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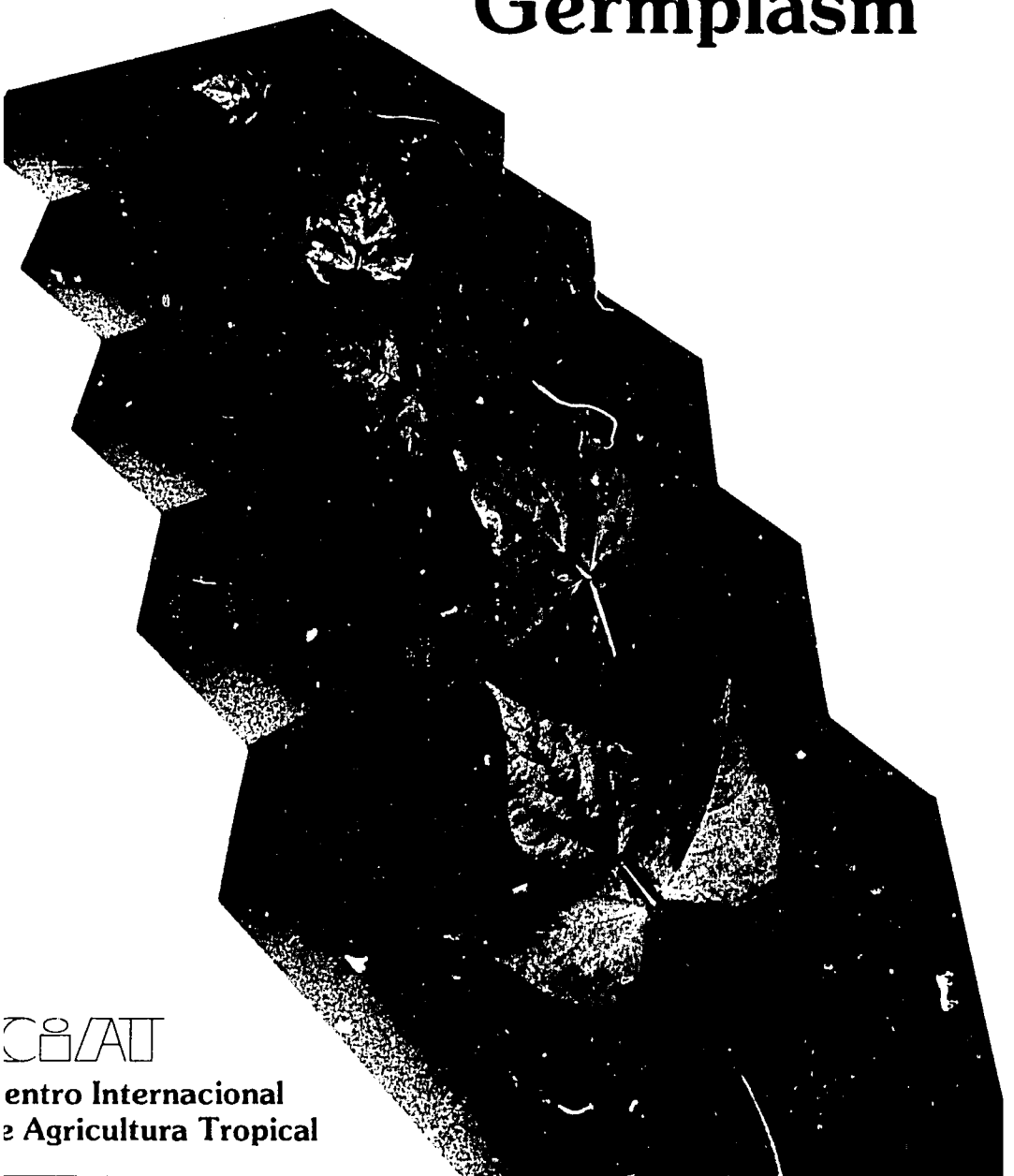
Standard System for the Evaluation of Bean Germplasm



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Cover: Bean trifoliates showing varying degrees of disease symptoms to the common bacterial blight pathogen (*Xanthomonas campestris* pv. *phaseoli*). Photo: CIAT Bean Program.

Contents

Foreword

Beans are generally characterized by their unstable yields resulting from biological, climatic, and edaphic factors which affect plant growth and productivity. Beans are usually cultivated under rainfed conditions where diseases contribute considerably to low and unstable yields. To avoid disease pressures farmers frequently plant beans late in the season resulting in the possible exposure of bean plants to stress after flowering.

