Chapter – 17

A REVIEW: STEMPHYLIUM BLIGHT OF ONION-THE PATHOGEN, THE DISEASE, CURRENT STATUS AND DIFFERENT METHODS OF DISEASE MANAGEMENT

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Introduction

Onion (*Allium cepa* L. 2n=16) is one of the most important and familiar crop throughout the world that belongs to the family Alliaceae. It is also used as a common spice, salad and vegetable in many countries of Asia. Onion has manifold uses as spices. It is also used as a condiment for flavoring a number of foods and medicines (Vohra *et al.,* 1974; Hassan, 2007). Onion bulbs are rich source of minerals like phosphorus, calcium and carbohydrates besides being rich in proteins and vitamin C. Onion contains chemical compounds with potential anti-inflammatory, anti-cholesterol and anti-cancer properties (Slimestad *et al.*, 2007). Among vegetables, onion often called as "queen of kitchen" is one of the oldest known and an important crop grown in India. It contains the lachrymatory principle, a strong antibiotic, having fungicidal, bactericidal and nematocidal properties (Purseglove, 1972). It also contains chemical compounds with potential anti-inflammatory, anti-cholesterol, anticancer and antioxidant properties, such as quercetin (Slimestad *et al*., 2007). It is also of high medicinal value in controlling human and plant diseases (Vohra *et al.*, 1974). Onion suffers from many diseases caused by fungi, bacteria, viruses, nematodes and abiotic factors (Paibomesai *et al*., 2012). Among the fungal diseases Stemphylium blight is the most serious and devastating disease of onion limiting the quality and quantity of both bulb and seed (Nisha, 2013).

Among the diseases, purple leaf blotch (PLB) caused by *Alternaria porri* (Ellis) Cif. and *Stemphylium* leaf blight (SLB) caused by *Stemphylium vesicarium* (Wallr.) E. Simmons, are the major diseases of onion world-wide affecting the foliage severely resulting in crop loss ranging from 30 to 100 per cent both in seed and bulb crop from year to year (Awad *et al.*, 1978; Cramer, 2000) and are more prevalent in warm and humid environment (Suheri and Price, 2000).

Causal Agent and Symptoms

Stemphylium leaf blight of onion is caused by *Stemphylium vesicarium* (Wallr.) E. Simmons (teleomorph: *Pleospora allii*. (Rabenh.) Ces. & De Not). It is an Ascomycete belonging to the family Pleosporaceae and the order Moniliales. The pathogen is closely related to *Alternaria* porri, (Simmons 1967). Diseases caused by these two fungi are sometimes misdiagnosed because the initial symptoms are similar (Simmons 1967; Suheri and Price 2001). In Ontario, *S. vesicarium* was reported on onion in 2008, following reports on asparagus (*Asparagus officinalis* L) (Roddy 2011). The initial symptoms of Stemphylium leaf blight on onion include small, yellowish brown to tan, water-soaked lesions (Rao and Pavgi 1975). However, the initial symptoms of purple blotch are small, sunken, whitish lesions with purple centers (Everts 1990). Stemphylium leaf blight is restricted to onion leaves and inflorescences (Rao and Pavgi 1975).

Pathogenicity and Host

Stemphylium vesicarium has been detected on a wide range of crops as both a pathogen and saprophyte. In addition to onion, *S. vesicarium* is pathogenic on garlic (Basallote 1993), leek (Suheri and Price 2001), Welsh onion (Misawa and Yasuoka 2012), asparagus (Falloon 1987), and European pear (*Pyrus communis* L.). Also, in addition to known hosts, the pathogen can cause asymptomatic infections and develop as endophytes in the living tissues of various plants (Kohl *et al.* 2009; Misawa and Yasuoka 2012). Host-specific toxins are involved in the pathogenicity and aggressiveness of isolates (Singh *et al.* 1999). Isolates that are pathogenic on European pear cultivars produce two toxins, SV-toxin I and SV-toxin II (Singh *et al.* 1999) that are not pathogenic to asparagus or onion (Kohl *et al.* 2009). The toxicity and concentration of the toxins is correlated with Stemphylium leaf blight severity (Singh *et al.* 1999). Isolates of *S. vesicarium* from asparagus, onion, and garlic were reported to be pathogenic to all three crops (Basallote-Ureba *et al.* 1993).

