverse occurred with K. Alves *et al.* (1983) recorded that the rising N rates from 40 to 120 kg N/ha decreased disease incidence.

2.6 Chemical Control

Datar (1996) tested the fungicides, carbendazim, copper oxychloride, zineb, mancozeb, iprodione, thiophanate methyl, dithianon and ziram at 100, 250 and 500 ppm which significantly reduced the percent conidial germination of *A. porri* on onion cv. N-53-1 over the control.

Gupta *et al.* (1996a) reported that Stemphylium blight (*S. vesicarium*) and purple blotch (*A. porri*) are important diseases causing considerable damage to onion crops in India. Diseases are severe during the rainy season especially when thrips are also associated with the crop. Studies were undertaken in Karnal, Haryana, India, during kharif, 1994 and 1995 to determine an effective and economical spray schedule for disease control. Treatments comprised of either 5, 4 and 3 sprays of mancozeb, chlorothalonil and fosetyl (as Aliette) starting at 40 DAP at intervals of 10 days. It was shown that 3-4 sprays of 0.25% mancozeb at 10-day intervals starting at 50 DAP reduced infection by *S. vesicarium* and *A. porri*. Three sprays of 0.25% Kavatch at 10-day intervals starting 60 days after transplanting was also effective.

Upadhyay and Tripathi (1995) conducted a field trial to determine the effect of Bavistin (carbendazim), Blitox (copper oxychloride), Calixin (tridemorph), captafol, Dithane M-45 (mancozeb), Dithane Z-78 (zineb), Jkstein (methyl benzimidazole carbamate), Karathane EC [dinocap] and Topsin M-70 (thiophanate-methyl) on control of *A. porri* on onions (*Allium cepa*).

All treatments significantly reduced disease intensity and gave increased yields over the control. The best results were obtained with captafol.

Sugha (1995) conducted a field trial on the management of purple blotch of garlic caused by *A. porri* during winter season of 1989-90, 1990-91 and 1991-92 and reported that three foliar sprays of iprodione @ 0.1% alone or in combination with copper oxychloride 0.1% and mancozeb 0.1% at 15-day intervals resulted in 53.5 to 62% protection to the crop. Clove dip in iprodione 0.25% for 1 hr before sowing followed by 2 sprays of metalaxyl + mancozeb (Ridomil MZ @ 0.25%) or iprodione @ 0.2% proved highly effective, giving 79.6-84.9% control of the disease. Iprodione and metalaxyl + mancozeb were superior to chlorothalonil copper oxychloride, mancozeb and zineb in providing protection to garlic crop from purple blotch in Himachal Pradesh.

The efficacy of 10 fungicides in controlling downy mildew caused by *Peronospora destructor* and purple blotch caused by *A. porri* on onion was tested by El-Shehaby *et al.* (1995) in experimental plots. Fungicide sprays at the rate of 250g/100 litres were started 45 days after planting and repeated every 15 days until harvesting. Metalaxyl 8% + mancozeb 64% (as Ridomil MZ 72%) and metalaxyl 10% + mancozeb 48% (as Ridomil MZ 58) were the most effective, reducing disease on seed and bulb onions by 86% and increasing seed and bulb yield by 194 and 199%, respectively, compared with the control.

Srivastava *et al.* (1995) reported that Stemphylium blight (*S. vesicarium*) and purple blotch (*A. porri*) cause total failure of the onion seed crop in Karnal, Haryana, India in rabi 1992-93 and 1993-94. They conducted trial with iprobenfos (as Kitazin), iprodione (as Rovral), fosetyl (as Aliette), Kavatch, thiophanate-methyl (as Topsin M), benomyl, metalaxyl (as Ridomil) and mancozeb. Observations on disease intensity were recorded at fortnightly intervals just before each spray and a total of 5 sprays were applied. They recommended that seed growers in North India should apply fortnightly sprays of 0.25% mancozeb or 0.25% iprodione to control onion seed diseases caused by *S. vesicarium* and *A. porri.*

Sugha *et al.* (1993) reported from India that 3 sprays of metalaxyl + mancozeb (0.3%) at 15-day intervals from the appearance of disease gave the most effective control of purple blotch of onion. Sprays of metalaxyl + mancozeb (0.3%) were superior to those of copper oxychloride 0.25%, captafol 0.2% and mancozeb 0.25%.

During surveys in the Cape Province of South Africa, Aveling *et al.* (1993) reported *A. porri* and *S. vesicarium* to be destructive seed-borne pathogens of onion. Six fungicides were evaluated for their efficacy in reducing pathogens both on seed and in culture. These fungicides included anilazine, benomyl, a carbendazim/flusilazole mixture, procymidone, tebuconazole, and thiram. An untreated control, hot water soak (50^{o}C for 20 minute), and a sodium hypochlorite treatment were also included for comparison. Treated seeds were rated for germination by the blotter method and by emergence and seedling growth in seedling trays in the glasshouse. None of the treatments eradicated *A. porri* and *S. vesicarium* from onion seeds. The hot water soak proved to be the best treatment for reducing these pathogens, although the percentages of germination and emergence of onion seeds were reduced compared to the control.

Singh *et al.* (1992) reported the effect of nitrogen, phosphorus and potash on the development of Alternaria leaf spot of cabbage. The severity of white leaf spot of cabbage, caused by *A. brassicicola*, increased with increasing application of N, while addition of potassium decreased disease severity. Phosphorus had no significant effect on disease severity. The increased disease severity resulting from increasing N levels was reduced when K was also present.

Srivastava *et al.* (1991) stated that there is a great effect of nitrogen, phosphorus and potassium on the incidence of myrothecium leaf spot (*Myrothecium roridum*) of soybean (*Glycine max*). In field trials during 1987 using P at 13, 26 and 40 kg/ha, K at 17 and 33 kg/ha and N at 20 kg/ha, the higher levels of P reduced incidence of *M. roridum* and correspondingly increased yields. Interactions of N X P, N X K and P X K had a significant effect on disease intensity and seed yield.

Sharma and Sharma (1991) studied the effect of nitrogen and phosphorus on the yield and severity of turcicum blight (*Setosphaeria turcica*) of maize in Nagaland, India. The optimum combination for highest grain yield and max. disease control was 90 kg/ha N and 40 kg/ha P_2O_5. It is concluded that a balanced dose of N and P is required for low disease incidence and optimum grain yield.

Gupta *et al.* (1991) studied on the economical spray schedule of mancozeb for the control of purple blotch disease of kharif onion. In field trials at the Regional Research Station, Karnal, Haryana, India, during 1987-89, 3 sprays of mancozeb at 0.25% applied at 7-day intervals after the appearance of disease symptoms provided good control of *A. porri* on onions (disease intensity = 8.73%) and resulted in max. yield (280 q/ha).

A preliminary trial on onion seed production was carried out in Sri Lanka on red-skinned mother bulbs of Bombay onion (*Allium cepa*) cv. *Poona* Red, weighing 50-100 g. Captan, Dithane and Benlate were sprayed at 10-day intervals. The use of the houses with a plastic film roof and fungicide application prevented purple blotch (*A. porri*) and rain damage to flowers although devernalization did occur to an extent (75% bolting occurred). It was suggested that decreasing the plant spacing, shading of the roof, use of jungle bees as pollinators and the selection of fully mature bulbs as mother bulbs could improve seed yield (Yazawa, 1990).

Gupta and Pathak (1989) reported that seed yields and 1000 seed wt of Nasik Red onion were significantly reduced by *A. porri* infection. Disease severity was computed in terms of the coefficient of disease index (CODEX). A linear relationship was found between yield and CODEX. For seed yield the line y = 444.15-3.26 x, in which y is the yield in kg and g respectively and x the CODEX 1 week before harvest.

Sharma (1987) evaluated some fungicides against purple blotch of onion under field condition at Uttar Pradesh. He reported that five sprays of Difolatan (captafol) or Dithane Z-78 (zineb) were the most effective treatments for the control of *A. porri.*

In field trials in Sao Paulo under natural infection, metalaxyl gave the best results against metalaxyl against *A. porri* (Ramos *et al.*, 1985).

Bedi and Gill (1978) studied on purple blotch of onion and its control in the Punjab. *A. porri* on onions was significantly reduced by Bordeaux mixture or Dithane M-45 (mancozeb) + Thiodan (endosulfan).

Of the 5 fungicides tested by Ashrafuzzaman and Ahmad (1976), Benlate (benomyl]) at 500 ppm or Dithane M-45 (mancozeb) at 500 ppm gave the best control of *A. porri* on onions and significantly increased the yield. Lower concentrations (125 or 250 ppm) were less effective.

CHAPTER 3

MATERIALS AND METHODS

3.1. Experiment 1: Incidence of Purple Blotch of Onion and pathogenecity Test of *S. botryosum*

Survey of purple blotch of onion seed-crop was conducted at Manikganj, Pabna, Rajshahi and Faridpur during 1991-92 and 1992-93. Most of the onion cultivars are local land races, grown in the country and named as Taherpuri, Jhitka, Faridpuri bhati etc. Disease samples were collected during the survey to identify the causal pathogen(s). Pathogenicity of *S. botryosum* was tested on a local cultivar (Taherpuri) in inoculation tests. The fungus was isolated on carrot meal agar supplemented with onion plant extract for growth and sporulation. Onion plants were grown in earthen pots for inoculation. Sixty days old plants grown from onion bulbs of a local cultivar, Taherpuri were inoculated with the conidial suspension (10^4 conidia/ml). Onion seed stalks (floral axis) were wounded with needle so that the fungus can easily penetrate within the host tissue. The inoculated plants in pots were covered with polythene bags for 24 hours for maintaining high humidity. Disease specimens along with fungal cultures were sent to International Mycological Institute (IMI), Kew, England for identification of the new pathogen. Incidence of purple blotch was recorded on a 0-5 scoring scale (Sharma, 1986) as follows:

0 = no disease symptoms

1 = a few spots towards the tip, covering less than 10% leaf area

2 = several dark purplish brown patches covering less than 20% leaf area

3 = several patches with paler outer zone, covering up to 40% leaf area

4 = long streaks covering up to 75% leaf area or breaking of leaves/seed stalks from the centre

5 = complete drying of the leaves/seed stalks or breaking of the leaves/seed stalks from the base.

The per cent disease index (PDI) was calculated as below:

$$PDI = \frac{\text{Total sum of numerical ratings}}{\text{Number of observations}} \times \frac{100}{\text{Maximum disease rating}}$$

3.2 Experiment 2: Effect of Date of Planting and Onion Cultivars on the Severity of Purple Blotch and Seed Yield of Onion

The experiment was conducted at the Central Research Station, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during 1993-94 and 1994-95. The crop period was from November to April. Chemical properties and nutritional status of the experimental field are shown in table 2. The experiment was laid out in RCBD factorial. Two cultivars viz. Taherpuri (V_1) and Jhitka (V_2) were considered for the first factor and four dates of planting viz. 1st November (D_1), 15th November (D_2), 1st December (D_3) and 15th December (D_4) for the second factor. The treatments were replicated three times. Plant spacing was maintained as row to row 30 cm and plant to plant 15 cm. A raised bed (3 m X 2 m) was considered for each unit plot. There was 50 cm space in-between plots and 1 m in between blocks.

Farm yard manure (FYM) and fertilizers - N, P_2O_5, K_2O and S were applied @ 10 tons, 200 kg, 150 kg, 80 kg and 20 kg per hectare respectively (Bokshi *et al.*, 1989). Urea, triple super phosphate, muriate of potash and gypsum were applied as sources of N, P, K and S respectively. The entire quantity of FYM, TSP (triple superphosphate) and gypsum were applied at the time of final land preparation. Urea and MP (muriate of potash) were applied in four and two equal instalments respectively during the cropping season. Urea was applied for the first time at final land preparation, and 45, 65 and 85 days after planting. MP was applied at final land preparation and 45 days after planting. Adequate moisture was maintained by proper irrigation in the field. The experimental plots were kept free of weeds by periodical weeding. Data were recorded on the number of seed stalk per hill, seed stalk height, umbel diameter, incidence of purple blotch and seed yield (g) per plot. Yield of seed per plot was converted to yield (ton) per hectare. The incidence of disease was recorded on a 0-5 scoring scale (Sharma, 1986). The data of various parameter recorded in the experiment were analysed statistically following the methods of Gomez and Gomez (1984). Means of different parameters were compared by DMRT. In case of PDI, analysis was done after arcsine transformation. The experiment was repeated in the next rabi season using the same treatments and following the same design during November 1994 to April 1995.

3.3 Experiment 3: Effect of Bulb Size and Spacing on the Severity of Purple Blotch and Seed Yield of Onion

The experiment was conducted at the Central Research Station, BARI, Joydebpur, during 1993-94 and 1994-95. The crop period was from November to April. Chemical properties and nutritional status of the experimental field are shown in table 2. The experiment was laid out in RCBD factorial. Two plant spacings eg. 15 cm (S_1) and 20 cm (S_2) plant to plant and 30 cm row to row were considered for the first factor and five bulb sizes eg. 40 (B_1), 70 (B_2), 100 (B_3), 130 (B_4) and 160 (B_5) bulbs/kg more or less equal size were considered for the second factor. Plot size of 3 m X 1.5 m constituted a unit plot. Each treatment was replicated thrice. Each treatment consisted of one unit plot in each replication. There was 30 cm space between the rows. The distance of 50 cm and 1 m was maintained in-between plots and blocks respectively. The cultural management such as application of FYM, fertilizers, irrigation and weed control was done as mentioned. Data were recorded and analysed following the procedures as mentioned in experiment 2. The incidence of disease was recorded on a 0-5 scoring scale.

3.4 Experiment 4: Effect of Fertilizer on Plant Growth, Severity of Purple Blotch and Seed Yield of Onion

The experiment was conducted at the Central Research Station, BARI, Joydebpur, Gazipur during 1993-94 and 1994-95. Among the fertilizers, N at four levels, P at 5 levels, potassium at 4 levels and sulphur at two levels were included in this study. The rates used for nitrogen were 0, 100, 150, 200 kg/ha, phosphorus 0, 100, 150, 200, 250 kg/ha, potassium 0, 75, 100, 125 kg/ha and sulphur 20 and 40 kg/ha. The fertilizer dose in different combinations maintaining 14 treatments are shown in table 3.

The experiment was laid out following randomized complete block design with three replications. Sources of the fertilizers were urea for nitrogen, TSP for phosphorus, MP for potash and gypsum for sulphur. The entire quantity of TSP and S, one fourth of urea and one third of MP were applied as basal application during final land preparation. Remaining urea was applied in 3 equal splits of 45, 65 and 85 days after planting. Rest of MP was splitted and applied at 45 and 65 days after planting. Disease severity was recorded on a 0-5 scoring scale and seed yield was also recorded. Data were recorded and analysed following the procedures as mentioned in experiment 2.

Table 1. Chemical properties of the experimental field in 1993-94

Soil properties	Analytical data	Soil properties	Analytical data
pH	5.70	Potassium (meq/100ml	1.80
Organic matter (%)	0.85	Sulphur (μg/ml)	9.00
NH_4-N (μg/ml)	10.00	Zinc (μg/ml)	1.90
Phosphorus (μg/ml)	7.00	Boron (μg/ml)	0.10

Table 2. Chemical properties of the experimental field in 1994-95

Soil properties	Analytical data	Soil properties	Analytical data
pH	5.80	Potassium (meq/100ml	0.35
Organic matter (%)	0.80	Sulphur (μg/ml)	10.00
NH_4-N (μg/ml)	9.00	Zinc (μg/ml)	1.00
Phosphorus (μg/ml)	9.00	Boron (μg/ml)	0.30

Table 3. Fertilizer dose (kg/ha) and treatment combinations

Treatment	Fertilizer (kg/ha)			
	N	P	K	S
T_1	0	0	0	0
T_2	0	200	100	20
T_3	100	200	100	20
T_4	150	200	100	20
T_5	200	200	100	20
T_6	150	0	100	20
T_7	150	100	100	20
T_8	150	150	100	20
T_9	150	250	100	20
T_{10}	150	200	0	20
T_{11}	150	200	75	20
T_{12}	150	200	125	20
T_{13}	150	200	0	20
T_{14}	150	200	100	40

3.5 Experiment 5: Effect of Micronutrients on Plant Growth, Severity of Purple Blotch and Seed Yield of Onion

The experiment was conducted in two consecutive rabi seasons of 1993-94 and 1994-95 at Central Research Station, BARI with different micronutrients. The experiment was laid out on RCBD with three replications. Row to row and plant to plant spacings were 30 cm and 15 cm respectively. The treatments in this experiment were: $T_1 = Zn_0B_0Mo_0Cu_0$, $T_2 = Zn_0B_1Mo_1Cu_1$, $T_3 = Zn_4B_0Mo_1Cu_1$, $T_4 = Zn_4B_0Mo_1Cu_1$, $T_5 = Zn_4B_1Mo_0Cu_1$ and $T_6 = Zn_4B_1Mo_1Cu_0$. The doses of micronutrients were used as kg/ha. The sources of elements were Zinc oxide for Zn, Solubor for B, Sodium molybdate for Mo and Copper sulphate for Cu.

The micronutrients were applied at the time of final land preparation. The Farm yard manure (FYM) and fertilizers eg. N, P_2O_5, K_2O and S were applied @ 10 tons, 200 kg, 150 kg, 80 kg and 20 kg per hectare, respectively (Bokshi *et al.*, 1989). Urea, triple super phosphate, muriate of potash and gypsum were applied as sources of N, P, K and S respectively. The entire quantity of FYM, triple super phosphate and gypsum were applied at the time of preparation of land. Urea and muriate of potash were applied in four and two equal instalments respectively. Urea was applied at final land preparation, 45, 65 and 85 days after planting. Muriate of potash was applied at final land preparation and 45 days after planting. Irrigation and other intercultural operation were done as and when necessary. Severity of purple blotch was recorded on a 0-5 scoring scale at the mature stage of plant growth. Yield of seeds was also recorded after harvest. Data were recorded and analysed following the procedures as mentioned in experiment 2.