Most farmers in the tropics are unable to control biotic and abiotic factors which affect production through purchased inputs. As a result CIAT and national bean programs are emphasizing the search for genetic variability to reduce the adverse effects of these biotic and abiotic factors on production. Since the number of problems that affect the bean crop is large, researchers in national and international programs have formed a network on genetic improvement in which germplasm evaluation and research results are exchanged.

This booklet presents a standard system for the evaluation of bean germplasm under field conditions. The Centro Internacional de Agricultura Tropical (CIAT) Bean Program uses this system in Colombia and many countries in Latin America, Africa, and other regions to classify germplasm into useful and practical categories. The standardization of germplasm evaluation resulting from the use of the system will facilitate the exchange of research results

among research institutions. This is important for an international collaborative network such as the one that exists for beans between CIAT and national programs.

A first draft of the standard system was presented for discussion to participants at the International Bean Trials Workshop held on 26-29 November 1984, in Cali, Colombia. The modified draft was reviewed by many prominent international bean scientists. The revised version was presented for discussion at the 1985 Bean Improvement Cooperative Meeting in Oregon, USA, and all significant suggestions were incorporated. The United States Western Regional Research Committee (W-150) has also cooperated in the development of this standardized system; its participation has broadened the scope of this evaluation system and has resulted in its increased acceptance and application. Where possible, all above suggestions have been included in this booklet. CIAT's Bean Program gratefully acknowledges these contributions.

For standard bean quality and nutritional evaluations refer to the Instituto de Nutrición de Centroamérica y Panamá (INCAP) publication **Métodos para establecer calidad tecnológica y nutricional del frijol (*Phaseolus vulgaris*).**

Aart van Schoonhoven
Marcial A. Pastor-Corrales

CIAT Bean Program

Standard Evaluation Scale and Its Use

Several different scales have been used to evaluate bean germplasm. The more commonly used scales are from 1 to 3, 1 to 5, and 1 to 9. Sometimes the scales 1 to 3 and 1 to 5 include intermediate values, e.g., 2.5 or 4.5.

In the above scales, the criteria for resistant, intermediate, and susceptible reactions are similar. However, the scale would not have a discriminative or resolutive capacity if it were to contain few classes. Alternatively, when too many classes are used, time is lost trying to decide the best rating that agrees with the sample under observation.

The scale that is presented in this publication has the following characteristics:

1. The standard evaluation scale considers 9 numerical categories from 1 to 9. No decimals are used. The '0' rating is reserved for any situation where a rating cannot be made. It does not represent an absence of symptoms.

2. A '1' rating is reserved for an absence of symptoms which is often equated with the highest level of resistance. Higher numbers in ascending order represent progressively more susceptibility and a less desirable germplasm. Number '9' represents extreme susceptibility (presence of severe symptoms, damage, or stress).

3. The scale is fixed. This means that a specific level of symptoms or damage corresponds to a fixed number on the scale. Each number on the scale has a unique and precise description. Accordingly, a highly susceptible material that has not been infected in a nursery under low inocuium pressure would be given a 2 or 3 rating.

4. The values of 1, 2, and 3 are considered 'resistant'; the values 4, 5, and 6 'intermediate'; and the values 7, 8, and 9 'susceptible.'

It is important to note that when evaluating bean germplasm, particularly for their reaction to pathogens and insects, it is highly desirable and useful to have check cultivars known for their reaction distributed throughout the nursery. This helps in insect pressure or disease-level assessment as well as in evaluating pathogen and insect distribution throughout the nursery.

All future CIAT bean publications will be reporting germplasm evaluation data on the 1-9 scale with no intermediate decimals.

Developmental Stages of the Common Bean Plant

The implementation of this standardized system was brought about to facilitate comparisons of: overall plant development; damage caused by insects and diseases; and the effect of adverse soils or climatic factors.

The genetic differences among the materials that constitute the test group can be determined using the above criteria. To compare the evaluation results carried out on different occasions, it is necessary to refer to the developmental stage of the plant at the time the measurements were taken. Since plants of the same genotype planted under different climatic conditions may be at a different developmental stage at any time, it is appropriate to use a scale based on plant morphology and on the physiological changes that occur during the plant's development. Therefore, the developmental stages in Table 1 are used in the proposed standard evaluation system. Those stages can be used for individual plants or for populations of plants.