Isolates from parsley were pathogenic to members of the Apiaceae family but not to Allium crops (Koike *et al.* 2013).

Losses through Stemphylium Blight

Stemphylium leaf blight is an important disease of onion in both tropical and temperate countries (FAO, 1997). The disease caused 90% yield losses on onion in Texas and New York State in 1978 (Miller *et al.* 1978; Lorbeer 1993), 80 85% yield loss in Portugal (Tomaz and Lima 1988), and large losses in Egypt (Hassan *et al.* 2007), India (Rao and Pavgi 1975), Japan (Misawa and Yasuoka 2012), New Zealand (Suheri and Price 2001), South Africa (Aveling 1992) and Spain (Basallote 1993). On asparagus, it can result in 100% loss of spears (Falloon 1987). Brown spot disease on pear, caused by *Stemphylium vesicarium,* resulted in 60 - 90% loss of yield (Llorente and Montesinos 2002).

Disease Cycle

Sexual and Asexual Spores

The disease cycle of Stemphylium blight is characterized by sexual and asexual phases (Basallote-Ureba *et al.* 1999). In the sexual phase, pseudothecia develop on both diseased and symptomless tissues of host and non-host plants (Misawa and Yasuoka 2012). On onion, however, pseudothecia development is restricted to the inflorescence (Rao and Pavgi 1975). The development of pseudothecia in temperate regions occurs in the winter at temperatures between 5 - 15 °C and high relative humidity (Llorente and Montesinos 2002). At these low temperatures, ascospores maturation takes 1 - 6 months (Simmons 1969). The pseudothecia are black and bear several cylindrical asci (Simmons 1969). Pseudothecia release ascospores in the spring, coinciding with rainfall events. Ascospores are yellowish brown and ellipsoidal, with the upper half narrowly tapered. Matured ascospores have 5 - 7 complete transverse septa and zero to several incomplete longitudinal septa. The average size of a mature ascospore is about 18 × 38 µm. Ascospores of *P. allii* are indistinguishable from ascospores of *P. herbarum* (Fries) Rabenhorst (anamorph: *S. botryosum* Wallroth), but the asci of *P. herbanum* are smaller (Simmons 1969). Ascospores can infect onion plants under laboratory conditions, but their role in the epidemiology of Stemphylium leaf blight is unclear. In Allium crops, primary infection in the field is associated with asexual conidia (Misawa and Yasuoka 2012). Conidia are olive-brown, oval to ovoid, and are borne on conidiophores that are pale to brown with dark edges and bands. The conidia have 1 - 5 transverse septa and are constricted at 1 - 3 transverse septa.

The conidia also have 1 - 2 complete longitudinal septa (Simmons 1969). Conidia of *S. vesicarium* are twice as long as wide (mean 18 × 34 μm), whereas those of *S. botryosum* have roughly equal length and width (25 × 28 μm, (Simmons 1969).

Inoculum Dispersal and Distribution:

Information on inoculum availability and distribution for Stemphylium leaf blight on onion is not available. In pear and garlic crops in Spain (Rossi *et al.* 2008), Welsh onion in Japan (Misawa and Yasuoka 2012) and asparagus in Michigan, USA (Granke and Hausbeck 2010), both ascospores and conidia are present during the cropping season. Ascospores are captured in the early part of the cropping season and conidia are captured later, during disease development. In Allium crops, there was a time lag between when ascospores are first detected and first incidence of Stemphylium leaf blight (Misawa and Yasuoka 2012). In pear orchards, it is postulated that ascospores colonise plant debris on the orchard floor and produce abundant conidia, which then infection pear (Llorente and Montesinos, 2002; Rossi *et al.* 2008). In asparagus, both ascospores and conidia infect spears in the field (Granke and Hausbeck 2010). Both ascospores and conidia are air-borne. The daily release and volume of ascospores and conidia are influenced by precipitation, temperature, relative humidity, vapour pressure deficit, wind speed, and solar radiation (Granke and Hausbeck 2010; Misawa and Yasuoka 2012; Rossi *et al.* 2008). Daily release of airborne ascospores and conidia show a diurnal pattern, as with many other Ascomycetes.