3.6 Experiment 6: Efficacy of Fungicides in Controlling Purple Blotch of Onion Seed Crop

The study was conducted at BARI, Joydebpur, Gazipur during 1993-94 and 1994-95 following RCBD with three replications. Onion bulbs of a local cultivar used in this study was collected from Taherpur, Rajshahi. A total of nine treatments were tested: (1) Dithane M-45 (0.2%), (2) Penncozeb (0.2%), (3) Ridomil MZ-72 (0.2%), (4) Rovral 50 wp (0.2%), (5) Rovral 50 wp (0.2%) + Ridomil MZ-72 (0.2%), (6) Cupravit (0.2%), (7) Score 250EC (0.05%), (8) Tilt-250EC (0.05%) and (9) Control. The fungicides with their active ingredient are shown in table 4.

Table 4. Selected fungicides and their active ingredient

Fungicide	Active ingredient
Cupravit	Copper oxychloride with 50% metallic copper
Dithane M-45	Mancozeb 80% + manganese ethylene
Penncozeb	Mancozeb 80%
Ridomil MZ-72	Metalaxyl 80 g a.i./kg + Mancozeb 640 g a.i./kg
Rovral 50 wp	Iprodione 50%
Score 250EC	Difenconazol 250 g a.i./l
Tilt 250EC	Propiconazol 250 g a.i./l

The cultural management such as application of FYM, fertilizers, irrigation and weed control was done as in experiment 2. The spray schedule was started immediately after initiation of disease symptoms. Fungicides were sprayed five times at an interval of 15 days during the crop period. A total of five sprays Severity of purple blotch was recorded following 0-5 scoring scale. Yield of seed was also recorded after harvest. Data were recorded and analysed following the procedures as mentioned in experiment 2.

3.7 Experiment 7: Integrated Disease Management (IDM) Approach to Control the Purple Blotch of Onion Seed-Crop

The experiment was conducted at the Central Research Station, BARI during rabi season of 1995-96 and 1996-97 with different treatments integrating different components of control measures (Onion bulb size, fertilizers, micronutrients and fungicides). The treatments were: T_1 = Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 160 bulbs/kg + 15cm plant spacing+Cowdung (10 t/ha), T_2 = Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg + 15 cm plant spacing + Cowdung(10 t/ha), T_3 = Rovral @ 0.2% + Ridomil @ 0.2%) + 70 bulbs/kg + Zn_4B_1 kg/ha + 20 cm plant spacing + Cowdung (10 t/ha), T_4 = $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg + 15 cm plant spacing + Cowdung (10 t/ha), T_5 = Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha +70 bulbs/kg + 15 cm plant spacing + Cowdung (10 t/ha), T_6 = $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg + 15 cm plant spacing, T_7 = Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha + 70 bulb/kg + 15 cm plant spacing, T_8 = Rovral @ 0.2% + Ridomil @ 0.2% + 70 bulb/kg + 15 cm plant spacing + Cowdung (10 t/ha), T_9 = 70 bulbs/kg + 15 cm plant spacing + Cowdung (10 t/ha) and T_{10} = 70 bulbs/kg + 15 cm plant spacing (control). The components were selected based on their efficacy against disease under individual experiments. The experiment was conducted in RCBD with three replications. Unit plot size was 3 m X 2 m. The entire quantity of TSP, S, Zn and B, one fourth of urea and one third of MP were applied as basal application during final land preparation. Remaining urea was applied in 3 equal splits of 45, 65 and 85 days after planting. Muriate of potash was splitted twice and applied at 45 and 65 days after planting. The fungicides were sprayed at an interval of 15 days after initiation of disease symptoms (45 days after planting). Incidence of disease was recorded on a 0-5 scoring scale. Seed yield per plot was also recorded. Data were recorded and analysed following the procedures as mentioned in experiment 2.

3.8 Experiment 8: On-farm Trial on the Integrated Disease Management (IDM) Practice for Controlling Purple Blotch of Onion Seed-Crop

The experiment was conducted at the farmers' field of Shibalaya, Manikgonj during the rabi seasons of 1997-98 and 1998-99. The different components for controlling disease viz. fertilizer management, micronutrients, fungicides and onion bulb size were tested in this trial. Four different treatments selected based on on-station trial and the farmers' practice were selected. The trial was laid out in RCBD with five replications. The unit plot size was 5m X 2 m. The treatments were: $T_1 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ + 120 bulbs/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%), $T_2 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ + 70 bulbs/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%), $T_3 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ + 70 bulbs/kg, $T_4 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ + Bulb 120 nos./kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%) i.e. farmers' practice and addition of fungicides and $T_5 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ + Bulb 120 nos./kg i.e. farmers' practice. The soil of the experimental field is slightly acidic and except sulphur, all the nutrient status was very low (Table 5 and 6). The spacing was used at 30 cm X 15 cm in case of three treatments T_1, T_2 and T_3, and 15 cm X 10 cm in case of T_4 and T_5.

Cowdung @ 10 t/ha, 1/4 urea, 1/3 MP and total TSP, Zn and B were applied as final land preparation. Rest of the urea was applied at three instalments (45, 65 and 85 DAP). Remaining MP was applied at two instalments (45 and 65 DAP). The fungicides (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%) were sprayed at an interval of 15 days after initiation of disease symptoms (45 days after planting). The crop was irrigated twice in January and March, 1998. Weeding and mulching were done as and when necessary. After the completion of flowering, thin jute rope tied with bamboo stick were set along the row of the plot, so that the seed stalk did not lodge.

Severity of disease was recorded on a 0-5 scoring scale. Harvesting was done at 3 instalments in the month of April, 1998. The seed yield of onion was taken after proper cleaning and drying. Data were recorded and analysed following the procedures as mentioned in experiment 2.

Table 5. Chemical properties of the experimental field in 1997-98

Soil properties	Analytical data	Soil properties	Analytical data
pH	6.40	Potassium (meq/100ml	0.80
Organic matter (%)	0.95	Sulphur (μg/ml)	14.00
NH_4-N (μg/ml)	12.00	Zinc (μg/ml)	1.20
Phosphorus (μg/ml)	8.00	Boron (μg/ml)	0.15

Table 6. Chemical properties of the experimental field in 1998-99

Soil properties	Analytical data	Soil properties	Analytical data
pH	6.20	Potassium (meq/100ml	0.35
Organic matter (%)	0.85	Sulphur (μg/ml)	12.00
NH_4-N (μg/ml)	8.00	Zinc (μg/ml)	3.50
Phosphorus (μg/ml)	10.00	Boron (μg/ml)	0.30

CHAPTER 4

RESULTS

4.1 Experiment 1: Incidence of Purple Blotch of Onion and Pathogenicity Test of *S. botryosum*

The causal fungi *Alternaria porri* (Ellis) Cif. and *Stemphylium botryosum* Wallr. were identified on the disease samples collected from different locations. The identification of *S. botryosum* was confirmed by Commonwealth Mycological Institute, Kew, UK (IMI 350909). *A. porri* was reported by many workers to be the causal pathogen of purple blotch of onion (Linares *et al.*, 1988; Bose and Som, 1986; Anonymous, 1985, Munoz *et al.*, 1984). During the present study both the fungi, *A porri* and *S. botryosum* were found to be associated with purple blotch samples from different locations of Bangladesh. *S. botryosum* showed blighting symptoms on the inoculated leaves and seed stalk (Plate 1). It is the first report of *Stemphylium botryosum* Wallr. on association with purple blotch of onion in Bangladesh.

The severity of the disease varied with locations. In 1991-92, the highest PDI was noticed at Pabna followed by Manikganj, Faridpur and Rajshahi. In 1992-93, the PDI ranged from 62.00 to 68.60%. The highest PDI was recorded at Manikganj (Plate 2) followed by Pabna and Faridpur (Table 7).

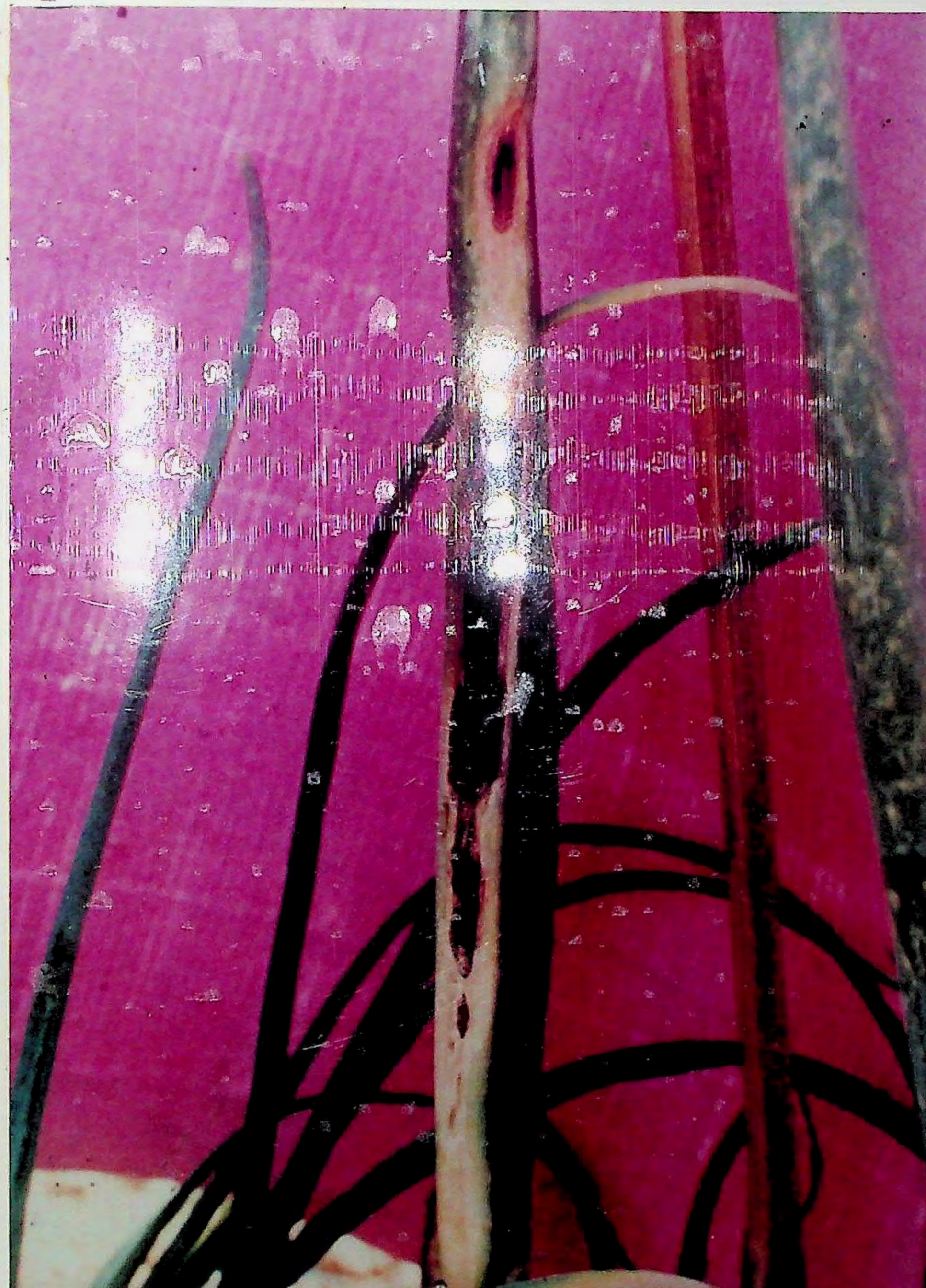


Plate 1. Symptoms of purple blotch of onion seed stalk developed after inoculation.

a

b

Plate 2. Farmers' fields severely infected by purple blotch of onion seed-crop:
a) Barail, Rajshahi and b) Manikganj.

Table 7. Severity of purple blotch of onion seed-crop at different locations during 1991-92 and 1992-93

Location	Per cent Disease index	
	1991-92	1992-93
Manikganj	73.45	68.60
Pabna	76.00	67.20
Rajshahi	55.80	62.00
Faridpur	71.30	66.50

4.2 Experiment 2:Effect of Date of Planting and Onion Cultivars on the Severity of Purple Blotch and Seed Yield of Onion

4.2.1 Crop Season 1993-94

Four dates of planting used in the study during 1993-94 showed significant difference among themselves in all parameters (Table 8). The highest seed stalk/hill was observed in November 1 planting followed by November 15 planting and they were statistically similar. The lowest number of seed stalk/hill was recorded in December 15 planting and it was significantly different as compared to December 1 planting. Seed stalk height varied from 62.05 to 73.27 cm. The maximum seed stalk height was observed in November 1 planting followed by December 1 planting and the minimum was found in December 15 planting. Umbel diameter was maximum

Table 8. Effect of date of planting and variety on plant growth, purple blotch severity and seed yield of onion during 1993-94

Treatment	Seed talk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
D_1 (November 1)	3.32 a	73.27 a	6.48 a	55.00 b	626.50 a
D_2 (November 15)	3.17 a	67.62 b	5.93 b	46.83 a	689.80 a
D_3 (December 1)	2.45 b	70.08 ab	6.03 b	74.00 c	459.78 b
D_4 (December 15)	2.30 b	62.05 c	5.47 c	83.83 d	217.30 c
Variety					
V_1 (Taherpuri)	2.92 a	66.99 a	6.24 a	63.92 a	511.38 a
V_2 (Jhitka)	2.70 a	69.52 a	5.71 b	65.92 a	485.30 a
Interaction					
V_1 x D_1	3.63 a	74.13 a	6.67 a	53.67b	636.88 ab
V_1 x D_2	3.37 ab	64.37 bcd	6.13 bc	46.67 a	693.28 a
V_1 x D_3	2.30 d	68.53 abc	6.43 ab	72.00 c	493.78 bc
V_1 x D_4	2.37 d	60.93 d	5.73 c	83.33 d	221.62 d
V_2 x D_1	3.00 bc	72.40 a	6.27 ab	56.33 b	616.12 ab
V_2 x D_2	2.97 bc	70.87 ab	5.73 c	47.00 a	686.33 a
V_2 x D_3	2.60 cd	71.63 a	5.63 cd	76.00 c	425.78 c
V_2 x D_4	2.23 d	63.17 cd	5.20 d	84.33 d	213.00 d

Means in a column under planting date or variety or their interaction followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI analysis was done after arcsine transformation).

in November 1 planting followed by December 1 planting and the smaller size of umbel was observed in December 15 planting. The highest PDI was recorded in December 15 planting followed by December 1 planting. The lowest PDI was recorded in November 15 planting followed by November 1 planting. The highest seed yield was recorded in November 15 planting followed by November 1 planting. The lowest seed yield was recorded in December 15 planting.

In case of onion cultivar, the highest seed stalk/hill, umbel diameter and yield/ha were recorded 2.92, 6.24 cm and 511.38 kg, respectively in Taherpuri. The higher PDI was recorded in Jhitka cultivar as compared to Taherpuri.

Interaction effect of date of planting and variety on different parameters was significant. The highest number of seed stalk/hill was recorded in V_1 X D_1 followed by V_1 X D_2 and V_2 X D_1. The minimum number of seed stalk/hill was recorded in V_2 X D_4. The maximum seed stalk height was recorded in V_1 X D_1 followed by V_2 X D_1 and V_2 X D_3. The lowest seed stalk height was recorded in V_1 X D_4. The treatment V_1 X D_1 produced the highest umbel diameter. The smallest size of umbel was observed in V_2 X D_4 followed by V_2 X D_3 and V_1 X D_4. The lowest PDI was recorded in V_1 X D_2 followed by V_2 X D_2. On the other hand, the highest PDI was recorded in V_1 X D_4. The maximum seed yield/ha was found in V_1 X D_2 followed by V_2 X D_2 and V_1 X D_1. The lowest yield of onion seed/ha was recorded in V_2 X D_4 (Table 8).

The number of seed stalk/hill was significantly different from rest of treatment combinations except V_1 X D_2. The seed stalk number among V_1 X D_2, V_2 X D_1 and V_2 X D_2 was statistically similar. The seed stalk/hill in V_2 X D_4 was also statistically similar to those of V_1 X D_3, V_1 X D_4 and V_2 X D_3. The seed stalk height in V_1 X D_1 did not differ significantly as compared to V_1 X D_3, V_2 X D_1, V_2 X D_2 and V_2 X D_3. The umbel diameter was significantly higher in V_1 X D_1 as compared to rest of the treatment combinations except V_1 X D_3 and V_2 X D_1. Considering the PDI value, it appeared that V_2 X D_2 expressed significantly the best combination in reducing disease severity as compared to rest of the treatment combinations except V_1 X D_1 and V_1 X D_2. The treatment combination V_2 X D_4 was statistically similar to V_1 X D_4 in respect of PDI. In respect of seed yield/ha, V_1 X D_2 was statistically similar to V_2 X D_2 and V_1 X D_1 but differed significantly from rest of the treatment combinations. The seed yield from V_2 X D_4 was not statistically different from V_1 X D_4 (Table 8).