Table 1. **Developmental stages of the common bean plant.**

Stage[a]	Description[b]
V0	Germination: Water absorption by the seed, emergence of the radicle, and transformation into the primary root.
V1	Emergence: Cotyledons appear at soil level and begin to separate. The epicotyl initiates its development.
V2	Primary leaves: Totally opened primary leaves.
V3	First trifoliate leaf: The first trifoliate leaf opens and the second trifoliate leaf appears.
V4	Third trifoliate leaf: The third trifoliate leaf opens and the buds on the lower nodes produce branches.
R5	Preflowering: The first flower bud or the first raceme appears. Flower buds in determinate varieties are formed on the last stem or branch node. In indeterminate varieties racemes are first observed on the lower nodes.
R6	Flowering: The first flower opens.
R7	Pod formation: The first pod appears being more than 2.5 cm long.
R8	Pod filling: The first pod begins to fill (seed growth). At the end of the stage the seeds lose their green color and begin to show varietal characteristics Defoliation initiates.
R9	Physiological maturity: Pods lose their pigmentation and begin to dry. Seeds develop their typical varietal color.

a. V = vegetative; R = reproductive.
b. When evaluating populations, each stage begins when 50% of the plants show the conditions that correspond to the description.

SOURCE: Fernández, F.; Gepts, P.; and López, M. 1986.

Measurement of General Agronomic Characteristics

Seed color

The seed color is taken from recently harvested dry seeds. Seeds may have one color or they may have a predominant primary color along with a secondary color. Colors may also be arranged in different patterns, e.g., mottled, striped, spotted, blotched, or speckled. Table 2 gives a list of the principal nine color groups and the countries where they are grown.

If the seed has more than one color the secondary color is also recorded using the same color codes as for the primary color.

Seed size

Seed size is expressed as the weight in grams of 100 randomly chosen seeds.

Small: Less than 25 g.
Medium: 25 g to 40 g.
Large: More than 40 g.

Seed brilliance

Seed brilliance is taken from recently harvested seed and is expressed by three classes: 1) Opaque; 2) Intermediate; and 3) Brilliant.

Table 2. **Examples of bean varieties of the principal nine color groups and the countries where they are grown.**

Color group	Color or variety	Country where grown
1	White	
	Panamito	Peru, Ecuador
	Navy bean	USA
	Great Northern	USA
	Alubia	Argentina
2	Cream-beige	
	Carioca	Brazil
	Mulatinho	Brazil
	Pinto	Mexico
	Bayo	Mexico, Peru, Chile
3	Yellow	
	Canario	Peru
	Azufrado	Mexico
	Jalo	Brazil
4	Brown-maroon	
	Ricopardo	Brazil
	Redlands	Australia
	Chumbinho	Brazil
5	Pink	
	Rosinha	Brazil
	Flor de Mayo	Mexico
	Red Kidney	USA
6	Red	
	Calima	Colombia
	Pompadour	Dominican Republic
	Zamorano	Honduras
7	Purple	
	Sangretoro	Colombia
	Roxinho	Brazil

Continues

Table 2. **continued.**

Color group	Color or variety	Country where grown
8	Black	
	Jamapa	Mexico
	ICA Pijao	Colombia
	Rio Tibagi	Brazil
9	Others	
	Tórtolas	Chile
	Burros	Chile

Growth habit

To classify plants with a determinate growth habit, the first evaluation should be carried out during the developmental stage R6. A second evaluation should be conducted during R9 to classify plants with an indeterminate growth habit.

The evaluation scale to describe growth habit is as follows:

I. Determinate habit:
   Ia: Strong and erect stem and branches.
   Ib: Weak stem and branches.

II. Indeterminate bush habit, erect stem and branches:
   IIa: Without guides.
   IIb: With guides and ability to climb.

III. Indeterminate bush habit with weak and prostrate stem and branches:
   IIIa: Short guides with no ability to climb.
   IIIb: Long guides with ability to climb.

IV. Indeterminate climbing habit with weak, long and twisted stem and branches:

IVa: Pods distributed throughout the plant.
IVb: Pods concentrated on the upper part of the plant.

The subdivision of each growth habit into a and b is not always used.

Days-to-flowering

Measured in days-after-planting and coinciding with the initiation of developmental stage R6 when 50% of the plants have one or more flowers.

Days-to-maturity

Measured in days-after-planting and coinciding with the initiation of developmental stage R9 when 50% of the plants have reached physiological maturity.

Vegetative adaptation (vigor)

The evaluation should be carried out when plants reach their maximum development, generally in R5, and taking into account the effect that the growth habit has on plant vigor.