Sporulation and Infection

Stemphylium vesicarium sporulates on onion, garlic and asparagus, producing abundant conidia (Falloon 1987; Basallote-Ureba *et al.* 1993 Suheri and Price 2000, 2001). Sporulation usually occurs at the site of initial lesions. On onion and garlic leaves, sporulation is observed 6 days after the development of initial lesions (Basallote-Ureba *et al.* 1993). *Stemphylium* species infect their host mainly through stomata openings and wounds. Older onion leaves are more susceptible to infection than young leaves. Germination of conidia on onion leaves occurs at 4–35 °C (Srivastava *et al.* 1996; Suheri and Price 2000). The optimal conditions for conidial infection are temperatures > 18 °C, leaf wetness duration > 6 h, and high relative humidity (Suheri and Price 2000). The pathogen starts producing host-specific toxins immediately after infection. These toxins increase the severity of infection by inducing electrolyte losses from host tissues, causing ultra-structural changes in cells that lead to extensive veinal necrosis (Singh *et al.* 1999, 2000).

Typical symptoms of leaf spot and apical necrosis on onion and garlic occur 6–14 days after inoculation (Basallote-Ureba *et al.* 1993; Suheri and Price 2000; Misawa and Yasuoka 2012).

Occurrence of the Disease

Su (1936) reported *Stemphylium* blight of onion caused by *Stemphylium vesicarium* and its perfect stage *Pleospora allii as Macrosporium parasiticum (Pleospora herbarum)* from Barma. Stemphylium blight of onion was first recorded by Rao and Pavgi (1975) in India. Stated about Stemphylium blight caused by *Stemphylium vesicurium*, a serious pathogen, which confirmed to leaves and fluorescence stalk. Miller *et. al.,* (1978) reported on *Stemphylium* blight of onion in South Texas, a previously unrecognized disease of onion causes significant damage during 1976 both alone and with *Alternaria porri.* Wu (1979) surveyed on the seed-borne diseases of vegetables. Results of the survey on onion showed that *Alternaria porri and Stemphylium botryosum (Pleospora herbarum)* reduced germination of onion seeds. Inoculation with *Stemphylium vesicarium* on the short day onion cultivars. White Granex, Ben shamen and New Maxico Yellow Grano produced lesions identical to those in the field. Miller (1983) reported that measurements of infected leaves were taken weekly from bulb initiation to bulb maturity of onion.

In India, *S. vesicarium* was reported on onion from Maharashtra (Patil and Patil, 1992) and from Bihar (Sinha, *et.al.,* 1996). Sinha, *et. al.,* (1998) have observed the anamorph *S. vesicarium* and teliomarph *Pleospora spp.* on garlic as a new record for India. The incidence of leaf blight on garlic has also been reported from Himanchal Pradesh (Sugha and Kumar, 2005). Shuhana *et. al.,* (2008) have observed for the first time the Stemphylium blight of onion pathogen *S. vesicurium* (Wallr.) E. Simmons; perfect state *Pleospora alli* (Pers. Ex. Fr.) Rabenh) from Jammu and Kashmir.

Management of Stemphylium Blight

Biological Control Agents

Biological control agents such as *Bacillus subtilis*, *Saccharomyces cerevisiae*, *Pseudomonas fluorescens* and *Trichoderma* species reduced the severity of Stemphylium blight in onion under controlled conditions (Kamal *et al.* 2008). However, these products do not provide effective management of Stemphylium leaf blight when used as the sole management strategy under field conditions (Wright *et al.* 2005). In pear orchards, sanitation combined with application of *Trichoderma* spp. reduced Stemphylium blight incidence by 60% (Llorente *et al.* 2008).