4.2.2 Crop Season 1994-95

The results on the effects of date of planting and onion cultivar on plant growth, purple blotch and seed yield during 1994-95 are presented in table 9. The effect of date of planting on seed stalk/hill was not significant. The seed stalk height of plants and umbel diameter of November 1 planting were statistically similar to those planted in November 15 but significantly different from those planted in December 15. The PDI values of purple blotch of onion seed crop were significantly different among the dates of planting having maximum severity at November 15 followed by November 1, December 1 and December 15. The highest severity was

Table 9. Effect of date of planting and variety on plant growth, seed yield and severity of purple blotch of onion seed-crop during 1994-95

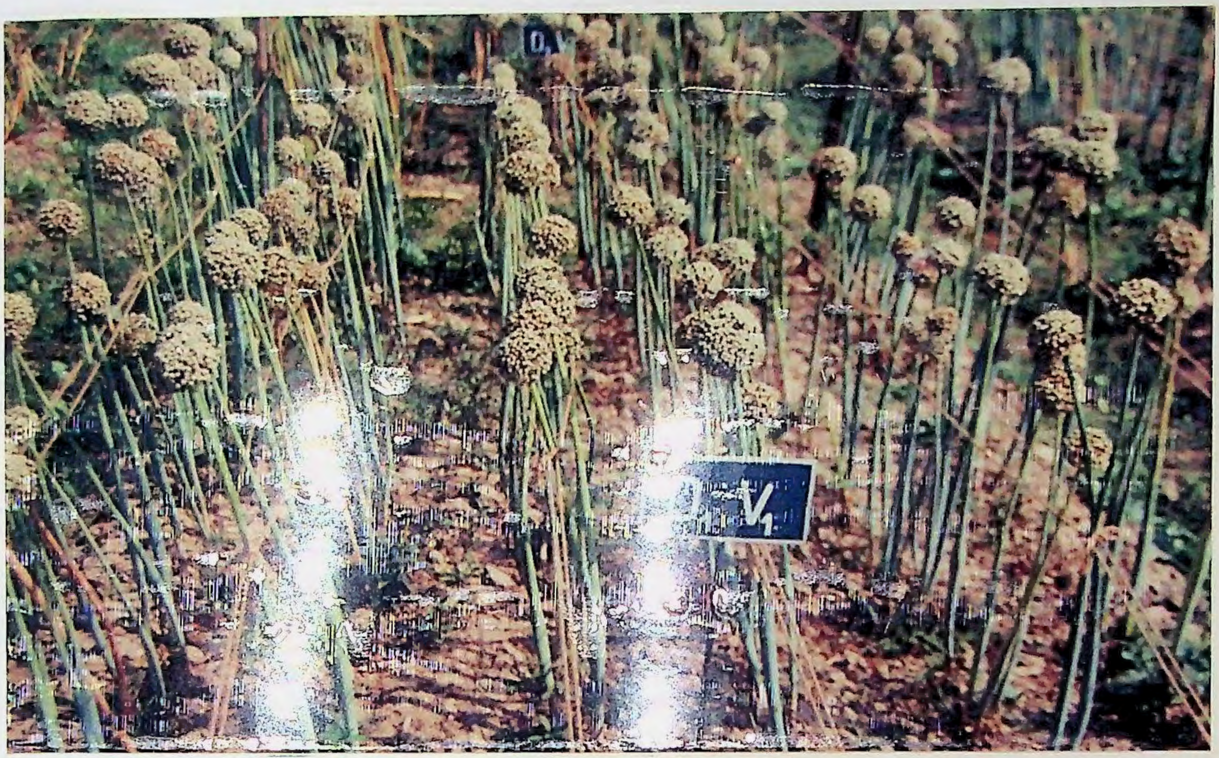
Treatment	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
D_1 (November 1)	3.30 a	79.33 a	6.98 a	45.42 b	721.17 b
D_2 (November 15)	3.37 a	77.83 a	6.97 a	41.40 a	828.33 a
D_3 (December 1)	3.20 a	74.50 a	6.58 a	55.08 c	523.50 c
D_4 (December 15)	2.98 a	60.33 b	5.27 b	81.08 d	199.67 d
Variety					
V_1 (Taherpuri)	3.18 a	74.08 a	6.73 a	53.66 a	585.00 a
V_2 (Jhitka)	3.25 a	71.92 a	6.18 a	57.83 a	551.27 a
Interaction					
$V_1 \times D_1$	3.37 ab	80.33 a	7.33 a	43.50 ab	703.50 b
$V_1 \times D_2$	3.20 ab	78.00 a	7.20 ab	40.13 a	877.00 a
$V_1 \times D_3$	3.47 a	75.00 a	6.73 bc	53.00 c	534.50 c
$V_1 \times D_4$	2.67 b	63.00 b	5.63 d	78.00 d	225.00 d
$V_2 \times D_1$	3.23 ab	78.33 a	6.63 bc	47.33b	738.83 b
$V_2 \times D_2$	3.53 a	77.67 a	6.73 abc	42.67 ab	779.67 b
$V_2 \times D_3$	2.93 ab	74.00 a	6.43 c	57.17 c	512.50 c
$V_2 \times D_4$	3.30 ab	57.67 b	4.90 e	84.17 e	174.17 d

Means in a column under planting date or variety or their interaction followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI analysis was done after arcsine transformation).

recorded in December 15 planting and the lowest in November 15 planting. The highest yield of onion seed/ha was observed in November 15 planting followed by November 1 and December 1 plantings.

In case of Taherpuri, the seed stalk height, umbel diameter and yield/ha were higher as compared to Jhitka. The lowest PDI and yield of seed were recorded in Jhitka as compared to Taherpuri.

Interaction effects of date of planting in reducing purple blotch of onion seed crop and seed yield are presented in table 9. In case of seed stalk/hill, the highest number was recorded in V_2 X D_2 followed by V_1 X D_3 and V_1 X D_1. The lowest number of seed stalk/hill was recorded in V_1 X D_4. The highest seed stalk height was recorded in V_1 X D_1 and the lowest in V_2 X D_4 (Plate 3). Large umbel diameter was observed in V_1 X D_1 followed by V_1 X D_2, V_1 X D_3 and V_2 X D_2. The lowest diameter of umbel was recorded in V_2 X D_4. The lowest PDI of purple blotch was recorded in V_1 X D_2 and the highest in V_2 X D_4. The highest yield was obtained in V_1 X D_2. The lowest yield of seed was recorded in V_2 X D_4 followed by V_1 X D_4 and V_2 X D_3. In 1994-95 crop season, significant effect of all the attributes was observed in interaction effect. Although higher number of seed stalk/hill was recorded by V_2 X D_2 numerically, but it was statistically insignificant with all treatment combinations except V_1 X D_4. Significantly maximum plant height was measured in V_1 X D_1 and it did not differ significantly from that under V_1 X D_2, V_1 X D_3, V_2 X D_1, V_2 X D_2 and V_2 X D_3. In case of umbel diameter, there was no significant



a

b

Plate 3. Onion seed-crop planted at: a) November 1 cv. Taherpuri (D_1V_1) and b) December 15 cv. Jhitka (D_4V_2).

difference among the treatments, V_1 X D_1, V_1 X D_2 and V_2 X D_2, but other treatments differed significantly. The significantly lowest umbel diameter was computed by V_2 X D_4, which clearly differed significantly with rest treatments. Regarding PDI, significantly the lower PDI value was calculated in V_1 X D_2, which was statistically similar with V_1 X D_1 and V_2 X D_2. The maximum yield was computed in V_1 X D_2, which differed significantly with all other combinations. The treatment, V_2 X D_2 exhibited second in increasing yield but it was statistically similar to V_2 X D_1 and V_1 X D_1.The treatment V_2 X D_4 appeared to be the least yielder and it was statistically similar to V_1 X D_4.

4.3 Experiment 3: Effect of Bulb Size and Spacing on the Severity of Purple Blotch and Seed Yield of Onion

4.3.1 Crop Season 1993-94

The effect of bulb size and spacing and their interaction on plant growth, purple blotch severity and seed yield of onion was significant during 1993-94 (Table 10). The seed stalk number/hill ranged from 2.83 to 4.77. The maximum number of seed stalk/hill was found in 40 bulbs/kg which was statistically similar to the size of 70 bulbs/kg onion. The minimum number of seed stalk/hill was recorded in seed size of 160 bulbs/kg. The effect of seed size of 160 bulbs/kg, 130 bulbs/kg and 100 bulbs/kg on seed stalk number/hill was statistically similar but significantly lower as compared to the smallest size of bulb. The seed stalk height ranged from

Table 10. Effect of bulb size and planting spacing on plant growth, purple blotch severity and seed yield during 1993-94

Treatment	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
Bulb size					
40 bulbs/kg	4.77 a	79.40 a	6.95 a	46.67 a	724.72 a
70 bulbs/kg	4.08 ab	78.97 a	6.52 b	51.17 ab	669.45 b
100 bulbs/kg	3.63 bc	74.67 ab	6.33 b	54.00 b	618.88 c
130 bulbs/kg	2.88 c	73.92 ab	6.25 b	61.83 c	385.55 d
160 bulbs/kg	2.83 c	69.72 b	5.80 c	68.50 d	281.11 e
Spacing					
15 cm	3.89 a	74.92 b	6.21 a	56.73 a	565.12 a
20 cm	3.39 a	75.76 a	6.51 a	56.13 a	506.78 b
Interaction					
15 cm X 40 bulbs/kg	4.87 a	77.20 abc	6.70 b	46.67 a	752.22 a
15 cm X 70 bulbs/kg	4.50 ab	79.23 ab	6.33 bcd	50.33 ab	709.45 b
15 cm X 100 bulbs/kg	4.10 abc	75.20 abc	6.23 cd	53.33 ab	663.33 cd
15 cm X 130 bulbs/kg	2.97 c	74.37 abc	6.17 cd	65.00 cd	396.67 f
15 cm X 160 bulbs/kg	3.03 bc	68.53 c	5.63 e	68.33 d	303.88 g
20 cm X 40 bulbs/kg	4.67 a	81.60 a	7.20 a	46.67 a	697.22 bc
20 cm X 70 bulbs/kg	3.67 abc	78.70 ab	6.70 b	52.00 ab	629.45 d
20 cm X 100 bulbs/kg	3.17 bc	74.13 abc	6.43 bc	54.67 ab	574.45 e
20 cm X 130 bulbs/kg	2.80 c	73.47 abc	6.33 bcd	58.67 bc	374.45 f
20 cm X 160 bulbs/kg	2.63 c	70.90 bc	5.96 de	68.67 d	258.33 h

Means in a column under bulb size or spacing or their interaction followed by same letter are not significantly different (P = 0.05) according to DMRT (In case of PDI analysis was done after arcsine transformation).

69.72 to 79.40 cm. Significantly higher seed stalk height was observed in treatment with 40 bulbs/kg, which was statistically similar to other treatments except 160 bulbs/kg. The umbel diameter ranged from 5.80 to 6.95 cm. Statistically the largest umbel was found in plots planted with seed size of 40 bulbs/kg. The umbel size in plots planted with seed size of 70 bulbs/kg, 100 bulbs/kg and 130 bulbs/kg was statistically similar but significantly larger as compared to seed size of 160 bulbs/kg. The purple blotch severity (PDI) varied from 43.08 to 55.89. The highest PDI was recorded in 160 bulbs/kg seed size followed by 130 bulbs/kg and 100 bulbs/kg. The PDI value under largest seed size (40 bulbs/kg) was statistically similar to seed size of 70 bulbs/kg. The lowest number of seed stalk/hill was recorded from the treatment combinations of 20 cm spacing X 160 bulbs/kg followed by 20 cm X 130 bulbs/kg, 15 cm X 130 bulbs/kg. The seed stalk number under those treatments were statistically similar and significantly different from treatment combinations of only 15 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg and 20 cm X 40 bulbs/kg. The effect of bulbs used for seeds on yield of seed was significantly different from each other having the highest seed yield was recorded in 40 bulbs/kg seed size onion followed by seed size of 70 bulbs/kg and 100 bulbs/kg, 130 bulbs/kg and 160 bulbs/kg. The seed yield was directly correlated with size of the bulbs (Table 10).

The seed yield under the spacing of 15 cm significantly higher as compared to the spacing of 20 cm during 1993-94 growing season. Effect of planting spacings on seed stalk/hill, seed stalk height and umbel diameter was not significant (Table 10).

The interaction effect of different bulb sizes and planting spacings influenced all parameters significantly (Table 10). Seed stalk/hill ranged from 2.63 to 4.87. The maximum number of seed stalk/hill was observed in treatment combination of 15 cm X 40 bulbs/kg followed by 20 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg, 15 cm X 100 bulbs/kg and 20 cm X 70 bulbs/kg and they were statistically similar. The lowest number of seed stalk/hill was recorded from the treatment combinations of 20 cm spacing X 160 bulbs/kg followed by 20 cm X 130 bulbs/kg, 15 cm X 130 bulbs/kg. The seed stalk number under those treatments were statistically similar and significantly different from treatment combinations of only 15 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg and 20 cm X 40 bulbs/kg. The stalk height varied from 68.53 to 81.60 cm. The highest seed stalk height was recorded in treatment combinations of 20 cm X 40 bulbs/kg followed by 15 cm X 70 bulbs/kg, 20 cm X 70 bulbs/kg, 15 cm X 40 bulbs/kg, 15 cm X 100 bulbs/kg, 15 cm X 130 bulbs/kg, 20 cm X 100 bulbs/kg and 20 cm X 130 bulbs/kg. However, the seed stalk height under these eight treatments was significantly similar. The lowest seed stalk height was recorded under the treatment combinations of 15 cm X 160 bulbs/kg and it was significantly lower as compared with two treatment combinations of 20 cm X 40 bulbs/kg and 20 cm X 70 bulbs/kg. Significantly the largest umbel was recorded in treatment combination of 20 cm X 40 bulbs/kg. The second largest umbel was found in treatment combination of 15 cm X 40 bulbs/kg followed by 20 cm X 70 bulbs/kg, 20 cm X 100 bulbs/kg and 15 cm X 70 bulbs/kg. The smallest umbel was found in plots planted with smallest bulbs (160 bulbs/kg) using 15 cm spacing. The umbel diameter under this treatment combination was statistically similar to the combination of 20 cm X 160 bulbs/kg but significantly lower as compared to rest of the treatment combinations. The PDI of values of purple blotch ranged from 46.67% to 68.67%. The highest severity of purple blotch was recorded in treatment combination of 20 cm X 160 bulbs/kg followed by 15 cm X 160 bulbs/kg, 20 cm X 130 bulbs/kg, 15 cm X 130 bulbs/kg, 20 cm X 70 bulbs/kg and 20 cm X 130 bulbs/kg. The effect of these treatment combinations on PDI was statistically similar and significantly higher as compared with other treatment combinations. The treatment combination of 20 cm X 40 bulbs/kg showed the best performance in reducing PDI value but it was statistically similar to the treatment combination of 15 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg, 15 cm X 100 bulbs/kg, 20 cm X 70 bulbs/kg and 20 cm X 100 bulbs/kg. The yield of onion seeds per hectare ranged from 258.33 to 752.22 kg. The highest yield of seed was recorded in treatment combination of 15 cm X 40 bulbs/kg followed by 15 cm X 70 bulbs/kg, 20 cm X 40 bulbs/kg and 15 cm X 70 bulbs/kg. Among the interaction of bulb size and plant spacing, 15 cm X 40 bulbs/kg and 15 cm X 70 bulbs/kg were found to be the best, considering the severity of purple blotch and seed yield.

4.3.2 Crop Season 1994-95

The effect of bulb size and planting spacing on plant growth, purple blotch severity and seed yield of onion tested during 1994-95 crop season are presented in table 11. The results showed that seed stalk number/hill, seed stalk height, umbel diameter and seed yield were increased with the increase of bulb size used as seeds. On the contrary the highest PDI was found when seed size was the smallest. The seed stalk number/hill under the treatment 70 bulbs/kg was significantly higher as compared to bulb size, 100 bulbs/kg and 130 bulbs/kg, both

Table 11. Effect of bulb size and planting spacing on plant growth, severity of purple blotch and seed yield of onion during 1994-95

Treatment	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
Bulb size					
40 bulbs/kg	4.13 a	81.42 a	7.25 a	51.67 a	678.62 a
70 bulbs/kg	3.30 b	77.70 b	6.75 b	55.00 a	626.95 b
100 bulbs/kg	2.63 c	75.58 c	6.57 c	61.00 b	556.38 c
130 bulbs/kg	2.43 cd	74.77 cd	6.43 c	67.00 c	353.33 d
160 bulbs/kg	2.15 d	73.12 d	5.96 d	77.17d	259.72 e
Spacing					
15 cm	2.91 a	76.77 a	6.54 a	50.83 a	514.00 a
20 cm	2.95 a	76.26 a	6.64 a	53.67 a	476.00 b
Interaction					
15 cm X 40 bulbs/kg	4.20 a	81.23 a	7.20 a	51.00 a	708.88 a
15 cm X 70 bulbs/kg	3.30 b	78.27 b	6.70 bc	54.67 ab	636.12 bc
15 cm X 100 bulbs/kg	2.67 c	75.20 cd	6.50 cd	60.00 bc	586.12 d
15 cm X 130 bulbs/kg	2.40 cd	75.17 cd	6.43 d	62.00 bc	363.88 f
15 cm X 160 bulbs/kg	2.00 d	74.00 de	5.87 e	73.67 d	275.00 h
20 cm X 40 bulbs/kg	4.07 a	81.60 a	7.30 a	52.33 a	648.33 b
20 cm X 70 bulbs/kg	3.30 b	77.13 bc	6.80 b	55.33 abc	617.78 c
20 cm X 100 bulbs/kg	2.60 cd	75.97 bcd	6.63 bcd	62.00 c	526.67 e
20 cm X 130 bulbs/kg	2.47 cd	74.37 cde	6.43 d	72.00 d	342.78 g
20 cm X 160 bulbs/kg	2.30 cd	72.23 e	6.06 e	80.67 e	244.45 i

Means in a column under bulb size or spacing or their interaction followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was done after the arcsine transformation).

the treatments were equally effective on seed stalk number. The minimum number of seed stalk/hill was recorded in case of bulb size, 160 bulbs/kg and it was significantly lower as compared to the size 100 bulbs/kg. Seed stalk height ranged from 73.12 to 81.42 cm. The trends in seed stalk height and umbel diameter were similar to seed stalk number/hill. The PDI values under bulb size of 40 and 70 bulbs/kg and the values were significantly lower as compared to the bulb size of 100, 130 and 160 bulbs/kg. The different in PDI values under the three smaller bulb sizes were significantly different. Seed yield increased significantly with the increase of bulb size. The effect of onion cultivar on plant growth, seed yield and severity of purple blotch was not significant.

