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Studies on the Effect of Relative Humidity on Fungal Diseases of Legumes

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ABSTRACT

Humidity refers to the amount of water vapour that is held in the air. This varies according to temperature, with warm air able to hold far more water vapour than cold air. So for example, at 30°C a cubic metre of air can hold a maximum of 31g of water as vapour. At 0°C that same cubic metre will hold less than 5g of water as vapour. Relative humidity refers to the amount of water vapour in the air compared to the maximum it can hold at that temperature. So a cubic metre of air at 30°C, which contains 20g of water as vapour is approximately 64% of the maximum amount, ie 64% RH. As temperature drops, air is less able to hold water vapour. The vapour will therefore condense out as liquid water. This has implications for packaging and transport. For example, if sealed cartons of warm legumes are placed in a cool room, the air inside the cartons will lose moisture as it cools, resulting in condensation on the product and the inside of the carton. Conversely, when cold cartons are moved into ambient conditions they cool the surrounding air. Depending on the RH, water vapour from the cooled air will then condense on the outside of the cartons. Temperature fluctuations therefore almost inevitably result in condensation. This can weaken packaging materials and increase water loss from packed legumes. Condensation can encourage development of rots and increase the chance of products splitting. Relative humidity is particularly implicated in fungal infection and growth. Dry conditions prevent spores from germinating, and even if germination is successful the exposed tissue may be too dry to permit infection. Most fungi cannot grow if RH is below 85-90%. However, humidity this low is not suitable for products susceptible to moisture loss, such as legumes basically which should ideally be held at >95% RH.

KEYWORDS*: relative humidity, legumes, vapour, condensation, fungi, germination, dry, moisture*

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INTRODUCTION

Diseases on legumes due to effect of relative humidity:-

1. *Colletotrichum lindemuthianum* is primarily a pathogen of the common legume *Phaseolus vulgaris* L., but, it can infect related species and varieties such as *P. vulgaris* var. arborigineus (Burk.) Baudet; *P. acutifolius A. Gray* var. *acutifolius; P. coccineus* L.; *P. lunatus* L.; *P. lunatus* var. macrocarpus; *Vigna mungo* (L.) Hepper; *V. radiata* (L.) Wilczer var. *radiata; V. ungiculata* (L.) Walpers ssp. *ungiculata; Lablab purpureus* (L.) Sweet;*Vicia fabia* L. In high relative humidity it causes disease of which the most common is anthracnose.

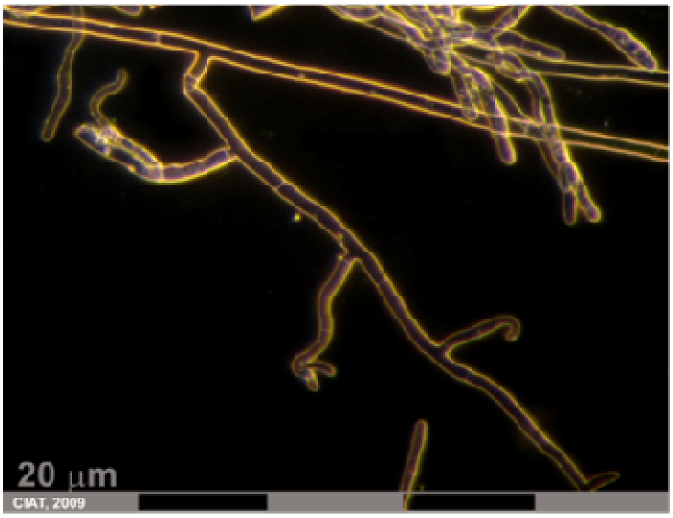
Symptoms of anthracnose can appear on any leguminous plant part, although initial symptoms may appear on cotyledonary leaves as small, dark brown to black lesions. The infected tissues manifest minute rust-colored specks, it gradually enlarge longitudinally and form sunken lesions or eye spots that reach the hypocotyl of the young seedling, causing it to rot off .Lesions may first develop on leaf petioles and the lower surface of leaves and leaf veins as small, angular, brick-red to purple spots which become dark brown. Later the lesions may also appear on veinlets on the upper surface of leaves. Sporulation can occur in lesion on the petiole and larger leaf veins. Pod infection appear as flesh to rust-colored lesions. The lesions developed into sunken cankers (1-10 mm in diameter) that are delimited by a slightly raised black ring and surrounded by a reddish brown border .The conidia that can appear as a gelatinous mass in the lesion center, with age, becoming gray-brown or black granulations. If severely infected young pods shrivel and dry up. The fungus can invade the pod, and the mycelia and conidia infect the cotyledon or seed coat of the developing seed. Infected seed are often discolored and may contain dark brown to black cankers. [1]

2. Angular leaf spots symptoms occur on all aerial parts of the leguminous plant. Lesions are most common on leaves and usually appear within six days after inoculation.