Application of certain antagonistic microorganism's isolates for controlling onion Stemphylium blight under greenhouse conditions affected significantly the disease severity. Application of *Trichoderma harzianum* and *P. fluorescens* gave the highest reduction in the disease severity. In most cases application of these bioagents at the same time of inoculation with the pathogen gave higher reduction in disease severity than the application 3 days before inoculation. The obtained results are in agreement with those obtained by many other researchers (Leeman *et al.,* 1995; Paulitz and Bèlanger, 2001 and Hassan and Abd El-Rehim 2002).

Barnwal *et al.* (2003) reported the efficacy of *Pseudomonas fluorescens* and hexaconazole in controlling *Stemphylium botryosum* causing blight in onion during the field experiment conducted during the *rabi* season of 1998-2000. The methods of application used were seed treatment, root dip or foliar spraying, used alone or in combination. All the treatments reduced the severity of the disease compared to the control, with hexaconazole treatment resulting in lower disease severity compared to *P. fluorescens* treatment. Crop yield was higher with hexaconazole than *P. fluorescens* treatment. Within treatments, twice foliar spraying resulted in the lowest disease severity in onion and highest yield.

Various bioagents *Bacillus subtilis*, *Pseudomonas fluorescens*, *Trichoderma har zianum, Gliocladium* spp. and *Saccharomyces cerevisiae* were tested against Stemphylium blight under, *in vitro* conditions. The highest inhibition of *S. vesicarium* mycelial growth was achieved by *Pseudomonas fluorescens, B. subtilis* and *T. harzianum* and in *in-vivo* study the bioagents *viz., B. subtilis*, *S. cerevisiae* and *P. fluorescens* exhibited the highest reduction in disease severity whereas, *Trichoderma harzianum* gave the lowest (Hussein *et al.*, 2007). Hussein, *et. al.*, (2007) reported that the bioagents, *i.e. B. subtilis*, *Sacc. cerevisiae* and *P. fluorescens* exhibited the highest reduction in disease severity. On the other hand, *T. harzianum* gave the lowest reduction in the disease severity. Bio-control agents such as *Trichoderma viride* (Tv- 1) and *T. harzianum* (Th-1), each at 1×10^{9} spores ml^{-1} and Phyto extracts (*Cannabis indica* @10% and *Curcuma longa* @10%), mancozeb @ 0.25% proved most effective in managing foliar blight of onion but was at par with hexaconazole @ 0.06%. Among bio-control agents used, application of *T. harzianum* (Th-1) resulted in lower disease intensity as compared to *T. viride* (Tv-1), though both were statistically at par with each other, but were significantly superior over the control. The Phyto-extracts, *C. indica* and *C. longa* proved ineffective in the disease management (Shahnaz *et al.,* 2013).

Kamal *et al.* (2016) conducted an experiment and reported that the antagonistic activity of 20fungal isolates recovered from onion plants, two isolates to control the dis ease under greenhouse conditions were selected namely, *Trichoderma harzianum* isola te 3013 and Stachybotrys chartarum isolate.Application of *T. harzianum* isolate 3013 a nd Stachybotrys chartarumisolate 2031 showed, when applied before pathogen infectio n, a reduction in disease by 67.9 and 71.3%, respectively. As well as after pathogen in fection they caused a reduction in the disease by 72.8 and 73.2%.