The effect of interaction between bulb size and planting spacing on plant growth, seed yield and PDI value was significant. The maximum and minimum seed stalk number/hill was recorded in treatment combinations of 15 cm X 40 bulbs/kg and 15 cm X 160 bulbs/kg, respectively. The seed stalk number, seed stalk height and umbel diameter recorded in plots planted with seeds size of 40 bulbs/kg maintaining plant to plant spaces of 15 cm and 20 cm were statistically similar but significantly higher as compared to other treatment combinations. In order of descending the treatment combinations can be listed as: 15 cm X 40 bulbs/kg, 20 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg, 20 cm X 70 bulbs/kg, 15 cm X 100 bulbs/kg, 20 cm X 100 bulbs/kg, 20 cm X 130 bulbs/kg, 20 cm X 160 bulbs/kg and 15 cm X 160 bulbs/kg. The seed stalk height ranged from 72.23 to 81.60 cm. The maximum seed stalk height was recorded in 20 cm X 40 bulbs/kg followed by 15 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg, 20 cm X 70 bulbs/kg, 20 cm X 100 bulbs/kg, 15 cm X 100 bulbs/kg, 15 cm X 130 bulbs/kg, 20 cm X 130 bulbs/kg and 15 cm X 160 bulbs/kg and 20 cm X 160 bulbs/kg. The umbel diameter ranged from 6.06 to 7.30 cm. In order of ascending the effects of treatment combinations on umbel diameter can be listed as: 15 cm X 160 bulbs/kg, 20 cm X 160 bulbs/kg, 20 cm X 130 bulbs/kg, 15 cm X 130 bulbs/kg, 15 cm X 100 bulbs/kg, 20 cm X 100 bulbs/kg, 15 cm X 70 bulbs/kg, 20 cm X 70 bulbs/kg, 15 cm X 40 bulbs/kg and 20 cm X 40 bulbs/kg. In respect of PDI value, 15 cm X 40 bulbs/kg appeared to the best combination in reducing the PDI value of purple blotch. The treatment combination, 20 cm X 40 bulbs/kg ranked next to 15 cm X 40 bulbs/kg followed by 15 cm X 70 bulbs/kg, 20 cm X 70 bulbs/kg, 15 cm X 100 bulbs, 15 cm X 130 bulbs/kg, 20 cm X 100 bulbs/kg, 20 cm X 130 bulbs/kg, 15 cm X 160 bulbs/kg and 20 cm X 160 bulbs/kg. When they were analysed statistically it appeared that though the treatment combination 15 cm X 40 bulbs/kg showed the least PDI value but it was statistically similar to 15 cm X 70 bulbs/kg, 20 cm X 40 bulbs/kg and 20 cm X 70 bulbs/kg. Statistically the treatment interaction, 20 cm X 160 bulbs/kg appeared to be least effective and it differed significantly as compared to rest of the treatments. Regarding seed yield, the maximum and the minimum seed yield per hectare was harvested from plots having treatment combinations of 15 cm X 40 bulbs/kg and 20 cm X 160 bulbs/kg, respectively (Plate 4). The treatment, 20 cm X 40 bulbs/kg appeared to be second in increasing yield and it was statistically similar to 15 cm X 70 bulbs/kg. The treatment 15 cm X 70 bulbs/kg showed statistically similar effect on seed yield as compared to 20 cm X 70 bulbs/kg. The poorest treatment combination was 20 cm X 160 bulbs/kg, which gave significantly the lowest seed yield.

a

b

Plate 4. Showing the growth of seed stalks affected by onion bulb size:
a) bigger bulb size (40 bulbs/kg) producing multiple and vigorous seed stalks and b) smaller bulb size (160 bulbs/kg) producing less number of weak seed stalks.

4.4 Experiment 4: Effect of Fertilizer on Plant Growth, Severity of Purple Blotch and Seed Yield of Onion

4.4.1 Crop Season 1993-94

The seed stalk number/hill ranged from 2.97 to 4.23. The maximum number of seed stalk/hill was observed in T_{12} ($N_{150}P_{200}K_{125}S_{20}$) followed by T_9 ($N_{150}P_{250}K_{100}S_{20}$), T_4 ($N_{150}P_{200}K_{100}S_{20}$) and T_{14} ($N_{150}P_{200}K_{100}S_{40}$). These four treatments caused significant increase in seed stalk number as compared with control (T_1) when no fertilizer was used and T_2 ($N_0P_{200}K_{100}S_{20}$). The treatments T_4 ($N_{150}P_{200}K_{100}S_{20}$), T_5 ($N_{200}P_{200}K_{100}S_{20}$), T_6 ($N_{150}P_0K_{100}S_{20}$), T_7 ($N_{150}P_{100}K_{100}S_{20}$), T_8 ($N_{150}P_{150}K_{100}S_{20}$), T_9 ($N_{150}P_{250}K_{100}S_{20}$), T_{11} ($N_{150}P_{200}K_{75}S_{20}$), T_{12} ($N_{150}P_{200}K_{125}S_{20}$) T_{13} ($N_{150}P_{200}K_{100}S_0$) and T_{14} ($N_{150}P_{200}K_{100}S_{40}$) significantly increased seed stalk number over control T_1 ($N_0P_0K_0S_0$) but their effectiveness was statistically similar. The minimum seed stalk number was found in T_1 which was significantly similar to T_2 and T_{10} ($N_{150}P_{200}K_0S_{20}$). The highest seed stalk height of 79.93 cm was recorded in T_5 followed by T_{14}, T_{11}, T_3, T_6, T_7, T_8, T_9 and T_{10}. The influence of these 10 treatments were statistically similar but significant as compared to T_1 (Table 12). The treatments T_2, T_{12} and T_{13} did not cause significant effect in case of seed stalk height. The umbel diameter ranged from 5.53 to 6.77 cm. The largest umbel was found in T_4 followed by T_3, T_{11}, T_{13} and T_8. The smallest umbel was recorded in T_1. Except T_2, other 12 treatments gave significant increase in umbel size as compared with T_1. However, the umbel size under T_3, T_4, T_6 and T_8 to T_{14} was statistically similar but significantly higher than that under T_2 only. PDI values ranged from 30.33 (T_{14}) to 67.67 (T_1). Application of fertilizers ($T_2 - T_{14}$) gave significant reduction in severity of purple blotch of onion seed crop as

Table 12. Effect of fertilizers on plant growth, severity of purple blotch and seed yield of onion during 1993-94

Dose of NPKS (kg/ha)	Seed stalk/hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
$T_1=N_0P_0K_0S_0$	2.97 c	70.90 b	5.53 e	67.67 e	166.67 g
$T_2=N_0P_{200}K_{100}S_{20}$	3.17 bc	74.13 ab	5.77 de	56.53 d	312.78 f
$T_3=N_{100}P_{200}K_{100}S_{20}$	3.83 ab	79.13 a	6.63 ab	44.89 bc	548.33 bcd
$T_4=N_{150}P_{200}K_{100}S_{20}$	4.10 a	79.30 a	6.77 a	33.20 a	642.05 a
$T_5=N_{200}P_{200}K_{100}S_{20}$	3.80 ab	79.93 a	6.20 bcd	45.33 bc	582.22 c
$T_6=N_{150}P_0K_{100}S_{20}$	3.83 ab	77.80 a	6.47 abc	51.00 cd	450.00 e
$T_7=N_{150}P_{100}K_{100}S_{20}$	3.67 ab	77.73 a	6.00 cd	47.00 bc	509.45 cde
$T_8=N_{150}P_{150}K_{100}S_{20}$	3.63 ab	78.70 a	6.53 ab	42.67 b	630.00 a
$T_9=N_{150}P_{250}K_{100}S_{20}$	4.17 a	78.50 a	6.50 ab	31.33 a	638.33 a
$T_{10}=N_{150}P_{200}K_0S_{20}$	3.57 abc	77.97 a	6.47 abc	48.00 bc	481.11 de
$T_{11}=N_{150}P_{200}K_{75}S_{20}$	3.87 a	79.33 a	6.60 ab	36.00 a	630.00 a
$T_{12}=N_{150}P_{200}K_{125}S_{20}$	4.23 a	75.87 ab	6.53 ab	31.33 a	641.67 a
$T_{13}=N_{150}P_{200}K_{100}S_0$	3.70 ab	76.23 ab	6.57 ab	46.67 bc	615.00 ab
$T_{14}=N_{150}P_{200}K_{100}S_{40}$	3.90 a	79.60 a	6.50 ab	30.33 a	643.67 a

Means in a column followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was done after the arcsine transformation).

compared to control (T_1). The lowest PDI was achieved with T_{14} followed by T_9, T_{12}, T_4 and T_{11}. The effectiveness of these five treatments to reduce PDI was statistically similar but significantly higher as compared to all other treatments. The PDI value under T_2 was significantly higher than those under T_3 - T_{14} except T_6. The differences among PDI values under T_3, T_5, T_7, T_8, T_{10} and T_{13} were not significant. The highest PDI was recorded in T_1. Seed yield/ha significantly increased due to application of fertilizers (T_2-T_{14}) as compared to control (T_1). The best treatment for increasing yield of seed was T_{14} followed by T_4, T_{12}, T_9, T_8, T_{11} and T_{13}. The influence of these seven treatments on seed yield was statistically similar but significantly higher as compared to rest of the treatments except T_3. The seed yield under T_3 was not statistically different from seed yield under T_5 and T_7. The best effective treatment to increase seed yield was T_{14}. The lowest seed yield/ha was recorded in T_1.

4.4.2 Crop Season 1994-95

The results of the experiment conducted during 1994-95 on the effect of fertilizers on seed stalk number/hill, seed stalk height, umbel size, seed yield and severity of purple blotch of onion are summarised in table 13. In 1994-95, significant increase in seed stalk number/hill was achieved with only three treatments viz. T_4, T_7 and T_{14}. The effectiveness of the three treatments was statistically similar. However, the seed stalk number per hill may be arranged, in descending order, as: T_4, T_7, T_{14}, T_{12}, T_9, T_8, T_{13}, T_5, T_{11}, T_3, T_{10}, T_6, T_2 and T_1. The highest seed stalk height of 79.93 cm was recorded under T_5 and the lowest seed stalk height of 70.90 cm was

Table 13. Effect of fertilizers on plant growth, seed yield and severity of purple blotch of onion during 1994-95

Dose of NPKS (kg/ha)	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
$T_1=N_0P_0K_0S_0$	2.57 e	70.90 b	6.20 c	70.00 g	191.67 f
$T_2=N_0P_{200}K_{100}S_{20}$	2.77 de	74.13 ab	6.50 bc	64.67 fg	367.83 e
$T_3=N_{100}P_{200}K_{100}S_{20}$	3.20 abcde	79.13 a	7.17 a	44.67 abc	555.00 c
$T_4=N_{150}P_{200}K_{100}S_{20}$	3.93 a	79.30 a	7.33 a	38.67 ab	647.17 a
$T_5=N_{200}P_{200}K_{100}S_{20}$	3.30 abcde	79.93 a	6.97 ab	53.33 cdef	593.00 b
$T_6=N_{150}P_0K_{100}S_{20}$	2.87 cde	77.80 a	6.93 ab	63.33 fg	352.17 e
$T_7=N_{150}P_{100}K_{100}S_{20}$	3.80 ab	77.73 a	7.17 a	56.00 cdef	576.17 bc
$T_8=N_{150}P_{150}K_{100}S_{20}$	3.37 abcde	78.70 a	7.17 a	59.33 efg	643.33 a
$T_9=N_{150}P_{250}K_{100}S_{20}$	3.40 abcde	78.50 a	7.13 ab	40.00 ab	648.33 a
$T_{10}=N_{150}P_{200}K_0S_{20}$	2.97 bcde	77.97 a	6.77 abc	64.33 fg	456.67 d
$T_{11}=N_{150}P_{200}K_{75}S_{20}$	3.27 abcde	79.33 a	6.87 ab	46.00 abcd	644.67 a
$T_{12}=N_{150}P_{200}K_{125}S_{20}$	3.53 abcd	75.87 ab	6.93 ab	48.00 bcde	648.33 a
$T_{13}=N_{150}P_{200}K_{100}S_0$	3.33 abcde	76.23 ab	7.13 ab	56.67 cdef	629.17 a
$T_{14}=N_{150}P_{200}K_{100}S_{40}$	3.67 abc	79.60 a	7.13 ab	34.67 a	651.33 a

Means in a column followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was done after the arcsine transformation).

found under T_1. Though application of fertilizer caused increase in seed stalk height, significant increase was achieved with T_3 – T_{11} and T_{14}. The difference in seed stalk height under T_2 – T_{14} were not significant. Except T_2 and T_{10} other 12 treatments caused significant increase in umbel size over control (T_1) but their effectiveness was statistically similar. The maximum PDI value of 70.00 was recorded under T_1 and the difference in PDI values under T_1, T_2, T_6, T_8, and T_{10} were not significant. Other nine treatments caused significant reduction in severity of purple blotch. The effectiveness of T_3, T_4, T_9, T_{11} and T_{14} to reduce PDI was significantly higher than T_2, T_5 -T_8, T_{10}, T_{12} and T_{13}. All treatments having NPKS (T_2 - T_{14}) gave significant increase in seed yield over control (T_1). The highest seed yield/ha was recorded under T_{14} followed by T_9, T_{12}, T_4, T_{11}, T_8 and T_{13}. However, their effectiveness to increase seed yield was statistically similar but significantly higher as compared with rest treatments. These seven treatments gave approximately three times more yield than control (T_1).The least effective treatment was T_2 followed by T_6 (Plate 5).

a b

Plate 5. Onion seed crops affected by fertilizer doses: a) good and healthy crop condition at optimum fertilizer dose ($N_{150}P_{200}K_{100}S_{20}$) and b) comparatively high infection due to imbalance fertilizer dose ($N_{150}P_{0}K_{100}S_{20}$).

4.5 Experiment 5: Effect of Micronutrients on Plant Growth, Severity of Purple Blotch and Seed Yield of Onion

4.5.1 Crop Season 1993-94

The number of seed stalk/hill ranged from 2.63 to 3.77. Only the treatment T_6 ($Zn_4B_1Mo_1Cu_0$) yielded significantly higher number of seed stalk/hill as compared to control ($T_1 = Zn_0B_0Mo_0Cu_0$). The differences in seed stalk/hill under T_2 - T_6 were not significant. The effect of Zn, B, Mo and Cu on seed stalk height and umbel diameter was not significant. However, seed stalk height ranged from 76.47 to 78.67 cm and umbel diameter from 6.71 to 7.07 cm. Application of the micronutrients caused significant reduction in severity of purple blotch over T_1. Maximum reduction in PDI was achieved with T_5 followed by T_3 and T_6. The effect of these three treatments (T_3, T_5 and T_6) on PDI was statistically similar. The PDI value under T_2 and T_4 were also statistically similar but significantly higher as compared to T_3, T_5 and T_6. Seed yield per hectare under control (T_1) was significantly lower as compared to T_2 - T_6. Among the treatments, T_3 gave maximum seed yield which was statistically similar to seed yield under T_5 and T_6 but significantly higher as compared with T_2 and T_4. The difference between seed yield under T_2 and T_4 was also not significant (Table 14).

Table 14. Effect of four different micronutrients (Zn, B, Mo and Cu) on plant growth, seed yield and severity of purple blotch of onion seed crop during 1993-94

Dose of ZnBMoCu (kg/ha)	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
$T_1 = Zn_0B_0Mo_0Cu_0$	2.63 b	75.17 a	6.71 a	63.70 c	400.67 d
$T_2 = Zn_0B_1Mo_1Cu_1$	2.87 ab	76.47 a	6.94 a	52.23 b	595.50 bc
$T_3 = Zn_4B_1Mo_1Cu_1$	3.67 ab	78.67 a	7.03 a	43.40 a	690.55 a
$T_4 = Zn_4B_0Mo_1Cu_1$	2.77 ab	77.17 a	7.00 a	55.33 b	562.00 c
$T_5 = Zn_4B_1Mo_0Cu_1$	3.60 ab	78.17 a	7.07 a	42.00 a	637.50 ab
$T_6 = Zn_4B_1Mo_1Cu_0$	3.77 a	77.33 a	6.88 a	45.77 a	665.00 ab

Means in a column followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI, analysis was done after arcsine transformation).

4.5.2 Crop Season 1994-95

During 1994-95 the effect of micronutrients on seed stalk number/hill, seed stalk height and umbel diameter was not significant. However, the ranges of seed stalk number/hill, seed stalk height and umbel diameter were 3.80 - 4.27, 73.73 – 78.80 cm and 6.70 – 7.93 cm, respectively. Decrease of PDI values and increase of seed yield/ha over control treatment (T_1) were achieved with rest of the treatments ($T_2 – T_6$). PDI value under T_2 was significantly higher as compared to T_3, T_5 and T_6. The lowest PDI was recorded from T_3 but its effect was statistically similar to T_4, T_5 and T_6. The highest seed yield/ha was found under T_3. Its effect on seed yield/ha was statistically similar to T_6 but significantly higher as compared with rest of the treatments. The seed yield under T_5 was statistically similar to the yield under T_4 but significantly higher as compared with T_2. The effect of T_2 on seed yield was statistically similar to T_4 (Table 15).

Table 15. Effect of micronutrients (Zn, B, Mo and Cu) on plant growth, seed yield and severity of purple blotch of onion during 1994-95

Dose of ZnBMoCu (kg/ha)	Seed stalk/hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
$T_1 = Zn_0B_0Mo_0Cu_0$	3.80	74.83	6.70	71.67 d	377.67 e
$T_2 = Zn_0B_1Mo_1Cu_1$	3.93	73.73	6.93	58.00 bc	565.33 d
$T_3 = Zn_4B_1Mo_1Cu_1$	4.27	76.87	6.95	43.30 a	654.17 a
$T_4 = Zn_4B_0Mo_1Cu_1$	4.17	78.80	7.00	53.67 abc	572.83 cd
$T_5 = Zn_4B_1Mo_0Cu_1$	4.13	78.07	7.93	45.20 ab	606.67 bc
$T_6 = Zn_4B_1Mo_1Cu_0$	4.10	77.97	7.09	47.00 ab	632.00 ab

Means in a column followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was done after arcsine transformation).