Scale: 1. Excellent
3. Good
5. Intermediate
7. Poor
9. Very poor

Reproductive adaptation (pod load)

The evaluation should be carried out in R9. The characteristics that should be considered include: number of pods, pod shape, number of seeds per pod, and seed size.

Scale: 1. Excellent
3. Good
5. Intermediate
7. Poor
9. Very poor

Nodulation with *Rhizobium* spp.

The evaluation should be carried out in R6 (flowering) when the nodule number and mass are generally greatest. For nonclimbing beans in monoculture, 8 to 10 plants per plot should be examined. For climbing beans and beans in association, 4 to 6 plants may be sufficient. Using a shovel, plants from the end of each row are dug up and carefully removed. Gently separate roots from soil and sift through the soil to recover any nodules that may have fallen off. The number of effective-appearing nodules with a red to pink internal color is determined. The number of nodules per plant varies significantly from bush beans to climbing beans, hence the two scales presented here:

Scale:

	Number of red or pink nodules	
	Bush beans	**Climbing beans**
1. Excellent	More than 80	More than 240
3. Good	41 – 80	121 – 240
5. Intermediate	21 – 40	61 – 120
7. Poor	10 – 20	30 – 60
9. Very poor	Less than 10	Less than 30

Note: The large variation in nodule size is accounted for using the even numbered scores. For bush beans, for example, 30 large nodules per plant correspond to a score of 4; 30 medium nodules to a score of 5; and 30 small nodules to a score of 6.

Measurement of Damage Caused by Diseases

Viral diseases

It is possible to design a scale to assess the severity of viral diseases but production losses do not necessarily correlate with the severity values observed. Another problem is the difficulty in identifying the numerous viruses that attack beans. Field evaluations can also be affected by the presence of several viruses simultaneously infecting a plant and producing complex symptoms. Therefore, a simple qualitative evaluation scale has been designed for general use which does not require previous experience in the diagnosis of viral diseases.

General scale to evaluate viral diseases. The scale consists of three variables: symptoms, incidence, and yield (Table 3).

Symptoms. The plant should be thoroughly examined before recording any absence of symptoms. 'Intermediate' symptoms should be recorded by evaluators who are familiar with the possible extreme symptoms of the disease. 'General' symptoms affect all of the plant whereas 'Intense' denotes a high degree of symptom expression that includes reduced plant growth, and leaf or pod malformation. 'Severe' conditions will include extreme symptoms of dwarfing, leaf or pod malformation, or physiological alterations. Finally, 'systemic' or 'top necrosis' are symptoms that often lead to plant death.

Table 3. **General evaluation scale for viral diseases.**

Rating	Symptoms	Incidence (%)	Yield
1	Absent	0	Excellent
2	Doubtful	1 – 10	
3	Weak	11 – 25	Good
4	Moderate	26 – 40	
5	Intermediate	41 – 60	Intermediate
6	General	61 – 75	
7	Intense	76 – 90	Poor
8	Severe	91 – 99	
9	Death	100	Very poor

Incidence. This variable suggests the relative degree of confidence that can be given to the evaluation. Random samples can be taken at sites representative of the area being evaluated, e.g., samples of 20 or more plants in a longitudinal or diagonal direction. A visual evaluation of the whole area is recommended in those cases where disease gradients (variable linear-intensity of the disease) or disease foci are observed.

The visual evaluation of disease incidence is difficult since, according to the Weber-Fechner Law, visual grading progresses logarithmically. Therefore, the original 1-12 Horsfall and Barrat logarithmic scale has been modified to the 1-9 scaling system as shown in Table 3. This scale is also recommended when disease incidence estimates are based on actual plant counts.

Yield. This variable corresponds to reproductive adaptation and is highly important in those viral diseases for which a genetic resistance source cannot be readily identified.

Evaluations for viral diseases are recommended at the following developmental stages. Flowering (R6) to record

symptoms and incidence except when systemic necrosis is observed. Necrosis can be evaluated from the initiation of the vegetative period to the pod-filling stage (R8). Yield should be evaluated in R9 [refer to 'Reproductive adaptation (pod load)' page 14].