They may appear on primary leaves, but usually do not become prevalent on later foliage until late flowering or early pod set. Lesions initially are grey or brown, may be surrounded by a chlorotic halo, and have indefinite margins. They become necrotic and well defined with the typical angular shape by nine days after infection. Lesion then may increase in size, coalesce, and cause partial necrosis and yellowing of leaves which then fall off prematurely. On primary leaves, lesions are usually rounded, larger than those found on trifoliate leaves, and may develop concentric rings within themselves. Lesion size is inversely related to lesion number per leaf or leaflet [2]. Lesions appear on pods as oval to circular spots with reddish brown centers that are sometimes surrounded by darker colored borders. Infected pods bear poorly developed or entirely shriveled seeds. In seeds, symptoms can appear as seed discoloration. The fungus has a host range which includes: *Phaseolus vulgaris L.; P. lunatus L, P. coccineus L; P. acutifolius A. Gray var. Acutifolius; Vigna mungo (L.) Hepper;I V.angularis (Willd.) Ohwi et Ohashi; V. umbellata (Thunb.) Ohwi et Ohashi; V. ungiculata* (L.) Walpers ssp. ungiculata; *Pisum sativum* L *Desmodium cephalotus, D. gangeticum, D. pulchellum, Dolichos lablab* .

3. *Rhizoctonia solani* may induce seed rot, damping-off, stem canker, root rot, and pod rot. *Rhizoctonia* can infect seeds before germination, resulting in seed decay. Lesions on a young seedling expand rapidly and result in damping-off. Seed and seedling infection reduce seedling establishing and therefore lower plant densities often severely enough to be visually[3] .

The fungus can be seed transmitted in beans. *R. solani* infect pods in contact with the soil surface, causing water-soaking, the characteristics reddish brown sunken lesions, and distinct margins around the lesions. Minute brown sclerotia may develop on the surface of, or embedded in, these cankers.[4] These lesions may serve as an inoculum source for infection beans in transit and ensure fungus dissemination as well as causing seed discoloration. The pathogen have a large number of host species and having reported in seeds of *Brassica* spp., *Capsicum* spp., *Citrus* spp., *Gliocladium virens, Gosypium* spp., *Lycopersicon esculentum, Phaseolus* spp., *Spinacia oleracea, Vignia ungiculata, Zea mays, Zinnia elegans.*



R. solani attacks diverse species of beans as *Phaseolus vulgalis* L.; *P. lunatus* L.; *P. coccineus* L.; *Vignia angularis* (Willd.) Ohwi *et* Ohasi; *V. aconitifolia* (Jacq.) Maréchal; *V. unigulata* (L.) Walpers subsp. *ungiculata; Pisum sativum* L.; *Onobrychis viciifolia* Scop.; and *Pueraria lobata* (Willd.) Ohowi. Chlamydospores of *F. solani* f. sp. *phaseoli*, either associated with infected bean tissue or free in soil, are often under the influence of soil fungistasis. They can therefore remain dormant in soil with little mobility for a long time. When soil fungistasis is reversed, chlamydospores germinate where bean seed or rot exudates are available.[5] The pathogen was reported to directly penetrate bean tissue or enter through stromata and wounds. After penetration, the fungus grows intercellulary throughout cortical tissues, but is stopped, by the epidermis layer. Some distinguishing characteristic are the morphology of the macroconidia, the elongate monophialides bearing microconidia, which also help distinguish it from *F. oxisporum*, and the distinctive cream, blue-green or blue color of conidies on PDA.

The pathogen is disseminated within and between bean fields by such means as movement of infected soil, infected host tissues, colonized debris, drainage and irrigation water, contaminated bean seed. Once introduced into a field, this pathogen becomes uniformly at high densities after two or three bean crops. The pathogen is also capable of colonizing organic matter under certain environmental conditions, therefore maintaining or increasing its population in absence of bean[6]

4. The *Fusarium* yellows pathogen is morphologically similar to all the members of the species *F. oxysporum*. However, it is recognized by its physiological and pathological adaptation to beans, hence the interspecific taxa designation f. sp. (*formae speciales) phaseoli*.