4.6 Experiment 6: Efficacy of Fungicides in Controlling Purple Blotch of Onion Seed-Crop

4.6.1 Crop Season 1993-94

The seed stalk number per hill ranged from 3.70 to 4.10. But the effect of fungicidal spray on this parameter was not significant. No fungicide gave significant increase in seed stalk height, rather Penncozeb and Tilt 250EC caused significant decrease in seed stalk height as compared to control. Tilt 250EC also caused significant reduction in umbel diameter over control. Other fungicidal treatments gave increase in umbel size but the increase was significant only when Rovral 50WP (0.2%) and Ridomil MZ-72 (0.2%) were applied together. All fungicidal treatments gave significant reduction in PDI values over control. The combined application of Rovral 50WP and Ridomil MZ-72 caused the highest reduction in severity of purple blotch having PDI value of 6.00 as against control having PDI value of 54.23. Among the treatments with single fungicide, Rovral 50WP caused maximum reduction in PDI followed by Score 250EC. The efficacy of the fungicides to control purple blotch was statistically similar but significantly higher as compared with other fungicides. The PDI values under Dithane M-45 and Ridomil MZ-72 were statistically similar but significantly lower as compared with Penncozeb and Cupravit. The efficacy of Penncozeb and Cupravit was also not significantly different. Tilt 250EC appeared to be the fourth in its effectiveness and differed significantly from all of the treatments (Table 16).

Table 16. Efficacy of fungicides in controlling purple blotch of onion seed crop during 1993-94

Fungicide with dose	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
Dithane M-45 (0.2%)	3.70	81.57 ab	6.17 ab	27.00 d	660.33 c
Penncozeb (0.2%)	3.73	75.47 c	5.87 ab	32.00 e	620.00 d
Ridomil MZ-72(0.2%)	4.00	84.03 a	6.13 ab	26.83 d	666.33 c
Cupravit (0.2%)	3.97	81.37 ab	6.23 ab	33.67 e	590.00 e
Rovral 50WP (0.2%)	3.83	78.07 bc	6.20 ab	7.50 ab	713.00 b
Tilt 250EC (0.05%)	3.73	74.87 c	5.20 c	18.67 c	623.33 d
Rovral 50WP (0.2%) + Ridomil MZ-72(0.2%)	4.03	82.57 a	6.47 a	6.00 a	813.33 a
Score 250EC (0.05%)	4.10	82.47 a	6.20 ab	8.94 b	697.50 b
Control (Plain water)	3.83	80.07 ab	5.73 bc	54.23 f	413.83 f

Means in a column followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI, analysis was done after arcsine transformation of data).

Application of sprays with all fungicides gave significant increase in seed yield over control when the seed yield was the lowest. Significantly the highest yield was recorded under the treatment with Rovral 50WP and Ridomil MZ-72. Rovral 50WP and Score 250EC gave second highest yield of seeds. Their effect on this parameter was statistically similar but significantly higher as compared with Dithane M-45 and Ridomil MZ-72. Seed yield under the later two fungicides was also not significantly different. The lowest increase of seed yield was achieved with Cupravit followed by Penncozeb. The difference between seed yield under this treatment was significantly different (Table 16).

4.6.2 Crop Season 1994-95

Fungicidal spray caused either increase or decrease in seed stalk/hill over control but not significantly (P=0.05). The highest number of seed stalk/hill was found under the treatment with Ridomil MZ-72 and it was significantly higher as compared with Dithane M-45, Penncozeb and Cupravit. The difference among seed stalk number/hill under the treatments with all fungicides except Ridomil MZ-72 were statistically similar.

Significant increase in seed stalk height over control was observed under the treatments with Rovral 50WP + Ridomil MZ-72 (Plate 6). Significantly the highest seed stalk height was achieved with Ridomil MZ-72. Seed stalk height under Rovral 50WP and Rovral 50WP + Ridomil MZ-72 was statistically similar but significantly higher as compared to Penncozeb. Like

a b

Plate 6. Onion seed crops with and without fungicidal spray:
a) sprayed with Rovral 50WP @ 0.2% and Ridomil MZ-72 @ 0.2% and b) unsprayed.

seed stalk height, umbel diameter was increased significantly by only Ridomil MZ-72 over control. The difference in umbel diameter under all fungicides, except Tilt 250EC were statistically similar. Tilt 250E caused reduction in seed stalk height but not significant as compared to control.

The severity of purple blotch was decreased significantly by all fungicidal treatments over control. The maximum reduction in PDI value was achieved with combined application of Rovral 50WP + Ridomil MZ-72 followed by single Score 250Ec and Rovral 50WP (Table 17). The effect of these three treatments on disease severity was statistically similar. The PDI value was maximum under the fungicides Penncozeb followed by Cupravit, Dithane M-45, Ridomil MZ-72 and Tilt 250EC. The effectiveness of these five fungicides was significantly different. Seed yield/ha was also increased significantly by all fungicidal treatments over control. The maximum seed yield was achieved with combined application of Rovral 50WP and Ridomil MZ-72 followed by Score 250EC alone. The seed yield under these two treatments was statistically similar but significantly higher as compared with other treatments. The fungicide Penncozeb caused the minimum increase of seed yield over control followed by Cupravit and Dithane M-45. The efficacy of these three fungicides to reduce disease severity was not significantly different. However, the efficacy of Penncozeb was superior to Ridomil MZ-72 and Tilt 250EC. The effectiveness of Score 250EC and Rovral 50WP was also statistically similar.

Table 17. Effect of fungicides on plant growth, seed yield and severity of purple blotch of onion during 1994-95

Fungicide with dose	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
Dithane M-45 (0.2%)	3.07 b	76.67 bc	7.23 ab	33.00 c	628.83 de
Penncozeb (0.2%)	2.83 b	72.90 cd	7.00 abc	48.33 e	583.33 e
Ridomil MZ-72 (0.2%)	3.73 a	83.97 a	7.53 a	31.00 c	653.33 cd
Cupravit (0.2%)	2.97 b	77.03 bc	7.37 ab	39.67 d	620.00 de
Rovral 50WP (0.2%)	3.23 ab	78.77 b	7.43 a	10.67 a	694.50 bc
Tilt 250EC (0.05%)	3.00 b	69.83 d	6.63 c	21.33 b	638.83 d
Rovral 50WP (0.2%)+ Ridomil MZ-72(0.2%)	3.23 ab	78.73 b	7.30 ab	8.00 a	757.17 a
Score 250EC (0.05%)	3.40 ab	78.10 bc	7.40 ab	9.33 a	721.17 ab
Control	3.20 ab	72.83 cd	6.80 bc	58.00 f	490.00 f

Means in a column followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI, analysis was done after arcsine transformation of data).

4.7 Experiment 7: Integrated Disease Management (IDM) Approach to the Control Purple Blotch of Onion Seed-crop

4.7.1 Crop Season 1995-96

Number of seed stalk per hill ranged from 2.67 to 3.80 with minimum and maximum under T_1 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ +160 bulb/kg+15 cm plant spacing + Cowdung @ 10 t/ha) and T_4 ($N_{150}P_{200}K_{100}Zn_4B_1$+Zn+B + 70 bulb/kg + 15 cm plant spacing + Cowdung @ 10 t/ha), respectively. The seed stalk number under treatment T_1 was significantly lower as compared to T_2 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ + 70 bulb/kg + 15 cm plant spacing + Cowdung @ 10 t/ha), T_3 (Rovral @ 0.2% + Ridomil @ 0.2% + Zn_4B_1+Zn+B + 70 bulb/kg + 20 cm plant spacing + Cowdung @ 10 t/ha), T_4 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}Zn_4B_1$ kg/ha + 70 bulb/kg + 15 cm plant spacing + Cowdung @ 10 t/ha), T_5 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ + 70 bulb/kg + 15cm plant spacing + Cowdung @ 10 t/ha), T_7 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ + 70 bulb/kg + 15cm plant spacing) and T_8 (Rovral @ 0.2% + Ridomil @ 0.2% + 15 cm plant spacing + Cowdung @ 10 t/ha). Significantly the highest number of seed stalk/hill was recorded in T_4 and it was statistically similar to all other treatments except T_1 (Table 18).

The maximum plant height was recorded under T_2. Its effectiveness was statistically similar to T_3, T_7 and T_9 but significantly higher as compared with other six treatments.

Table 18. Effect of integrated disease management approach on plant growth, severity of purple blotch and seed yield of onion during 1995-96

Treatment	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
T_1=Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha +160 bulbs/kg+15cm plant spacing+Cowdung (10 t/ha)	2.67 b	69.00 d	6.30 c	21.67 d	688.00 e
T_2= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg +15 cm plant spacing + Cowdung (10 t/ha)	3.67 a	81.67 a	7.37 a	6.33 a	1025.50 a
T_3= Rovral @ 0.2% + Ridomil @ 0.2% + Zn_4B_1 kg/ha + 70 bulb/kg + 20 cm plant spacing + Cowdung (10 t/ha)	3.60 a	77.47 abc	7.03 ab	7.67 ab	855.83 c
T_4= $N_{150}P_{200}K_{100}Zn_4B_1$ kg/ha + 70 bulb/kg + 15 cm plant spacing + Cowdung (10 t/ha)	3.80 a	76.03 bc	6.87 abc	37.00 e	742.17 d
T_5= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha + 70 bulb/kg + 15cm plant spacing + Cowdung (10 t/ha)	3.70 a	75.50 bc	7.30 a	11.67 bc	930.00 b
T_6= $N_{150}P_{200}K_{100}Zn_4B_1$ kg/ha + 70 bulb/kg + 15 cm plant spacing	3.20 ab	75.93 bc	6.90 abc	41.00 e	552.50 f
T_7= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha + 70 bulb/kg + 15cm plant spacing	3.67 a	79.73 ab	7.13 ab	15.00 cd	908.33 b
T_8= Rovral @ 0.2% + Ridomil @ 0.2% + 15cm plant + spacing + Cowdung (10 t/ha)	3.47 a	74.53 c	6.63 bc	44.33 e	419.45 g
T_9= 70 bulb/kg +15 cm plant spacing + Cowdung (10 t/ha)	3.07 ab	77.40 abc	6.37 c	78.00 f	267.50 h
T_{10}= 70 bulb/kg +15 cm plant spacing	3.40 ab	74.87 bc	6.43 c	87.33 g	216.17 i

Means in a column followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI, analysis was performed after arcsine transformation of data).

Significantly the lowest seed stalk height was found under T_1. The seed stalk height under T_8 was statistically similar to $T_3 - T_6$, T_9 and T_{10} but significantly lower as compared to T_2 and T_7 (Table 18). Significantly the larger umbel was recorded in T_2 and it was statistically similar to $T_3 - T_7$ but significantly higher as compared with rest of the treatments. The effect of T_1, T_8, T_4, T_6, T_9 and T_{10} on umbel diameter was not significantly different (Table 18). The minimum PDI value of 6.33 was recorded under T_2 followed by T_3 under which PDI value was 7.67. The effect of the two treatments on this parameter was statistically similar but significantly lower as compared with other treatments except T_5 under which PDI value was 11.67. The maximum PDI value of 87.33 was found under T_{10} followed by T_9 having PDI value of 78.00 and T_8. The PDI values under T_8, T_9 and T_{10} were significantly different. The PDI values under T_8, T_7 and T_4 were 44.33, 41.00 and 37.00, respectively. The effect of these three treatments on PDI was statistically similar but significantly higher as compared to T_1 under which PDI value was 21.67 (Table 18).

Significantly the highest seed yield of 1025.50 kg/ha was obtained with T_2. The treatments T_5 and T_7 gave statistically similar but significantly higher seed yield as compared with other seven treatments. The minimum seed yield of 216.17 kg/ha was found under T_{10} followed by T_9, T_8, T_6, T_1, T_4 and T_3. The seed yield under these seven treatments were significantly different (Table 18).

4.7.2 Crop Season 1996-97

During 1996-97, the number of seed stalk/hill ranged from 2.33 to 4.33 with minimum under T_0 and maximum under T_3. Though the highest number of seed stalk/hill was recorded under T_3, its effect on this parameter was statistically similar to that of T_5 and significantly higher as compared with rest of the treatments. The treatment T_5 was also statistically similar to T_2 and T_4. The seed stalk number/hill under T_6 was statistically similar to T_2 and T_4 but significantly higher as compared to T_1 and $T_7 - T_{10}$. The seed stalk number under T_1 and T_{10} was statistically similar but significantly higher as compared to T_7, T_8 and T_9. The effect of the later three treatments on seed stalk number was also not significantly different (Table 19). The maximum seed stalk height was recorded under T_5 followed by T_8, T_7, T_2, T_1, T_6, T_4, T_3 and T_{10}. The effect of these nine treatments on this parameter was statistically similar. The minimum seed stalk height was found under T_9, which was significantly different from T_1, T_2, T_5, T_6, T_7 and T_8.

The highest umbel diameter of 7.27 cm was obtained with T_4.(Plate 7). Its effect on this parameter was statistically similar to T_1, T_2, T_5, T_6 and T_8 but significantly higher as compared to rest of the treatments. The minimum umbel diameter was recorded under T_9 followed by T_3, T_{10} and T_7. The umbel diameter under these four treatments was statistically similar.

Table 19. Effect of integrated disease management approach on plant growth, severity of purple blotch and seed yield of onion during 1996-97

Treatment	Seed stalk/ hill	Seed stalk height (cm)	Umbel diameter (cm)	PDI	Seed yield (kg/ha)
T_1= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha +160 bulb/kgs + 15cm plant spacing + Cowdung (10 t/ha)	2.50 e	78.97 a	6.93 abc	20.67 b	670.56 d
T_2= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulb/kg+15 cm plant spacing+Cowdung (10 t/ha)	4.10 bc	79.23 a	7.17 ab	10.67 a	1011.17 a
T_3= Rovral @ 0.2% + Ridomil @ 0.2% + Zn_4+B_1 kg/ha + 70 bulb /kg + 20 cm plant spacing + Cowdung (10 t/ha)	4.63 a	76.50ab	6.53 cd	9.33 a	725.00 c
T_4= $N_{150}P_{200}K_{100}Zn_4B_1$ kg/ha + 70 bulb/kg + 15 cm plant spacing + Cowdung (10 t/ha)	3.77 bc	77.47ab	7.27 a	48.67 c	581.17 e
T_5= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha + 70 bulb/kg + 15cm plant spacing + Cowdung (10 t/ha)	4.23 ab	79.93 a	7.07 ab	14.67 ab	938.83 b
T_6= $N_{150}P_{200}K_{100}Zn_4B_1$ kg/ha + 70 bulb/kg + 15 cm plant spacing	3.67 c	78.93 a	7.13 ab	38.67 c	481.17 f
T_7= Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}$ kg/ha + 70 bulb/kg + 15cm plant spacing	3.17 d	79.30 a	6.73 bcd	18.67 ab	725.50 c
T_8= Rovral @ 0.2% + Ridomil @ 0.2% + 15cm plant spacing + Cowdung (10 t/ha)	3.13 d	79.63 a	6.80 abc	42.00 c	395.00 g
T_9=70 bulb/kg +15 cm plant spacing + Cowdung (10 t/ha)	3.00 d	75.30 b	6.23 d	72.00 d	310.00 h
T_{10}=70 bulb/kg +15 cm plant spacing	2.33 e	76.30ab	6.53 cd	78.67 d	198.83 i

Means in a column followed by same letter are not significantly different (P = 0.05) according to DMRT (in case of PDI, analysis was performed after arcsine transformation of data).

Plate 7. Vigorous and healthy onion seed crop produced under integrated disease management (IDM) approach.

The PDI values under different treatments varied from 9.33 to 78.67. The lowest PDI was found under T_3 followed by T_2, T_5 and T_7. The effect of these four treatments on PDI values was not significantly different. However, PDI value under T_2 and T_3 was significantly lower as compared to T_1, T_4, T_6, T_8, T_9 and T_{10}. The PDI values under T_{10} and T_9 were statistically similar but significantly higher as compared with all other treatments (Table 19).

The seed yield/ha ranged from 198.83 kg/ha to 1011.17 kg/ha. The highest yield was found under T_2 followed by T_5 and T_3. The effect of these three treatments on seed yield was significantly different. The seed yield under T_3 and T_5 was identical. The seed yield was the lowest under T_{10} followed by T_9, T_8, T_6, T_4 and T_1. The difference among seed yield obtained with these six treatments were significant.

4.8 Experiment 8:On-farm Trial on the Integrated Disease Management (IDM) Practice for Controlling Purple Blotch of Onion Seed-Crop

4.8.1 Crop Season 1997-98

Five different treatments selected based on results of on-station trial were taken for this experiment, where various components viz. different sizes of onion bulbs, fertilizers, micronutrients and fungicides were incorporated. Seed stalk/hill ranged from 3.68 to 4.08 (Table 20). The maximum seed stalk/hill was found in T_2 ($N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%) + 70 bulbs/kg) and minimum seed stalk/hill was observed in T_4 ($N_{50}P_{70}K_{50}S_0Zn_0B_0$ kg/ha + Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%) + 120 bulbs/kg). The

Table 20. On-farm trial on the effect of integrated disease management approach on plant growth, severity of purple blotch and seed yield of onion during 1997-98

Treatment	Seed stalk/hill	Seed stalk height (cm)	Umbel diameter (mm)	PDI	Seed yield (kg/ha)
$T_1 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + Onion bulb 120/kg + (Rovral @0.2% + Ridomil MZ-72 @ 0.2%)	3.96 a	77.95 b	6.74 b	9.60 a	439.60 c
$T_2 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + Onion bulb 70/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%)	4.08 a	80.56 a	7.68 a	8.80 a	600.00 a
$T_3 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + Onion bulb 70/kg	3.94 a	80.20 a	6.56 c	28.67 c	243.60 d
$T_4 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ kg/ha + Onion bulb 120/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%)	3.68 b	77.12 bc	5.90 d	24.33 b	498.80 b
$T_5 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ kg/ha + Onion bulb 120/kg	3.90 a	75.80 c	5.94 d	76.00 d	197.60 d

Means in a column followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was performed after arcsine transformation of data).

number of seed stalk/hill under T_2 was statistically similar to that found T_1 (($N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%) + 120 bulbs/kg, T3 ($N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg) and T_5 ($N_{50}P_{70}K_{50}S_0Zn_0B_0$ kg/ha + 120 bulbs/kg) but significantly higher as compared to T_4. Seed stalk height ranged from 75.80 to 80.56 cm, where the highest height was recorded under T_2 and the lowest in T_5. Statistically similar seed stalk height was recorded under T_2 and T_3. These two treatments yielded significantly taller seed stalk as compared to other three treatments. The lowest seed stalk height was found under T_5, which statistically similar to T_4 and lower than that of recorded under T_1. The PDI values under T_5, T_3, T_4 and T_1 were 76.00, 28.67, 24.33 and 9.60, respectively. These were significantly different among themselves. The PDI values under T_1 and T_2 were statistically similar. The highest seed yield/ha was obtained with T_2 followed by T_4, T_1 and T_3. Their seed yield was significantly different. The lowest seed yield was found under T_5, which was statistically similar to T_3 (Table 20).