Codes for viral diseases and variables evaluated. The following codes for viral diseases and variables are used:

Specific (for known viral diseases)

BCMV:	Bean Common Mosaic Virus
BR:	Black Root (BCMV)
BGMV:	Bean Golden Mosaic Virus
BCIMV:	Bean Chlorotic Mottle Virus
BYMV:	Bean Yellow Mosaic Virus

General (for unknown viral diseases)

MOS:	Mosaic (chlorosis or yellowing)
NEL:	Necrosis (localized)
NES:	Necrosis (systemic)
DEF:	Deformation of plant organs
DWA:	Reduction in plant size

Variable

S:	Symptoms
I:	Incidence
Y:	Reproductive adaptation (yield)

Using the 1-9 evaluation system, the effect of viral diseases on plant varieties can be described as in the following example for BCMV:

Variety	Variable		
	Symptoms	Incidence	Yield
1	3	5	3
2	4	5	8

Fungal and bacterial diseases

The main objective of this bean-disease evaluation system is to have a standard system that is uniform, rapid, and accurate for evaluating the reaction of bean germplasm to fungal and bacterial pathogens under field conditions.

'Disease severity' is used as the principal criterion in evaluating some diseases whereas 'disease incidence' is used as the main criterion for other diseases.

Disease severity is defined here as the area of plant tissues affected by the disease-causing-organisms and expressed as the percentage of the total amount of tissues.

Disease incidence is defined as the number of units affected, generally considering whole plants but also taking into account plant parts such as leaves, stems, pods, or roots as units and then expressing these as a percentage of the total population of units chosen.

Researchers must obtain a precise and unbiased estimate of the disease severity or incidence or both and also record, in a similar way, the developmental stage of the plant because both disease parameters are frequently related to plant age. In addition, the chlorotic and necrotic tissues associated with the infected areas should be considered. Similarly it is important to consider that for some diseases, particularly for those caused by soil-borne pathogens, lesion depth and location may affect and incapacitate a larger area than that occupied by the lesion. At times these diseases may even affect the whole plant. The total areas affected by the infection should be included in the disease-severity rating.

It is often necessary and recommended to conduct more than one evaluation during the crop cycle in order to obtain

accurate data appropriate for comparisons and germplasm ratings. Early-maturing germplasm will often appear more susceptible to a disease than late-maturing germplasm if the evaluation is conducted during the latter part of the crop cycle.

Figures 1 to 6 present photographs and diagrams depicting and classifying several disease categories. The percentage of infection noted in all cases represents the actual area covered by lesions, pustules, and chlorotic and necrotic tissue. It is not a subjective estimate. Table 4 shows the general scale for the evaluation of bean diseases.

Table 4 **General scale to evaluate the reaction of bean germplasm to fungal and bacterial pathogens.**

Rating	Category	Description	Comments
1 2 3	Resistant	No visible symptoms or very light symptoms	Germplasm useful as parents or commercial varieties
4 5 6	Intermediate	Visible and conspicuous symptoms resulting only in limited economic damage	Germplasm can be used as commercial varieties or as sources of resistance to certain diseases
7 8 9	Susceptible	Severe to very severe symptoms causing considerable yield losses or plant death	Germplasm in most cases not useful as parents or commercial varieties

Angular leaf spot (and alternaria leaf spot, floury leaf spot, gray leaf spot, and white leaf spot)

[*Phaeoisariopsis griseola (= Isariopsis griseola)* (**and** *Alternaria* **spp.**, *Mycovellosiella phaseoli (= Ramularia phaseoli), Cercospora castellanii (= C. vanderysti),* **and** *Pseudocercosporella albida)*]

Evaluation stages: R6, R8.

Scale: (Figure 1).

1. No visible disease symptoms.

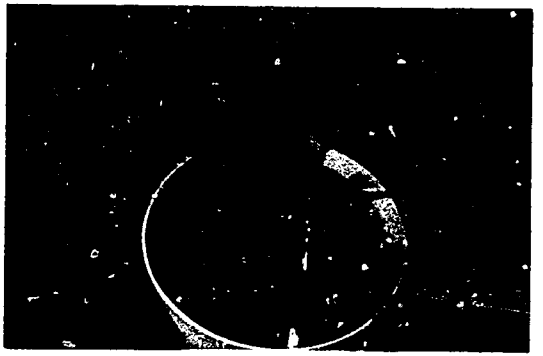
3. Presence of a few small nonsporulating lesions that cover approximately 2% of the leaf or pod surface area.

5. Presence of several, generally small lesions with limited sporulation that cover approximately 5% of the leaf or pod surface area.

7. Abundant and generally large sporulating lesions that cover approximately 10% of the leaf or pod surface area. On the foliage the lesions may coalesce to produce larger infected areas associated with chlorotic tissue. Lesions may also be found on the stem and branches.