Plant Extracts

Prasad and Barnwal (2004) also evaluated that effect of leaf extract of *Azadirachta indica, Pongamia pinnata, Datura metel, Ocimum sanctum* (*O. tenuiflorum*), *Eucaplutus citriodera* and *Mentha arvensis* a *Stemphylium* blight of onion cv. N-53 (Nasik red) in field trial. Furthermore, six extracts of plant species *viz., Azadirachta indica*, *Datura metel, Lantana camara, Parthenium hystorophorus, Ocimum spp., Argimone mexicana* and five bioagents *viz., T. harzianum, T. viride, Aspergillus niger, Penicillium citrinum* and *G. virens* against *S. botryosum* were evaluated. Among plant extracts *A. indica* (66.5%) and *D. metel* (64.5%) were the best in restricting the growth of pathogen over control and in evaluation of bioagents, *T. harizianum* (81.2%) and *T. viride* (74.5%) had significantly inhibited the growth of pathogen. Under field condition suppression of pathogen by treating the garlic cloves with *T. harzianum* @ 0.2% along with two foliar sprays of *A. indica* @ 0.2% and *T. harzianum* @ 0.2% at 15 days interval found to be most effective for management of this disease (Kumar *et al.*, 2012). Similarly, Mishra and Gupta (2012) evaluated eight plant extracts and bioagents under *in vitro* conditions Stemphylium blight of onion caused by *S. vesicarium*. Among the plant extracts, clove extracts of *Allium sativum* @ 10% resulted in maximum inhibition of growth (57.31%), followed by *Aloe vera* @ 10% (47.15%). Among the bioagents, *T. viride* was highly effective in inhibition of growth (56.15%). Akhtar, *et. al.,* (2015) reported that the plant extracts on plant height, bulb diameter and bulb yield of onion. All the plant parameters were increased with applying different plant extracts with their effectiveness. Kumar, *et. al.,* (2020) reported that the six extract of plant species *viz. Azadirachta indica, Datura metel, Lantana camara, parthenium hyserophores, Ocimum spp.* and *Argimone mexicana etc.* were tested *In vitro* against *Stemphylium vasicarium* and found that plant extract of *Azadirachta indica* gave (66.5 percent) and *Datura metel* gave (64.5 percent) in habitation over control.

References

1. Agrios, G. N. (2005) *Plant Pathology*. Fifth *Edition. ed*. London: Elsevier Academic Press.

2. Akhtar, U. S. Md. Harun or Rashid, Md. Maksudul Haque, Md. Aminur Rahman and Md. Rafiqul Islam (2015) Effect of fungicides and plant extracts on growth and yield of Onion (Allium Cepa L.). J. Basic. Appl. Sci. Res., 5(8): 25-28.

3. Anonymous (2015) Indian Horticulture Database 2014. National Horticulture Board, Ministry of Agriculture, Government of India. pp. 160-255.

4. Anonymous, (2015) Ministry agriculture cooperation and farmer welfare New Delhi, India. pp-1-123.

5. Aveling, T. A., (1992) First report of *Stemphylium vesicarium* on garlic in South Africa. Plant Disease, 76 (4): 426.

6. Awad, M. A., EI-Shenawy, Z., Omran, A. F. and Shatla, M. N. (1978) Cultural Practices in relation to Purple Blotch Disease of Onion. *Sci Hortic* 9: 237-243.

7. Barnwal, M. K. (2003) Epidemiology and management of Stemphylium blight of onion. Ph.D. Dissertation, Birsa Agricultural University, Jharkhand, India. pp-1-65.

8. Basallote, M. J., Prados, A. M., Perez de Algaba, A., and Melero Vara, J. M., (1993) First report in Spain of two leaf spots of garlic caused by *Stemphylium vesicarium*. Plant Disease 77: 952.

9. Basallote-Ureba, M. J., Prados-Ligero, A. M., and Melero-Vara, J. M., (1999) Aetiology of leaf spot of garlic and onion caused by *Stemphylium vesicarium* in Spain. Plant Pathology, 48(1): 139-145.

10. Brewster, J. L., (2008) Onions and Other Vegetable Alliums. 2nd ed. Cambridge, MA: CAB International.

11. Chase, M. W., Reveal, J. L., and Fay, M. F., (2009) A subfamilial classification for the expanded Asparagalean families Amaryllidaceae, Asparagaceae and Xanthorrhoeaceae. Botanical Journal of the Linnean Society, 161: 132–136.