4.8.2 Crop Season 1998-99

The effect of treatments T_1 and T_2 on seed stalk height was statistically similar. These two treatments gave significantly higher number of seed stalk/hill as compared to T_3, T_4 and T_5. These three treatments also gave statistically similar number of seed stalk/hill. The seed stalk height ranged from 62.80 to 79.50 cm (Table 21). The highest seed stalk height was recorded under T_2 followed by T_3. The effect of these two treatments on seed stalk height was statistically similar. The lowest seed stalk height was observed under T_5 followed by T_4. The seed stalk

Table 21. On-farm trial on the effect of integrated disease management approach on plant growth, severity of purple blotch and seed yield of onion during 1998-99

Treatment	Seed stalk/hill	Seed stalk height (cm)	Umbel diameter (mm)	PDI	Seed yield (kg/ha)
$T_1 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + Onion bulb 120/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%)	4.20 a	75.40 b	6.73 b	10.40 b	453.50 b
$T_2 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ t/ha + Onion bulb 70/kg	4.40 a	79.50 a	7.12 a	7.20 a	712.00 a
$T_3 = N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + Onion bulb 70/kg	3.65 b	77.65 ab	6.80 b	42.65 d	267.40 d
$T_4 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ kg/ha + Onion bulb 120/kg + (Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%)	3.70 b	66.00 c	5.93 c	27.50 e	432.80 c
$T_5 = N_{50}P_{70}K_{50}S_0Zn_0B_0$ t/ha + Onion bulb 120/kg	3.48 b	62.80 c	5.84 c	73.50	203.40 e

Means in a column followed by same letter are not significantly different ($P = 0.05$) according to DMRT (in case of PDI, analysis was performed after arcsine transformation of data).

height under these two treatments was statistically similar but significantly higher as compared to T_1. The umbel diameter ranged from 5.84 to 7.12 cm (Plate 8). Significantly the highest umbel diameter was observed under T_2. The umbel diameter under T_1 and T_3 showed statistically similar size but significantly higher as compared to T_4 and T_5, which also gave statistically similar sized umbel. The PDI values under T_5, T_3, T_4, T_1 and T_2 were 73.50, 42.65, 27.50, 10.40 and 7.20. The PDI values under all of these treatments were significantly different among themselves. The seed yield/ha was maximum under T_2 followed by T_1, T_4, T_3 and T_5. The seed yield under all five treatments was significantly different from each other.

a b

Plate 8. Onion seed crop under on-farm trial: a) good and healthy crop produced under IMD package $(N_{150}P_{200}K_{100}S_{20})Zn_4B_1$ kg/ha + Rovral 50WP @ 0.2% + Ridomil MZ-72 @ 0.2% + 70 bulbs/kg) and b) crop under farmers' practice $(N_{50}P_{70}K_{50}$ + 120 bulbs/kg) .

CHAPTER 5

DISCUSSION

Among the various factors responsible for declining onion seed production in Bangladesh, purple blotch, a serious disease is considered to be the major. The disease is caused mainly by *A. porri* (Ellis) Cif., but under the present investigation, *Stemphylium botryosum* Wallr. was also found to be frequently associated in the diseased specimens. The disease causes 20 to 25 per cent loss of seed yield in India (Thind and Jhooty, 1982) and 41-44% in Bangladesh (Hossain *et al.*, 1993).

The effect of date of planting on the seed yield of onion implied that the November 15 planting reduced PDI and gave the highest seed yield of onion. December 1 and December 15 plantings increased PDI and reduced seed yield. Munoz *et al.* (1986) reported that the early sown crop had lower disease index compared with the crop sown later than 15 September. On the contrary, Sandhu *et al.* (1983) mentioned the early sown crop (November 1) was always more susceptible to *A. porri* than the late sown crop. The present investigation showed that November 15 planted crop had lower disease severity.

It was found that there was no varietal differences regarding PDI as well as seed yield of onion per unit area of land which might be due to the fact that the two Cultivars used in the present investigation were of same origin with similar genetic trait. The local onion cultivars, Taherpuri and Jhitka were found to be susceptible to purple blotch. Bhangale and Joi (1985) screened 74 onion cultivars against *A. porri*, but they observed no resistant cultivar among them.

Regarding the combined effect of planting time and variety, it has been reflected that both the varieties when planted on November 15 performed better in respect of PDI and seed yield of onion. It led to conclude that around November 15 planting of onion seed crop is congenial for avoiding purple blotch disease of onion seed crop with consequent higher seed yield.

Mother bulb size was found to be the most important factors that influence the seed yield of onion. It was observed that with the increasing size of mother bulb, PDI value decreased and seed yield increased. Effect of bulb size and plant spacing were studied by Pall and Padda (1972) and reported that bigger bulb (50 g) with closer spacing gave the highest onion seed yield. Sidhu *et al.* (1994) produced 1100 kg/ha onion seed of Punjab Naroya variety using medium to large bulbs. Sandhu *et al.* (1983) showed the higher severity of *A. porri* in closer spaced plants (45 X 30 cm) than in wider spaced (60 X 45 cm). But the two different spacings used in the present investigation did not show any significant difference on PDI or seed yield, which might be due to the fact that the two spacings differed by only 20-15 = 5 cm that could not reflect any positive impact on the attributes observed.

When the interaction effects were studied between the mother bulb size and spacing, it was found that 40-70 bulbs/kg along with both the spacings scored less PDI value with increased seed yield. On the other hand, agronomic traits were also found to exhibit good impact, which has been reflected in PDI as well as seed yield per hectare.

Larger bulb size possesses much photosynthates compared to the smaller bulb size. So, the larger bulbs caused the better growth and development of the plants. Since the plants raised from larger bulbs had better growth and development, the severity of the disease was reduced and produced higher seed yield of onion.

Fertilizers showed marked influence on seed stalk height, umbel diameter, PDI and onion seed yield. The best performance in all the parameters was observed when all the fertilizers were incorporated in the same treatments. Seed stalk height and umbel diameter showed significant effect in presence of nitrogen, phosphorus and potassium. Significantly higher PDI was recorded in absence of any fertilizer. Significantly lower PDI was observed when nitrogen, phosphorus and potassium were incorporated. All the fertilizers increased onion seed except sulphur. The highest seed yield was recorded in T_{14} followed by T_4, T_9 and T_{12}. More or less similar observations were confirmed by Alves *et al.* (1983) and Mondal *et al.* (1989). They reported that the rising of N rates from 40 to 120 kg N/ha decreased incidence of purple blotch of onion. Mondal *et al.*(1989) reported from Bangladesh that higher doses of N

(150 or 200 kg urea/ha) in combination with higher doses of P (Triple superphosphate) and with 80 kg muriate of potash/ha increased the number of leaves and seed stalks/plant of onion and reduced the number of diseased (*A. porri*) inflorescence stalks and infected umbels, increasing yields by up to 234% over the controls. Pandey *et al.* (1994) from India claimed that 80 and 120 kg N/ha gave significantly higher yields, larger umbel diameter and less incidence of thrips. They noted that the incidence of purple blotch was unaffected by N application. The positive effect of use of proper fertilizer (NPK) dose on reducing the disease incidence of various crops have been suggested by many workers (Wilson, 1994; Chung and Huang, 1994; Sij *et al.*, 1993; Elad *et ai.*, 1993; Velazhahan and Ramabadran, 1992; Kalpna *et al.*, 1992; Singh *et al.*, 1992; Dasgupta *et al.*, 1991; Mohit and Singh; 1991; Kataria and Grover, 1987). The findings of the present study are in agreement with the above investigations. Considering results of both the years, the fertilizer doses as per the treatments T_{14} ($N_{150}P_{200}K_{100}S_{40}$), T_{12} ($N_{150}P_{200}K_{125}S_{20}$), T_4 ($N_{150}P_{200}K_{100}S_{20}$) or T_9 ($N_{150}P_{250}K_{100}S_{20}$) may be recommended for onion seed production.

Application of micronutrients like Zn, B, Mo and Cu have shown significant influence on seed yield and PDI values. It has been observed that the treatment T3 ($Zn_4Bo_1Mo_1Cu_1$) gave the highest seed yield and comparatively the lower PDI values where all forms of micronutrients were applied. This finding was very close to Bhargava and Singh (1992) who opined that the application of Cu, B and Mn significantly reduced the incidence of Alternaria blight (*A. cucumerina*) of bottle gourd. The present findings also suggest the importance of Zn and B in absence of which disease severity was high and seed yield was low.

So, Zn @ 4 kg/ha and B @ 1 kg/ha may be recommended for onion seed crops. Soil treatment with trace elements had varying effects on disease severity. Dabash *et al.* (1985) reported that the application of Zn or Mn reduced white rot disease (*S. cepivorum*) of onion. Foliar sprays with 2.5 or 25 ppm of Cu, B or Zn significantly reduced intensity of Alternaria blight of bottle gourd caused by *A. cucumerina* was reported by Bhargava and Singh (1992).

In the present study significant reduction of PDI and increase of seed yield was achieved with fungicidal sprays. Based on results of 1993-94 and 1994-95 experiments, it may be mentioned that Rovral 50WP (0.2%) + Ridomil MZ-72 (0.2%) was the best treatment in reducing PDI value and increasing seed yield of onion followed by Rovral 50WP @ 0.2% and Score 250EC @ 0.05%. Srivastava *et al.* (1995) reported that *S. vesicarium* and *A. porri* cause total failure of onion seed crop in Haryana, India. They recommended to spray Mancozeb (0.25%) or Iprodione (0.2%) to control the purple blotch. Gupta *et al.* (1996b) determined effective control measure of purple blotch of onion with 3 sprays of Chlorothalonil @ 0.2% or Iprodione @ 0.25%. El-Shehaby *et al.* (1995) reported Metalaxyl 8% + Mancozeb 64% (as Ridomil MZ-72) and Metalaxyl 10% + Mancozeb 48% (as Ridomil MZ 56) to be the most effective fungicide in controlling purple blotch disease. Findings of the present investigation agree with the findings of many earlier workers ((Srivastava *et al.* (1995); Gupta *et al.*, 1996b; El-Shehaby *et al.*, 1995). Rovral 50WP + Ridomil MZ-72 @ 0.2%, Rovral 50WP @ 0.2% or Score 250EC @ 0.05% may be recommended at an interval of 15 days for controlling purple blotch of onion seed-crop.

Integrated management approach was tested against purple blotch of onion seed crop during 1995-96 and 1996-97 and found that T_2 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulb/kg +15 cm plant spacing + Cowdung (10 t/ha) was the best treatment to reduce PDI values and to increase seed yield of onion.

On-farm trial was conducted in 1997-98 and 1998-99 to test the effectiveness of integrated disease management approach using five treatments. Among the treatments, T_2 comprised of $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulbs/kg + (Rovral 50WP @ 0.2% + Ridomil MZ-72 @ 0.2%) gave satisfactory reduction in purple blotch severity and increased seed yield. This treatment may be recommended for cultivation of onion seed crop.

CHAPTER 6

SUMMARY

Alternaria porri (Ellis) Cif. and *Stemphylium botryosum* Wallr. were frequently isolated from purple blotch of onion seed crop during the survey conducted at different onion growing areas of Bangladesh. On pathogenicity test, *S. botryosum* was found to be an additional causal pathogen of purple blotch of onion seed crop. The severity of the disease varied with locations. In 1992-93, the highest PDI was noticed at Pabna followed by Manikganj, Faridpur and Rajshahi. In 1992-93, the PDI ranged from 62.00 to 68.60%. The highest PDI was recorded at Manikganj followed by Pabna and Faridpur.

Studies conducted on the effect of date of planting on the severity of purple blotch and seed yield of onion showed that November 15 was the best planting time to reduce PDI of purple blotch and producing the highest seed yield of onion. On December 1 and December 15 plantings PDI values varied from 74.00 to 83.83 and seed yield from 459.78 to 217.30 kg/ha. There were no differences between two onion cultivars, Taherpuri and Jhitka regarding PDI as well as seed yield.

From the present study, it was observed that use of larger mother bulb caused low level PDI value and higher seed yield. When the interaction effects were studied between the mother bulb size and spacing, 15 cm X 40 bulbs/kg, 15 cm X 70 bulbs/kg and 20 cm X 40 bulbs/kg, showed satisfactory performance in respect of PDI value and seed yield. Among

these three treatments, 15 cm plant spacing and 70 bulbs/kg bulb size may be recommended for the production of onion seeds in the country.

Fertilizers showed significant effects on seed stalk height, umbel diameter, PDI and onion seed yield. The PDI was high in absence of any fertilizer. Lowest PDI value was recorded under T_{14} ($N_{150}P_{200}K_{100}S_{40}$) followed by T_9 ($N_{150}P_{250}K_{100}S_{20}$), T_{12} ($N_{150}P_{200}K_{125}S_{20}$) and T_4 ($N_{150}P_{200}K_{125}S_{20}$). The highest seed yield of 643.67 kg/ha was recorded under T_{14} followed by T_4, T_9 and T_{12}.

Micronutrients showed significant influence on increasing onion seed yield and to reduce PDI values. The severity was high and seed yield was low when Zn and B were not applied.

The effect of fungicides on severity of purple blotch and seed yield of onion was significantly different. Mixed application of Rovral 50WP @ 0.2% + Ridomil MZ-72 @ 0.2% gave the best control of purple blotch and maximum seed yield of onion followed by individual application of Rovral 50WP @ 0.2% and Score 250EC @ 0.05% when sprayed at an interval of 15 days.

Regarding the integrated disease management approach against purple blotch of onion seed crop T_2 (Rovral @ 0.2% + Ridomil @ 0.2% + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + 70 bulb/kg +15 cm plant spacing + Cowdung (10 t/ha) was found to be the best treatment to reduce PDI values and to increase seed yield of onion.

On-farm trial conducted during 1998-98 and 1998-99 crop seasons showed that the treatments T_2 ($N_{150}P_{200}K_{100}S_{20}Zn_4B_1$ kg/ha + onion bulbs 70/kg + Rovral 50WP @ 0.2% + Ridomil MZ-72 @ 0.2%) caused lowest severity of purple blotch and maximum seed yield of onion.

CHAPTER 7

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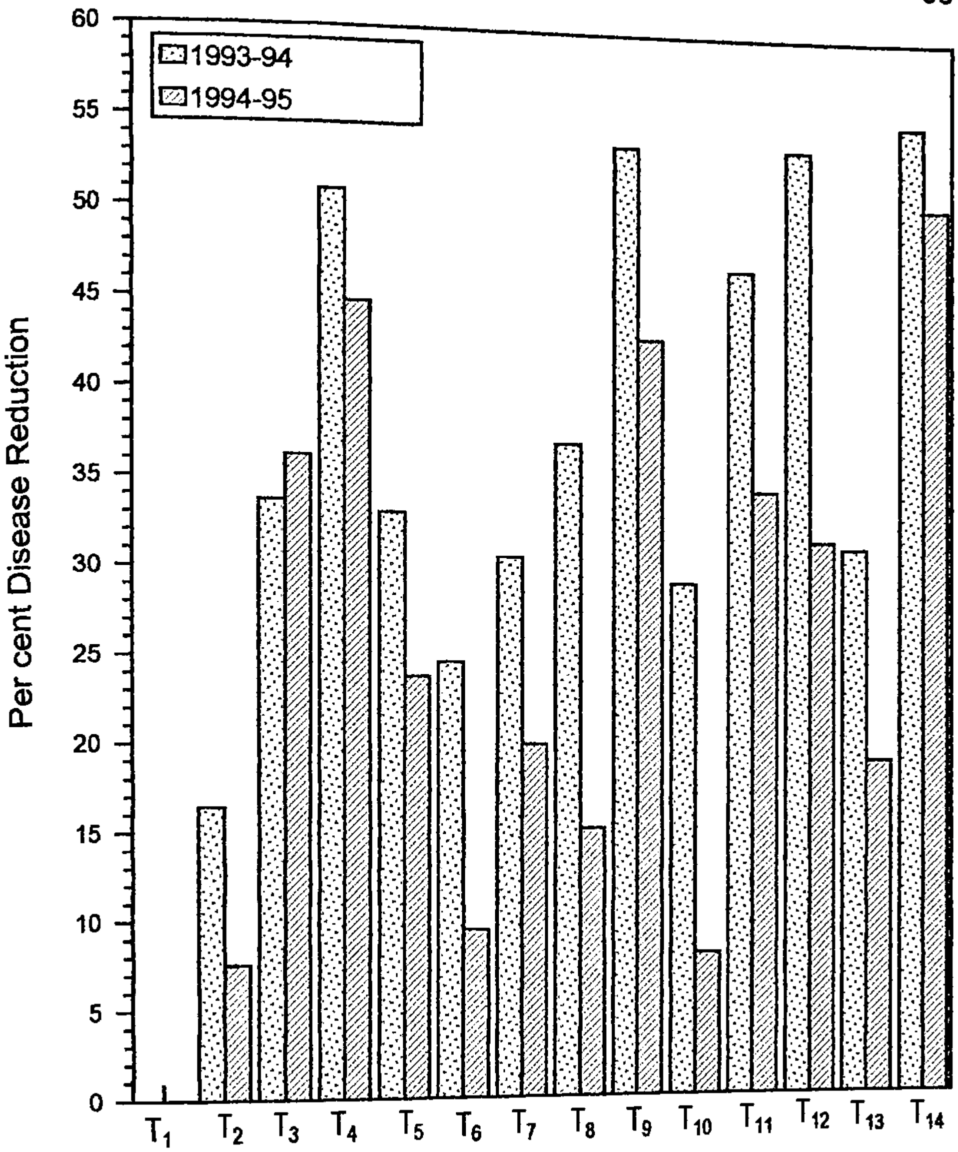
CHAPTER 8