9. Twenty-five percent or more of the leaf or pod surface area is covered by large sporulating and often coalescing lesions. Leaf tissues are generally chlorotic resulting in severe and premature defoliation. Infected pods are often deformed and shriveled and contain a low number of seeds. Abundant sporulating lesions are present on stem and branches.

1



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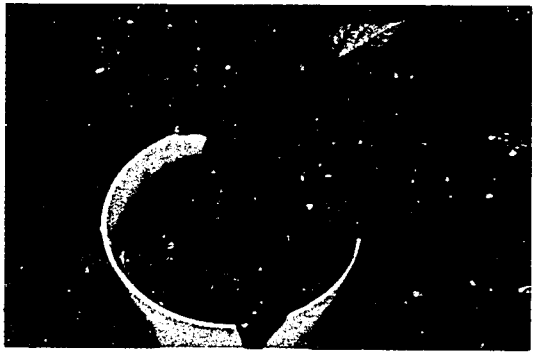

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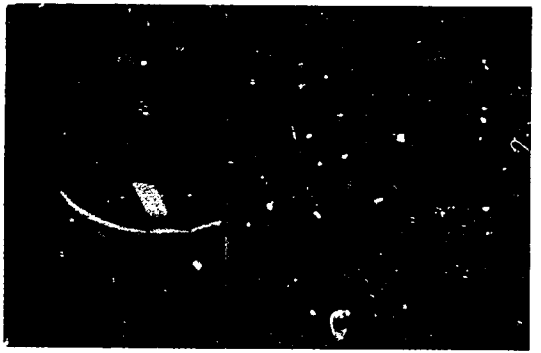

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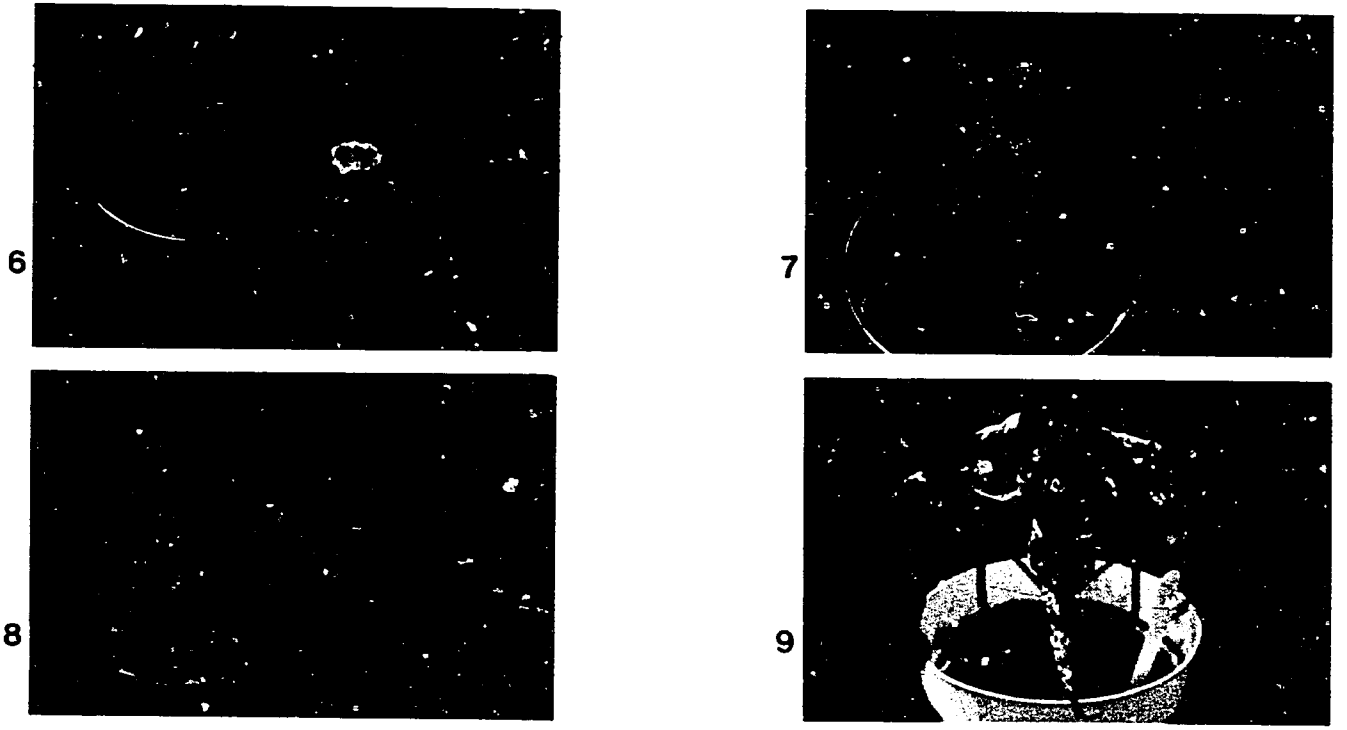