12. Cramer, C. S. (2000) Breeding and Genetics of Fusarium basal rot resistance in Onion. *Euphytica,* 115: 159-166.

13. Everts, K. L., (1990) Influence of Environment on Conidial Concentration of Alternaria porri in Air and on Purple Blotch Incidence on Onion. Phytopathology, 80 (12): 1387.

14. Falloon, P. G. (1987) Etiology and epidemiology of stemphylium leaf spot and purple spot of asparagus in California. Phytopathology, 77 (3): 407-413

15. FAO, (1997) Plant Production and Protection Div.; International Plant Genetic Resources Inst., Food and agriculture organisation. Technical Guidelines for the Safe Movement of Germplasm. *Allium* spp. IPGRI, Rome (Italy); Research Inst. of Crop Production. Prague (Czech Republic).

16. FAOSTATS (2015) Food and agriculture organization of the United Nations statistics division [online]. Production figures.

17. Fisher, R. A. and Yates, F. (1949) *Statistical tables for biological, agricultural and medical research*. pp: 112.

18. Fritsch, R. M. and Friesen, N. (2002) Evolution, domestication and taxonomy. *In*: H. Rabinowitch and L. Currah (eds.). Allium Crop Science: Recent Advances. New York: CABI, pp. 5–30.

19. Granke, L. L. and Hausbeck, M. K. (2010) Influence of environment on airborne spore concentrations and severity of asparagus purple spot. Plant Disease 94 (25): 843–850.

20. Gupta, R. P., Srivastava, P. K. and Sharma, R. C. (1996) Efficacy of fungicides and their spray interval on the control of purple blotch and Stemphylium blight diseases of onion. NHRDF Newsl, 16:11 -13.

21. Hassan, M. H. A. and Abd El-Rehim, G. H. (2002) Yeast application as a biofertilizer and biocontrol agent for onion neck rot disease in relation to bulb productivity and quality. *Assiut J. Agric. Sci.,* 33 (1): 241-251.

22. Hassan, M. H. A., Allam, A. D. A., Abo-Elyousr, K. A. M., and Hussein, M. A. M. (2007) First report of stemphylium leaf blight of onion caused by *Stemphylium vesicarium* in Egypt. Plant Pathology 56 (4): 724–724.

23. Hosen, M. I., Ahmed, A. U., Zaman, J., Ghosh, S. and Hossain, K. M. K. (2009) Cultural and physiological variation between isolates of *Stemphylium botryosum* the causal of stemphylium blight disease of lentil (*Lens culinaris*). World Journal of Agricultural Sciences. 5: 94-98.

24. Hussein, M. A. M; M. H. A. Hassan; A. D. A. Allam and K. A. M. AboElyousr (2007) Management of Stemphylium Blight of Onion by using Biological Agents and Resistance Inducers. *Egypt. J. Phytopathol.,* 35 (1): 49-60.

25. Kamal, A. E. M., Mohamed, H. M., Aly, A. D., and Mohamed, H. H., (2008) Enhanced onion resistance against Stemphylium leaf blight disease, caused by *Stemphylium vesicarium*, by di-potassium phosphate and benzothiadiazole treatments. Plant Pathology Journal, 24 (2): 171–177.

26. Kamal, A. M., Abo-Elyousr, Sobhy. I. I., Abdel-Hafez and Abdel-Rahim (2020) Control of stemphylium leaf blight disease of onion and elevation of seed production using certain bioagents. *Int. J. of Pl. Pathol.* 8: 1-7.

27. Köhl, J., Groenenboom-De Haas, B., Goossen-Van De Geijn, H., Speksnijder, A., Kastelein, P., De Hoog, S., and Gerrits van Den Ende, B., (2009) Pathogenicity of *Stemphylium vesicarium* from different hosts causing brown spot in pear. European Journal of Plant Pathology 124: 151–162.

28. Köhl, J., Groenenboom-de Haas, B. H., Kastelein, P., Rossi, V., and Waalwijk, C. (2009)
Quantitativede tection of pear pathogenic *Stemphylium vesicarium* in orchards. Phy topathology 99 (12): 1377–1386.