Appendices



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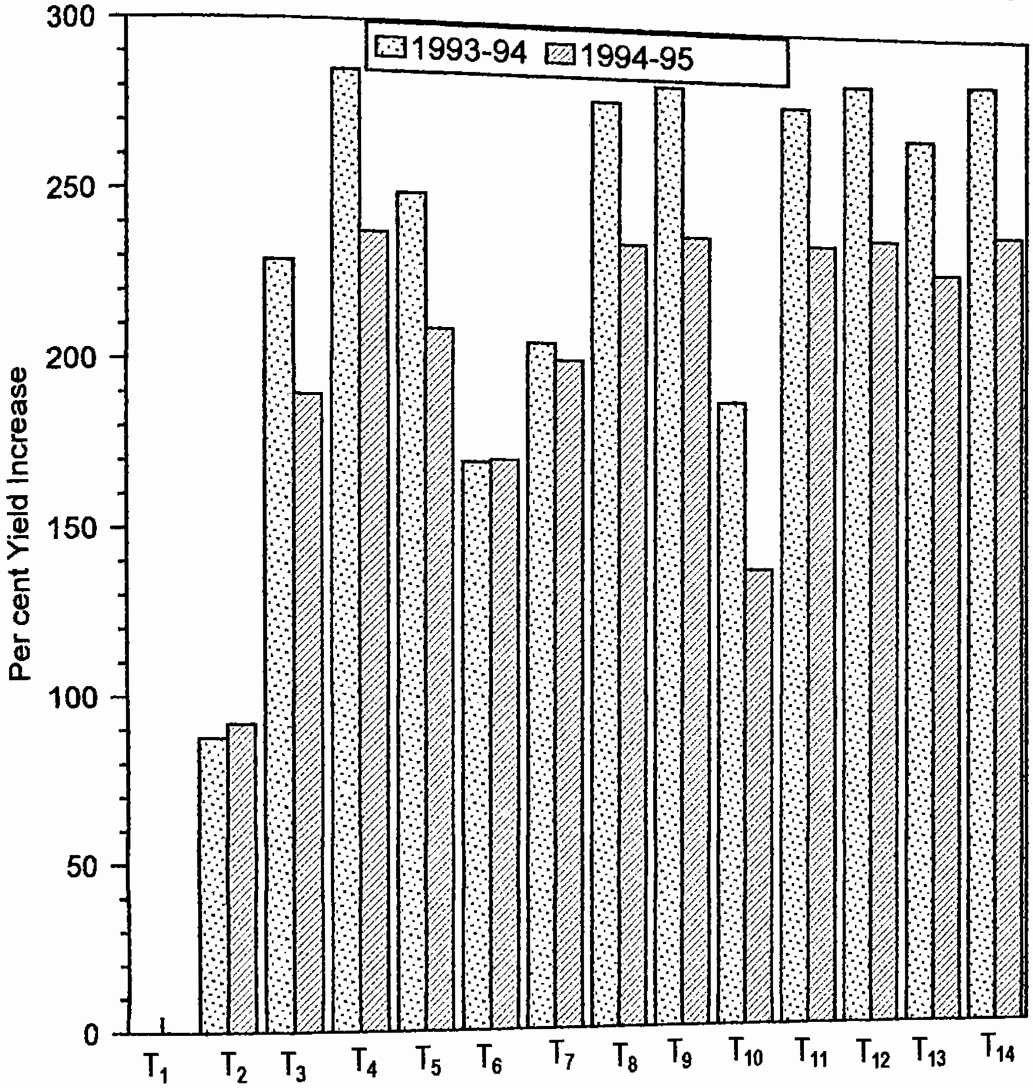
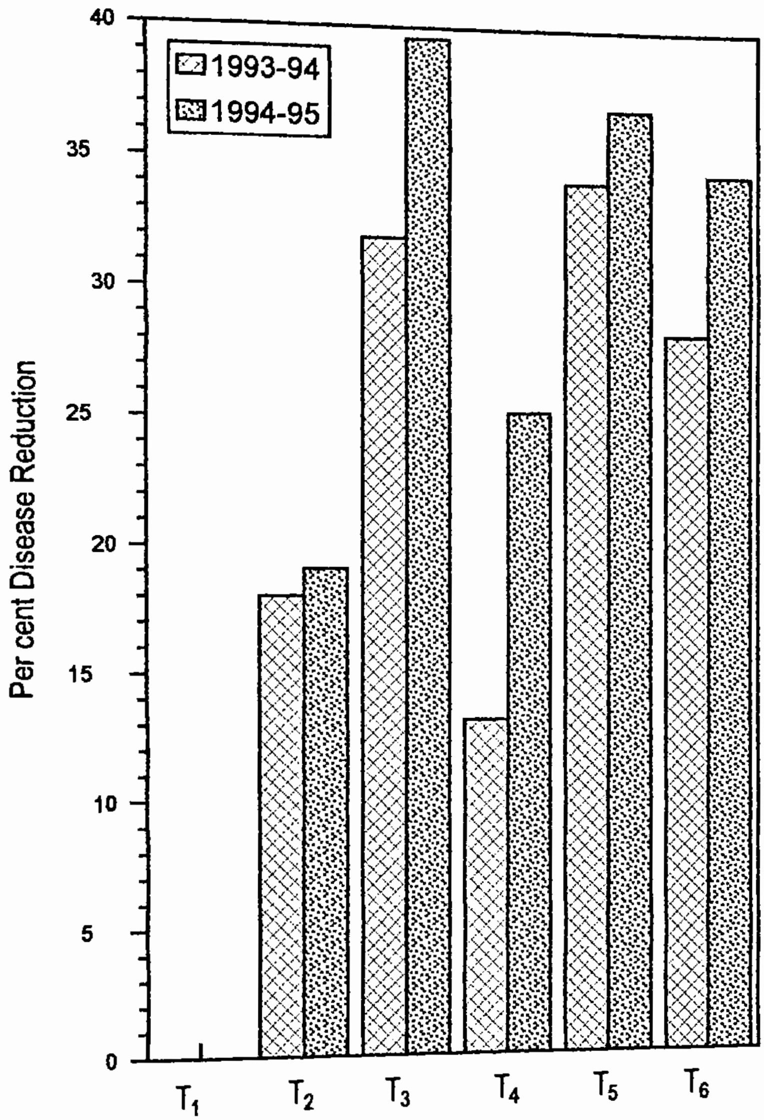
$T_2=N_0P_{200}K_{100}S_{20}$
$T_3=N_{100}P_{200}K_{100}S_{20}$
$T_4=N_{150}P_{200}K_{100}S_{20}$
$T_5=N_{200}P_{200}K_{100}S_{20}$
$T_6=N_{150}P_0K_{100}S_{20}$
$T_7=N_{150}P_{100}K_{100}S_{20}$
$T_8=N_{150}P_{150}K_{100}S_{20}$
$T_9=N_{150}P_{250}K_{100}S_{20}$
$T_{10}=N_{150}P_{200}K_0S_{20}$
$T_{11}=N_{150}P_{200}K_{75}S_{20}$
$T_{12}=N_{150}P_{200}K_{125}S_{20}$
$T_{13}=N_{150}P_{200}K_{100}S_0$
$T_{14}=N_{150}P_{200}K_{100}S_{40}$

Fig. 1. Reduction of purple blotch of onion due to the application of different fertilizers in 1993-94 and 1994-95



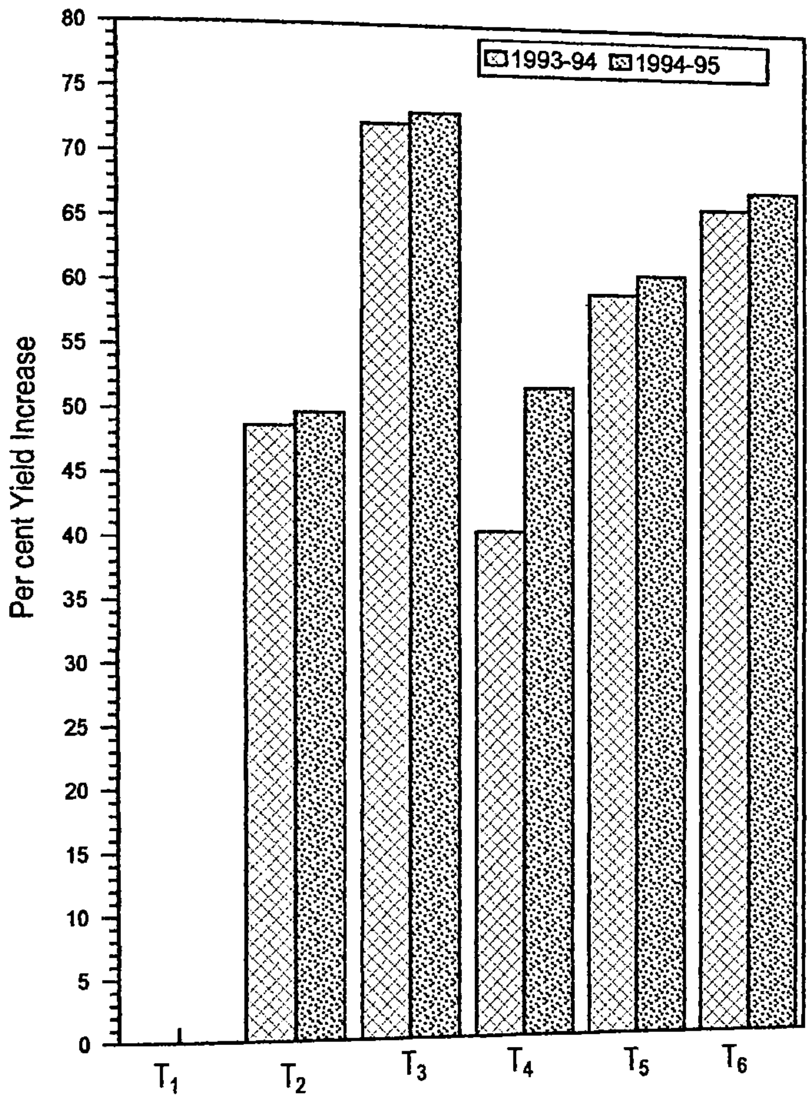
$T_1=N_0P_0Ko_0S_0$
$T_2=N_0P_{200}K_{100}S_{20}$
$T_3=N_{100}P_{200}K_{100}S_{20}$
$T_4=N_{150}P_{200}K_{100}S_{20}$
$T_5=N_{200}P_{200}K_{100}S_{20}$
$T_6=N_{150}P_0K_{100}S_{20}$
$T_7=N_{150}P_{100}K_{100}S_{20}$
$T_8=N_{150}P_{150}K_{100}S_{20}$
$T_9=N_{150}P_{250}K_{100}S_{20}$
$T_{10}=N_{150}P_{200}K_0S_{20}$
$T_{11}=N_{150}P_{200}K_{75}S_{20}$
$T_{12}=N_{150}P_{200}K_{125}S_{20}$
$T_{13}=N_{150}P_{200}K_{100}S_0$
$T_{14}=N_{150}P_{200}K_{100}S_{40}$

Fig. 2. Yield increase of onion seeds due to the application of different fertilizers in 1993-94 and 1994-95



$T_1 = Zn_0B_0Mo_0Cu_0$
$T_2 = Zn_0B_1Mo_1Cu_1$
$T_3 = Zn_4B_1Mo_1Cu_1$
$T_4 = Zn_4B_0Mo_1Cu_1$
$T_5 = Zn_4B_1Mo_0Cu_1$
$T_6 = Zn_4B_1Mo_1Cu_0$

Fig. 3. Per cent disease reduction of purple blotch of onion seed-cropdue to the application of micronutrients in 1993-94 and 1994-95



$T_1 = Zn_0B_0Mo_0Cu_0$ $T_4 = Zn_4B_0Mo_1Cu_1$

$T_2 = Zn_0B_1Mo_1Cu_1$ $T_5 = Zn_4B_1Mo_0Cu_1$

$T_3 = Zn_4B_1Mo_1Cu_1$ $T_6 = Zn_4B_1Mo_1Cu_0$

Fig. 4. Per cent yield increase of onion seeds due to the application of micronutrients in 1993-94 and 1994-95

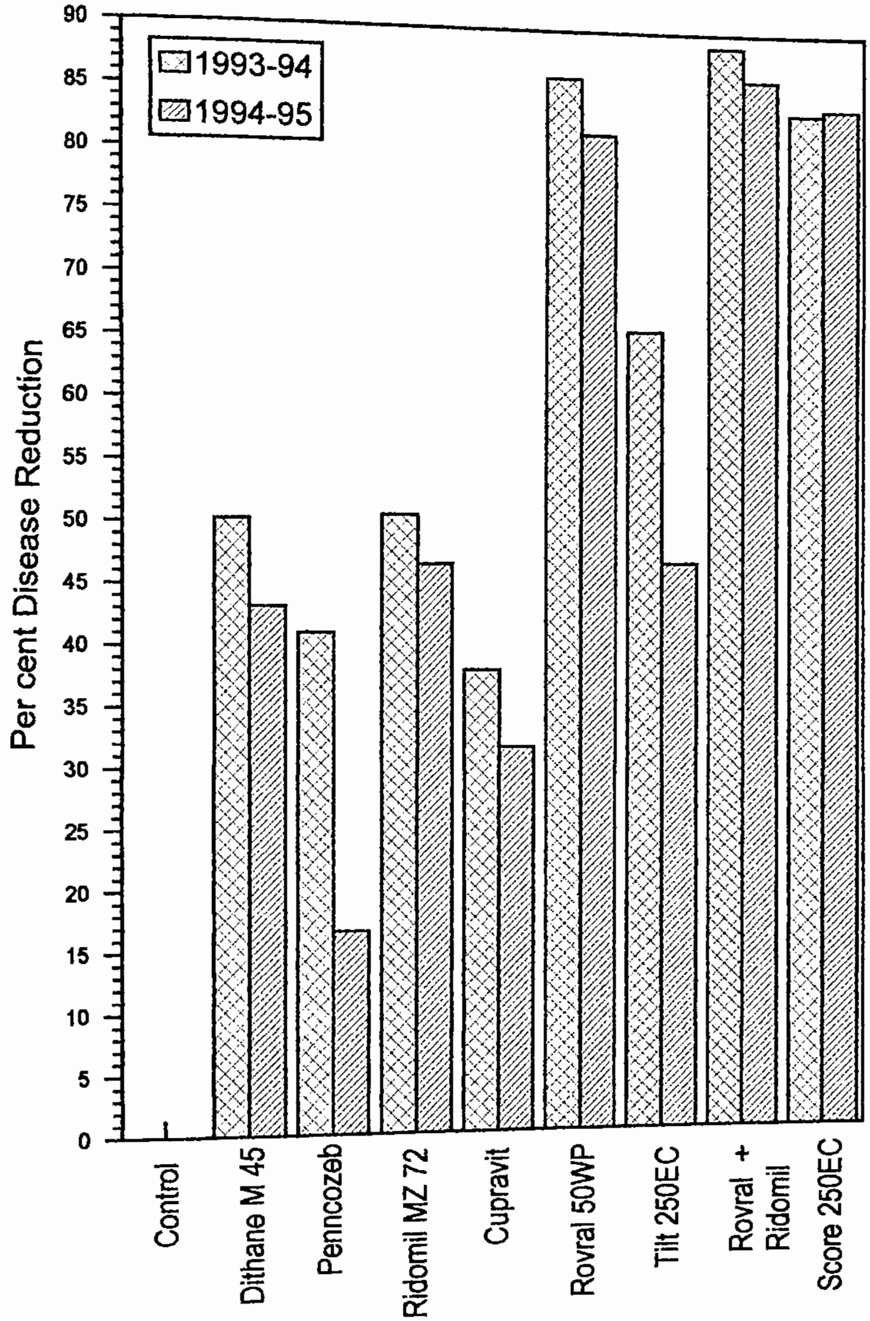


Fig. 5. Per cent reduction of purple blotch due to fungicides in 1993-94 and 1994-95