Figure 1. *Bean trifoliates showing the nine disease categories (1 = no visible disease symptoms; 9 = very severe disease symptoms) used to evaluate the reaction of bean germplasm to angular leaf spot* [Phaeoisariopsis griseola (= Isariopsis griseola) *and other pathogens*] *(see text).*

Rust

[*Uromyces appendiculatus* **var.** *appendiculatus (= U. phaseoli)*]

Evaluation stages: R6, R8.

Scales:

Two scales are presented. The first scale is for bean researchers working under field conditions who are solely interested in classifying the germplasm's reaction to the rust pathogen into three discrete categories: resistant, intermediate, or susceptible. For this purpose a scale similar to the one used for angular leaf spot can be used to estimate rust severity.

Scale 1

1. Highly resistant: no visible rust pustule present (immune).

3. Resistant: presence of only a few and generally small pustules on most plants that cover approximately 2% of the foliar area.

5. Intermediate: presence of generally small or intermediate pustules on all plants that cover approximately 5% of the foliar area.

7. Susceptible: presence of mostly large pustules often surrounded by chlorotic halos that cover approximately 10% of the foliar area.

9. Highly susceptible: presence of large and very large pustules, with chlorotic halos, that cover more than 25% of the foliar tissue and cause premature defoliation.

Scale 2

The second scale is the same as that utilized by the International Bean Rust Nursery (IBRN) and considers two criteria—pustule type and infection intensity.

Pustule type. Six grades are used to classify the bean plant reaction (pustule type) to the rust pathogen in accordance with the International Bean Rust Workshop held at the University of Puerto Rico, Mayaguez, in 1983. Five were used previously.

1. No visible symptoms.
2. Nonsporulating necrotic spots.
3. Sporulating pustules smaller than 300 μm in diameter.
4. Sporulating pustules 300-500 μm in diameter sometimes surrounded by chlorotic halos.
5. Sporulating pustules 500-800 μm in diameter frequently surrounded by chlorotic halos.
6. Sporulating pustules larger than 800 μm in diameter surrounded by chlorotic halos.

When several pustule types are present they are recorded in order of predominance with the most predominant type being listed first and the least prevalent type being listed last. Both leaf surfaces are examined and if the grades (pustule types) differ, either both or the highest grade should be recorded.

Infection intensity. Intensity, expressed in percent, is the leaf area visibly covered by either nonsporulating necrotic spots, sporulating pustules, or chlorotic halos surrounding these pustules. A modified Cobb scale is used

for estimating the percentage of leaf area affected similar to the one used for bean varieties in the IBRN.

The pustule type and the infection intensity are combined to obtain a final plant reaction classification of five categories as in Figure 2.

For work pertaining to greenhouse plants the following additions should be considered:

Grade 2 corresponding to the necrotic spot can be further divided into the following categories:

2	Necrotic spots smaller than 300 μm in diameter.
2+	Necrotic spots 300-1000 μm (1 mm) in diameter.
2++	Necrotic spots 1-3 mm in diameter.
2+++	Necrotic spots larger than 3 mm in diameter.

Supplemental postscripts also for use on greenhouse plants:

C	Small, faint chlorotic halo.
C+	Large, intensely-yellow chlorotic halo.