Initial symptoms appear on lower leaves which exhibit yellowing and wilting. These symptoms may be confused with those caused by phosphorous deficiency. This yellowing and wilting becomes more pronounced and progress upward into younger leaves. Stunting may also become evident, especially if plant infection occurred during the seedling state. The margin of infected leaves may become necrotic and diseased plants become progressively more chlorotic. The fungus also can cause water-soaked lesions on pods. Severely plants infected exhibit permanent wilting and premature defoliation. The characteristic pink-orange spore masses of fungus may appear on stem and petiole tissue. Vascular discoloration is the diagnostic symptom and is usually evident after the initial appearance of foliar symptoms .[7]

The main host for *Fusarium oxysporum* f. sp. *phaseoli* is the *Phaseolus* spp., however, the species have a great number of host as *Allium, Asparragus officinalis, Beta vulgaris, Bromus, Callisthepus chinensis, Cannabis sativa, Citrulus vulgaris, Cucumis sativus, Glyricine max, Gossypium, Lens culinaris, Linum grandiflorum, L. usitatissimun, Lupinus luteus, Lycopersicom esculentum, Matthiola incana, Medicago sativa, Oryza sativa, Phaseolus vulgaris, Pisum sativum, Psuedotsuga menziesii, Solanum melongena, Sorghum vulgare, Spunacia oleracia, Tegetes, Trifolium pretense, T. repens, Vicia fava, Vignia* ans *Zea mays*

5. The infectious process can result in damping-off, stem blight, and root rot. Initial symptoms on infected plants appear as dark-brown water-soaked lesions on the lower stem surface area just below the soil line. These lesions extend downward, through stem tissue and so start root-rot symptoms. Under moist conditions, lesions on the stem tissue continue to progress downward and eventually may kill the entire root system .Other symptoms consist of leaf yellowing and defoliation of the upper plant branches which may be followed by a sudden wilt condition. Abundant white coarse mycelium and sclerotia and soil particles are often found attached to stem tissue near the line soil.

Sclerotium rolfsii has a wide host range of more than 200 species of plants, involving most leguminous ones.

DISCUSSION

Grain legumes crops are vulnerable to range of diseases, mostly caused by fungi, especially due to wrong effects of relative humidity. In some instances, 100% yields losses have been reported. The yield potential of these crops is seldom achieved due to the cultivation of susceptible cultivars and lack of proper crop management practices to cope with these biotic stress factors. During the last three decades food legumes scientist have been working to develop ways to tackle these biotic stresses through host plant resistance and by adopting various management options. In many case such measures have been recommended in combination or singly. However, host plant resistance is the most economical, long term, environmentally acceptable means of controlling these biotic agents. In most of the grain legumes, germplasm has been collected, conserved at national and international levels characterized and used in genetic enhancement programs to develop improved varieties that are resistant to single and multiple stress factors. In the past, breeders have focused on yield and quality only, later on progress has been made to incorporate disease and pest resistance as key components of genetic enhancement programs. [8] Genetic control of the major biotic stresses has been resolved and the information has been used in breeding programs. Very recently, biotechnological approach has been adopted to tag molecular markers with resistance genes to enhance breeding efficiency through marker assisted selection. The transgenic technology also offers opportunity to genetic enhancement where genes for resistance are not available in nature. In this paper; attempted to enhancement in combating biotic stresses in a range of major grain legumes; lentil, chickpea, soybean, cowpea, mungbean, blackgram, pigeonpea and Rajma bean.

Some principles underlying selection for disease resistance

1. Genetic resources for resistance must be identified from existing materials: cultivar itself, commercial cultivars, other varieties, land races, weedy relatives, related species or genera.
2. Screening technique for resistance by exposure to the disease pathogen under natural or artificial induced epiphytotic is necessary to distinguish between resistance and susceptible plants.
3. Mode and inheritance of resistance must be understood.
4. The resistance gene must be transferred to an adapted cultivar.
5. Progeny testing of resistant plants to verify the inherent nature of resistance.[9]

RESULTS

Breeding approaches for disease resistance

The various approaches for breeding disease-resistant varieties are discussed below

Avoidance (Disease escaping varieties): It reduces the chance of contact between prospective host tissue or food plant and a potential natural enemy usually as a result of particular morphology, phenology or smell of the potential host plant. Mimicry, camouflage, thorns, hairs, spines, smell, color, taste, repellent odors are some of the examples.

Resistance: It is the ability of the host to reduce the growth and or development of the parasite or pathogen. It is of 2 types:

1. Race specific/vertical resistance/gene for gene resistance: A resistance that is effective to specific (a virulent) genotypes of a pathogen species.
2. Race nonspecific/horizontal resistance/no gene for gene resistance: A resistance that is equally effective to all the genotypes of a pathogen species.[10]

Tolerance: It neither restricts parasitic contact nor the growth and development of the parasite after establishment. As a consequence, it does not affect the amount of damage/symptoms per unit quantity of parasite present.

Susceptibility: Incapacity of a plant to reduce the growth, development and reproduction of the natural enemy.

Sensitivity: Character of the host plant to develop relatively severe symptoms or severe damage per unit quantity of the natural enemy.

Replanting of discarded varieties.

Cultivar diversification.