29. Koike, S. T., O'Neill, N., Wolf, J., Van Berkum, P., and Daugovish, O. (2013) Stemphylium leaf spot of parsley in California caused by *Stemphylium vesicarium*. Plant Disease, 97(3): 315–322.

30. Krik, C. (2008) Allium genetic resources with particular reference to onion. In: O. Dae-Geun and K. Chieri, (eds.). Proc. XXVII IHC - Cultivation and Utilization. Asian, Sub-Tropic, Underutilized Horticultural Crops. Wageningen: Acta Horticulture, pp. 135–138.

31. Kumar, U., Naresh, P. and Biswas, S. K. (2012). Ecofriendly management of stemphylium blight of garlic by plant extracts and bioagents. Hort Flora Research Spectrum. 22: 231- 245.

32. Kumar, Upesh, Prem Naresh and Suresh Kumar (2020) Epidemiology and management of stemphylium blight of garlic caused by *Stemphylium vasicarium* (Wallr.) Journal of Entomology and Zoology Studies, 8(4): 1006-1011.

33. Lancaster, J. E., Triggs, C. M., de Ruiter, J. M., and Gandar, P. W. (1996) Bulbing in onions: Photoperiod and temperature requirements and prediction of bulbing. Annals of Botany, 78: 423–430.

34. Leeman, M., Van Pelt. J. A., Hendrickx, M. J., Scheffer, R. J. and Bakker, P. (1995) Biocontrol of Fusarium wilt of radish in commercial greenhouse trials by seed treatment with *Pseudomonas fluorescens* WCS374. *Phytopathology,* 85: 1301-1305.

35. Llorente, I. and Montesinos, E. (2002) Effect of relative humidity and interrupted wetness periods on brown spot severity of pear caused by *Stemphylium vesicarium*. Phytopathology 92 (1): 99–104.

36. Llorente, I., Vilardell, A., Vilardell, P., and Montesinos, E., (2008) Evaluation of new methods in integrated control of brown spot of pear (*Stemphylium vesicarium*, teleomorph *Pleospora allii*). Acta Horticulturae, 800: 825–831.

37. Miller, M. E., Taber, R. A., and Amador, J. M. (1978) Stemphylium blight of onion in South Texas. Plant Disease Reporter, 62(10): 851–853.

38. Misawa, T. and Yasuoka, S., (2012) The life cycle of *Stemphylium vesicarium* the causal agent of Welsh onion leaf blight. Journal of General Plant Pathology, 78: 18–29.

39. Mishra, R. and Gupta, R. P. (2012) In vitro evaluation of plant extracts, bio-agents and fungicides against Purple blotch and Stemphylium blight of onion. J. of Medicinal Plants Research, 6(45): 5840- 5843.

40. Mishra, R. K., Jaiswal, R. K., Kumar, D., Saabale, P. R. and Singh, A. (2014) Management of major diseases and insect pests of onion and garlic: A comprehensive review. Journal of Plant Breeding and Crop Science. 6: 160-170.

41. Nisha, H. A. C. (2013) Cultural, Morphological and Molecular Characterization of *Stemphylium vesicarium* causing White Blotch of Onion. M. Sc. thesis, submitted to Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka pp. 1-92.

42. Paibomesai, M., Celetti, M., and Tesfaendrias, M. (2012) Update on Stemphylium leaf blight in onions in Ontario. Hort Matters, OMAFRA Specialist in Horticulture and Speciality Crops, 12(19): 11-12.

43. Paulitz, T. C. and Bélanger, R. R. (2001) Biological control in greenhouse systems. *Annu. Rev. Phytopathol.*, 39: 103-133.

44. Purseglove, J. W. (1972) Tropical crops: Monocotyledons. Longman Press, London.

45. Rao, R. N. N. and Pavgi, M. (1975) Stemphylium leaf blight in onion. Mycopathologia, 56(1): 1–6.

46. Roddy, E. (2011) Asparagus diseases - Purple spot (*Stemphylium*).

47. Rossi, V., Pattori, E., and Bugiani, R. (2008) Sources and seasonal dynamics of inoculum for brown spot disease of pear. European Journal of Plant Pathology, 121: 147–159.