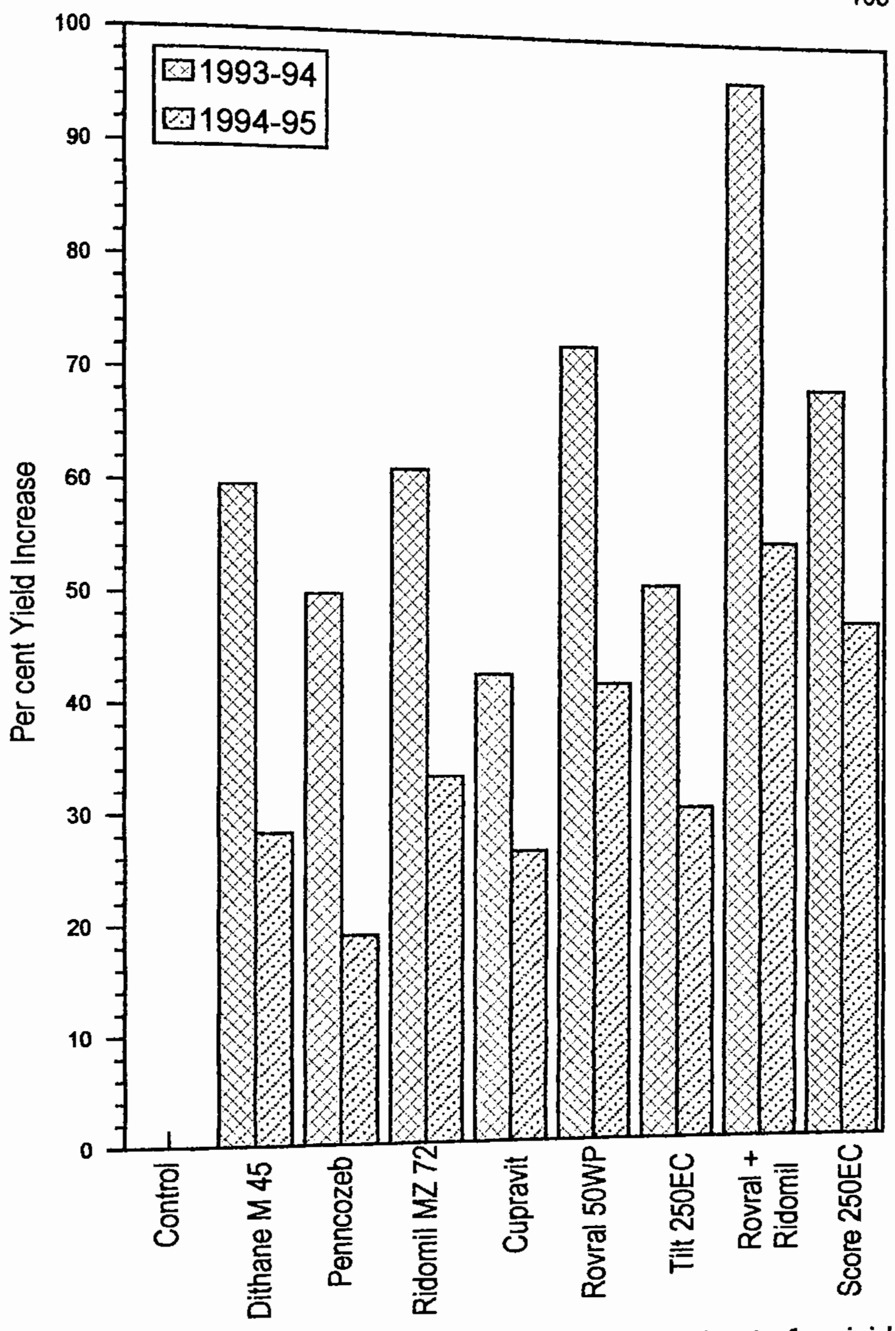
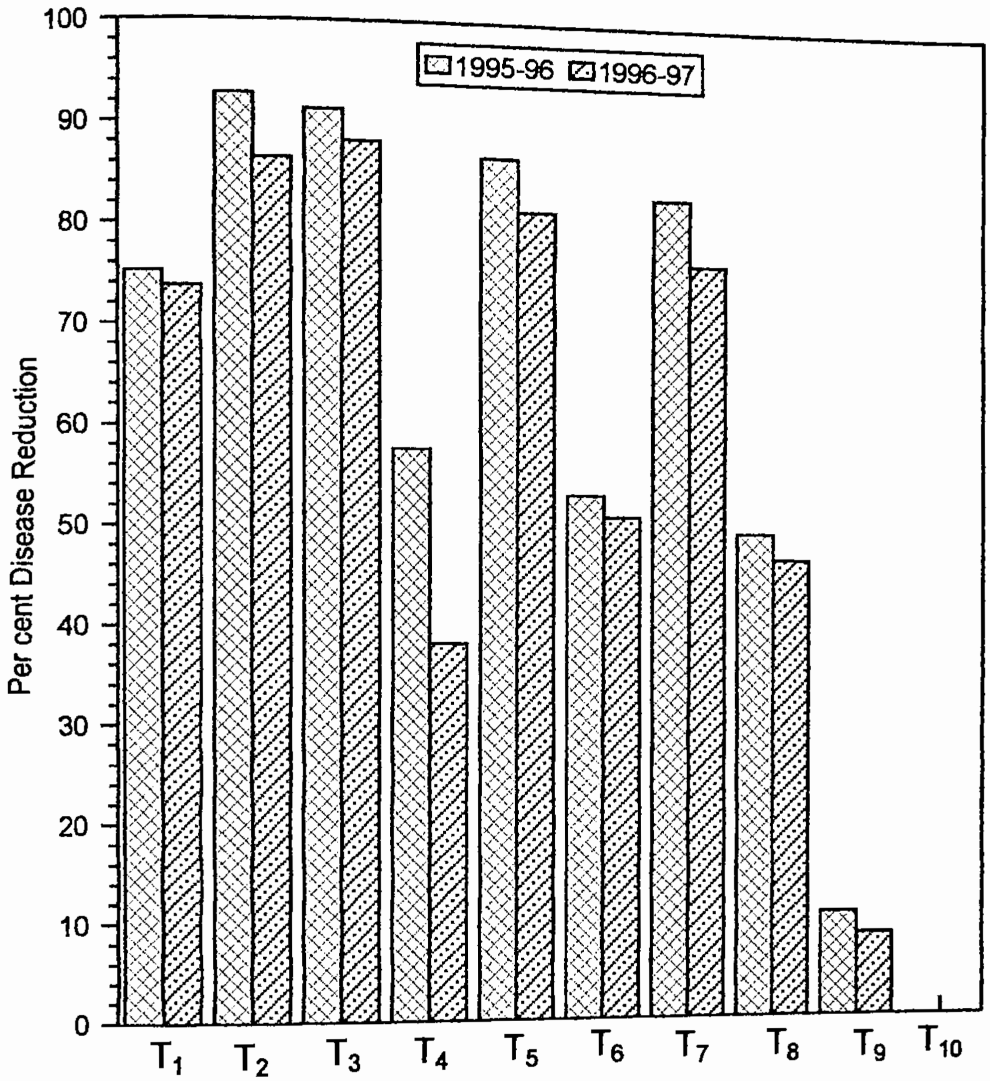


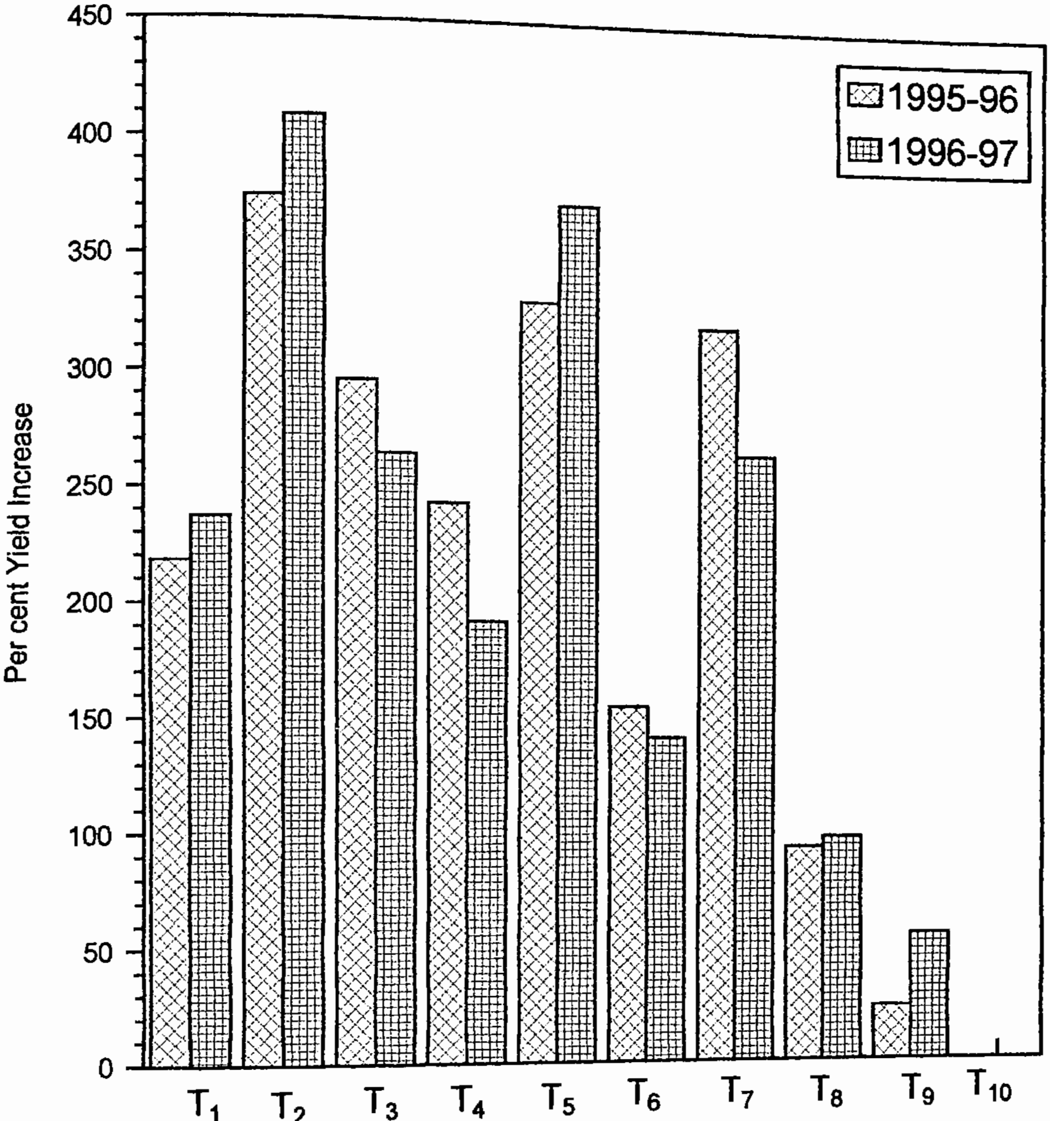
Fig. 6. Per cent yield increase of onion seeds due to fungicides in 1993-94 and 1994-95



T_1=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+160 bulbs/kg+15 cm plant spacing+ CD
T_2=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 cm plant spacing+CD
T_3=Fungicide+$N_0P_0K_0S_0Zn_4B_1$+70 bulbs/kg+20 cm plant spacing+CD
T_4=Fungicide +$N_{150}P_{100}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 plant spacing+CD
T_5=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_6=$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 cm plant spacing
T_7=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_0B_0$+70 bulbs/kg+15 cm plant spacing
T_8=Fungicide+$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_9=$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_{10}=$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing

(Fungicide=Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%; CD= Cowdung 10 t/ha)

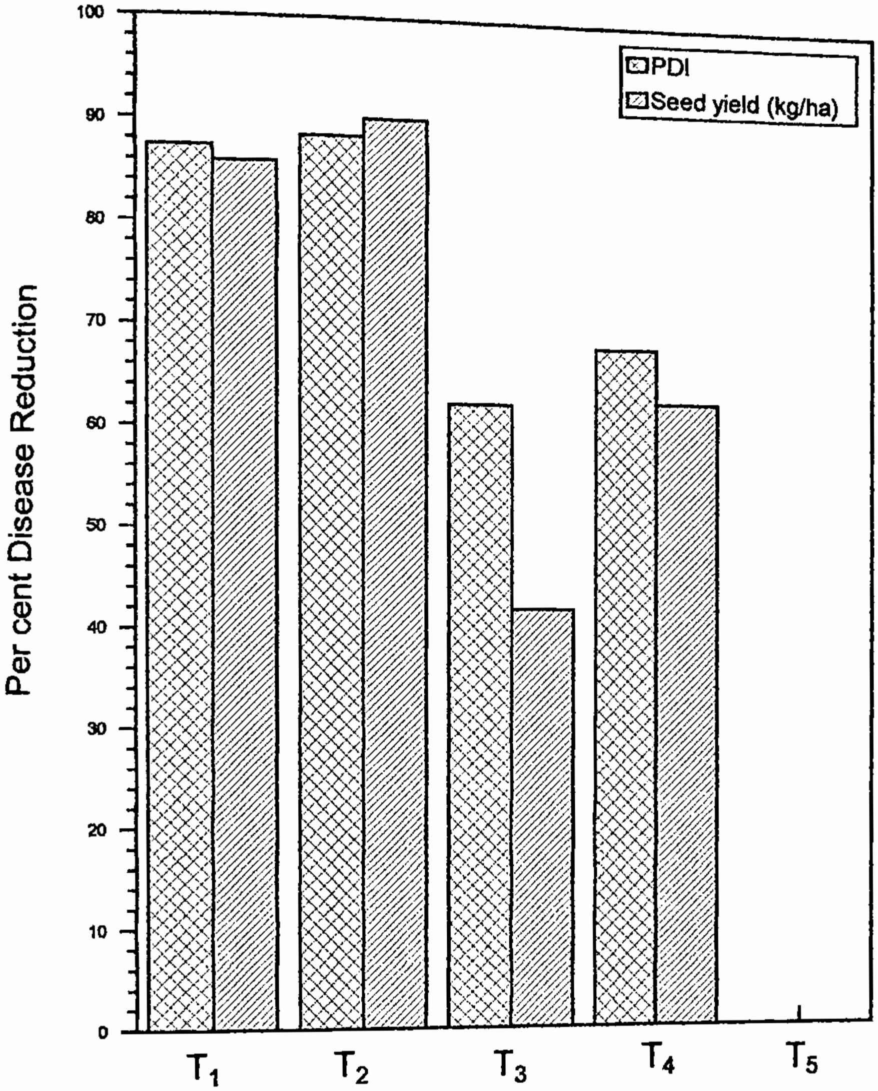
Fig. 7. Reduction of purple blotch of onion seed-crop due to integrated disease management approach in 1995-96 and 1996-97



T_1=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+160 bulbs/kg+15 cm plant spacing+ CD
T_2=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 cm plant spacing+CD
T_3=Fungicide+$N_0P_0K_0S_0Zn_4B_1$+70 bulbs/kg+20 cm plant spacing+CD
T_4=Fungicide +$N_{150}P_{100}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 plant spacing+CD
T_5=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_6=$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg+15 cm plant spacing
T_7=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_0B_0$+70 bulbs/kg+15 cm plant spacing
T_8=Fungicide+$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_9=$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing+CD
T_{10}=$N_0P_0K_0S_0Zn_0B_0$+70 bulbs/kg+15 cm plant spacing

(Fungicide=Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%; CD= Cowdung 10 t/ha)

Fig. 8. Yield increase of onion seeds due to integrated disease management (IDM) approach in 1995-96 and 1996-97



T_1=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+120 bulbs/kg

T_2=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg

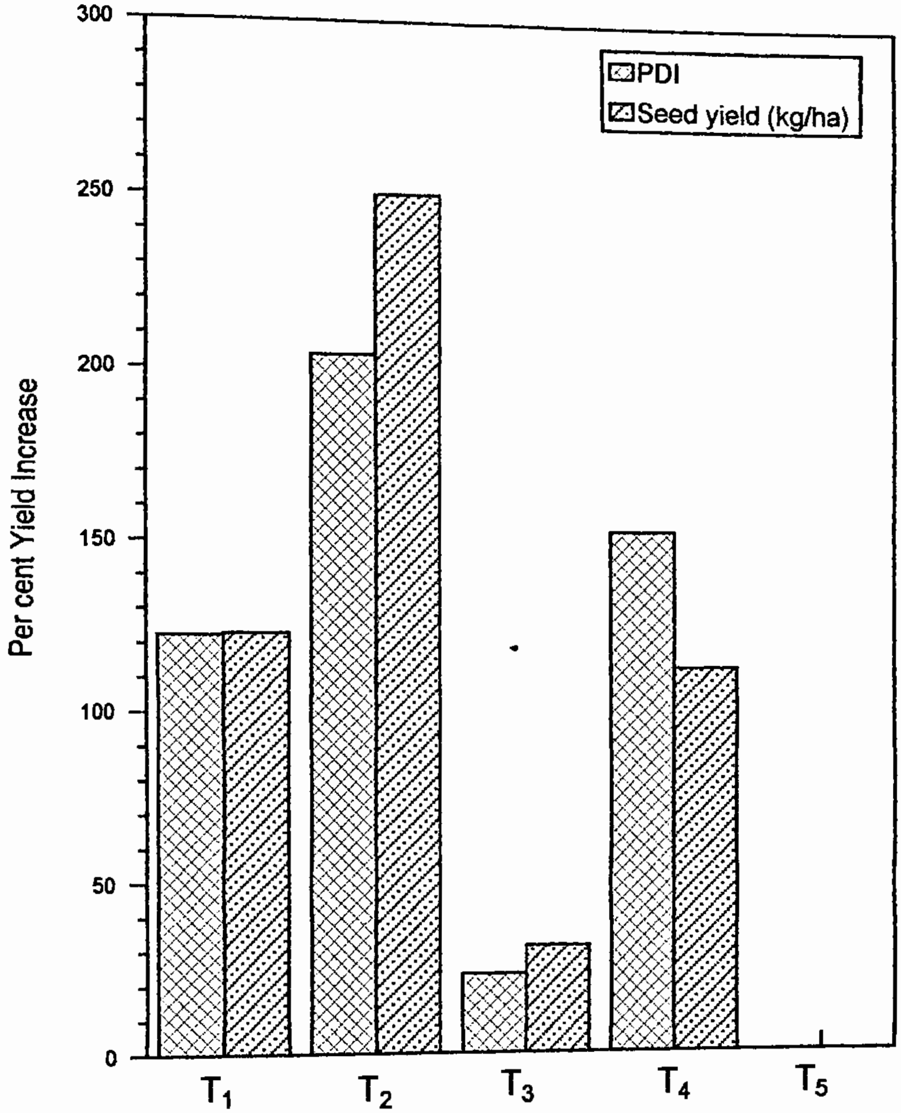
T_3=$N_{50}P_{70}K_{50}S_0Zn_0B_0$+70 bulbs/kg

T_4=Fungicide +$N_{50}P_{70}K_{50}S_0Zn_0B_0$+70 bulbs/kg

T_5=$N_{50}P_{70}K_{50}S_0Zn_0B_0$+120 bulbs/kg (Farmers' practice)

(Fungicide=Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%

Fig. 9. Reduction of purple blotch of onion seed crop due to the application of integrated disease management approach in on-farm trial during 1997-98 and 1998-99



T_1=Fungicide+$N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+120 bulbs/kg
T_2=Fungicide + $N_{150}P_{200}K_{100}S_{20}Zn_4B_1$+70 bulbs/kg
T_3=$N_{50}P_{70}K_{50}S_0Zn_0B_0$+70 bulbs/kg
T_4=Fungicide +$N_{50}P_{70}K_{50}S_0Zn_0B_0$+70 bulbs/kg
T_5=$N_{50}P_{70}K_{50}S_0Zn_0B_0$+120 bulbs/kg (Farmers' practice)

(Fungicide=Rovral @ 0.2% + Ridomil MZ-72 @ 0.2%

Fig. 10. Yield increase of onion seeds due to the application of integrated disease management approach in on-farm trial during 1997-98 and 1998-99 in On-farm trial