Gene for gene relationship

1. Flor 1956 based on his work on linseed rust postulated the gene for gene relationship between a host and pathogen. This relationship states that "A resistance gene, R is only effective if the infecting pathogen carries the corresponding avirulence gene, A"
2. Host resistance is conditioned by dominant allele, R.
3. In the pathogen, virulence is conditioned by recessive allele, a.
4. Resistance reaction occurs when complementary genes in both host and pathogen are dominant.

5. A host genotype that carries no dominant alleles at any of the loci is susceptible for all the races of pathogen (even if avirunlent) .
6. 'A' avirunlent allele is dominant over 'a' virulent allele and resistant allele 'R' is dominant over susceptible allele 'r'.
7. Compatibility depends on the genotype of the host and the genotype of the pathogen.[11]

Major diseases of grain legumes

Working with various species of grain legumes for the last few decades, grain legumes scientists have been identified several biotic agents, which substantially limit crop productivity and cause instability. Some of these agents pose a serious threat to the existence of the crops as well. Due to yield instability and high risk cultivation by effects of wrong relative humidity caused by various biotic stresses, farmers have abandoned the cultivation of some grain legumes, thus posing a severe threat to the sustainability of whole crop production system. Considering all these facts, several authors have reported the effects of numerous major and minor biotic factors, symptoms of the disease and its breeding strategies has been drawn as below (Table 1).

Table 1: Diseases of Chickpea

S. No.	Disease Causal Organism	Economic Importance
1	Botrytis gray mold *Botrytis cinerea*	Major
2	Wilt *Fusarium oxysporum* f sp. ciceri	Major
3	Black root rot *Fusarium solani*	Major in some locality
4	Collar rot *Sclerotium rolfsii*	Major in some locality
5	Dry root rot *Rhizoctonia bataticola*	Sometime major
6	Stem rot *Sclerotinia sclerotiorum*	Minor
7	Alternaria blight *Alternaria alternata*	Minor

Maintenance of relative humidity (RH) is the most ideal way of preventing infections as the basic cause is wrong relative humidity supplied to legumes. [12]

CONCLUSION

Relative humidity: It is the ratio of actual water vapour content to the saturated water vapour content at a given temperature and pressure expressed in percentage (%).

Diurnal variation in relative humidity:

1. Mean maximum relative humidity occurs in the early morning.
2. Mean minimum, relative humidity occurs in the early afternoon.
3. Low RH in the afternoon is due to expansion of air and thus increases the total water vapour capacity

Distribution of RH

1. Maximum RH is in the equatorial region due to high evaporation.
2. Decreases towards poles upto 30° N and S due to subsiding air mass.
3. RH increases in poles due to low temperature.

Effect of Relative Humidity on Crop Production

Relative humidity (RH) directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield.

The dryness of the atmosphere as represented by saturation deficit (100-RH) reduces dry matter production through stomatal control and leaf water potential.

Leaf Growth

1. Leaf growth not only depends on synthetic activities resulting from biochemical process but also upon the physical process of cell enlargement.
2. Cell enlargement occurs as a result of turgor pressure developed within the cells.
3. Turgor pressure is high under RH due to less transpiration. Thus leaf enlargement is high in humid areas

Photosynthesis

1. Photosynthesis is indirectly affected by RH. When RH is low, transpiration increases causing water deficits in the plant.
2. Water deficits cause partial or full closure of stomata and increase mesophyll resistance blocking entry of carbon dioxide.

Pollination

1. Moderately low air humidity is favourable for seed set in many crops, provided soil moisture supply is adequate.

For example, seed set in wheat was high at 60 per cent RH compared to 80 per cent when water availability in the soil was not limiting.

1. At high RH pollen may not be dispersed from the anthers

Pests

1. The incidence of insect pests and diseases is high under high humidity conditions.
2. High RH favours easy germination of fungal spores on plant leaves.

For example The blight diseases of potato and tea spread more rapidly under humid conditions. Several insects such as aphids and jassids thrive better under moist conditions.

Grain Yield

Very high or very low RH is not conducive for high grain yield. Under high humidity, RH is negatively correlated with grain yield of maize. The yield reduction was 144 kg/ha with an increase in one per cent of mean monthly RH. Similarly, wheat grain yield is reduced in high RH. It can be attributed to adverse effect of RH on pollination and high incidence of pests. On the contrary, increase in RH during panicle initiation to maturity increased grain yield of sorghum under low humidity conditions due to favourable influence of RH on water relations of plants and photosynthesis. With similar amount of solar radiation, crops that are grown with irrigation gives less yield compared to those grown with equal amount of 'water as rainfall. This is because the dry atmosphere, which is little affected by irrigation, independently suppresses the growth of crops.

Very High Relative humidity:

- Reduces evapotranspiration
- Increases heat load of plants
- Stomatal closure
- Reduced CO2 uptake
- Reduced transpiration influences translocation of food materials and nutrients.
- Moderately high RH of 60-70% is beneficial.
- Low RH increases the evapotranspiration[13]

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