48. Shahnaz, E., Razdan, V. K., Andrabi, M. and Rather, T. R. (2013) Variability among Alternaria porri isolates. *Indian Phytopath* 66: 164-167.

49. Sharma, S. R. (1986) Effect of fungicides on purple blotch and bulb yield of onion. *Indian Phytopath,* 39: 78-82.

50. Shashikanth, E. R., Gowda, V. and Girija, J. (2007) Genetics of resistance to purple blotch disease in onion (*Allium cepa* L.). *Karnataka J Agric Sci* 20: 810-812.

51. Simmons, E. G. (1967) Typification of *Alternaria*, *Stemphylium* and *Ulocladium*. Mycologia, 59(1): 67.

52. Simmons, E. G. (1969) Perfect states of *Stemphylium*. Mycologia, 61(1): 1–26.

53. Singh, P., Bugiani, R., Cavanni, P., Nakajima, H., Kodama, M., Otani, H., and Kohmoto, K. (1999) Purification and biological characterization of host-specific SV-toxins from *Stemphylium vesicarium* causing brown spot of European pear. Phytopathology, 89(10): 947–953.

54. Singh, P., Park, P., Bugiani, R., Cavanni, P., Nakajima, H., Kodama, M., Otani, H., and Kohmoto, K. (2000) Effects of host-selective SV-toxin from *Stemphylium vesicarium*, the cause of brown spot of European pear plants, on ultrastructure of leaf cells. Journal of Phytopathology, 148 (2): 87–93.

55. Slimestad, R., Fossen, T. and Vagen, I. M. (2007) Onions: A source of unique dietary flavonoids. *J Agric Food Chem* 55: 10067-10080.

56. Srivastava, A. K., Borse, V. A., Gupta, R. P., and Srivastava, P. K. (1996) Mode of perpetuation and role of nature in spread of Stemphylium blight and purple blotch diseases of onion. Newsletter National Horticulture Research and Development Foundation, 96: 9-11.

57. Suhag, L. S. and Bhatia, J. N. (2006) Stemphylium blight of Onion- A review in Seed Technology and Seed Pathology. Pointer Publisher, Jaipur, Rajasthan, India. pp. 392-412.

58. Suheri, H. and Price, T. V. (2000) Infection of onion leaves by *Alternaria porri* and *Stemphylium vesicarium* and disease development in controlled environments. Plant Pathology, 49(3): 375–382.

59. Suheri, H. and Price, T. V. (2001) The epidemiology of purple leaf blotch on leeks in Victoria, Australia. European Journal of Plant Pathology, 107 (5): 503–510.

60. Tomaz, I. and Lima, A. (1988) An important disease of onion caused by *Stemphylium vesicarium* (Wallr.) Simmons in Portugal. Horticultural, 68: 618.

61. Uddin, M. N., Islam, M. R., Akhtar, N. and Faruq. A. N. (2006) Evaluation of fungicides against Purple blotch complex of onion (Alternaria porri and Stemphylium botryosum) for seed production. *J Agric Edu Technol* 9: 83-86.

62. Vavilov, N. I. (1951) The Origin, Variation, Immunityand Breeding of Cultivated Plants. *Chronological Botany,* 13:1- 366.

63. Vohra, S. B., Rizman, M. and Khan, J. A. (1974) Medicinal uses of common Indian vegetables. Planta Medica, 23: 381-393.

64. Wheeler, B. E. (1969) An Introduction to Plant Diseases. John Wiley and Sons Ltd., London, UK.

65. Wright, M. G., Hoffmann, M. P., Kuhar, T. P., Gardner, J., and Pitcher, S. A. (2005) Evaluating risks of biological control introductions: A probabilistic risk-assessment approach. Biological Control, 35: 338–347.