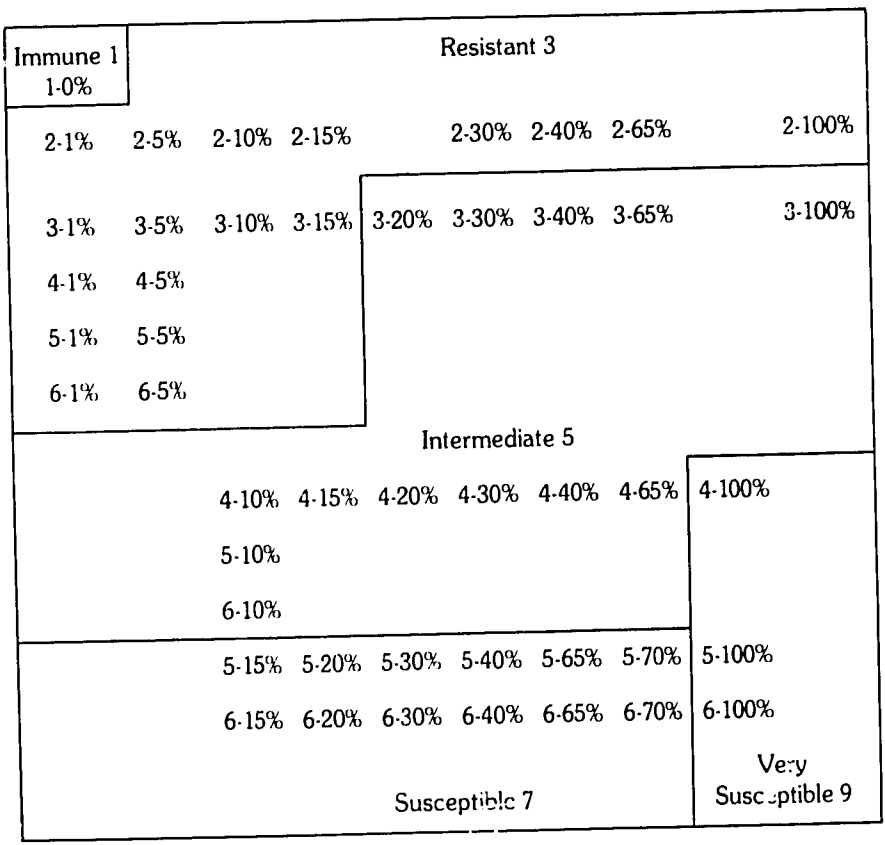

Figure 2. *Plant reaction classification determined by the combination of pustule type, based on a 1-6 scale and the infection intensity given as a percentage. For example, a pustule type 4 (the number on the left, with a rust intensity of 30% (number on the right) corresponds to a final plant reaction of 5, or the intermediate category (see text).*

Ascochyta blight, Diaporthe leaf and pod blight, Phoma red blight, Cercospora leaf spot, round leaf spot, Entyloma leaf smut, and powdery mildew

[*Phoma exigua* **var.** *diversispora (= Ascochyta boltshanseri) Diaporthe phaseolorum, Phoma* **sp.**, *Cercospora canescens, Chaetoseptoria wellmani, Entyloma petuniae,* **and** *Erysiphe polygoni*]

Evaluation stages: R6, R8.

Scale:

1. No visible disease symptoms.

3. Presence of a few small, dark, zonate lesions that cover approximately 2% of the leaf or pod surface area.

5. Presence of several small- to intermediate -sized lesions (up to 1 cm in diameter), with limited sporulation, that cover approximately 5% of the leaf or pod surface area.

7. Presence of large sporulating lesions that cover approximately 10% of the leaf or pod surface area. Lesions may also appear on the stem and branches. These lesions may coalesce on the foliage.

9. Presence of large sporulating lesions that cover approximately 25% or more of the leaf or pod surface area. Lesions on the leaves often coalesce causing necrosis of large segments that often fall out leaving a shothole-like appearance on the leaves resulting in premature and severe defoliation. Lesions also cover

large segments of the stem and branches, and infected pods are often shriveled containing a low number of seeds.

Anthracnose

(Colletotrichum lindemuthianum)

Evaluation stages: R6, R8.

Scale: (Figure 3).

1. No visible disease symptoms.
3. Presence of very few and small lesions, mostly on the primary vein of the leaf's lower side or on the pod, that cover approximately 1% of the surface area.
5. Presence of several small lesions on the petiole or on the primary and secondary veins of the leaf's lower side. On the pods, small (less than 2 mm in diameter) round lesions, with or without reduced sporulation, cover approximately 5% of the pod surface area.
7. Presence of numerous enlarged lesions on the lower side of the leaf. Necrotic lesions can also be observed on the upper leaf surface and on petioles. On the pods the presence of medium-sized (larger than 2 mm in diameter) lesions are evident but also some small and large lesions generally with sporulation and that cover approximately 10% of pod surface area may be found.
9. Severe necrosis on 25% or more of the plant tissue is evident as a result of lesions on the leaf, petioles, stem, branches, and even on the growing point which often results in death of much of the plant tissues. The presence of numerous, large, sporulating, sunken cankers can result in pod malformation, low seed number, and death of the pod.

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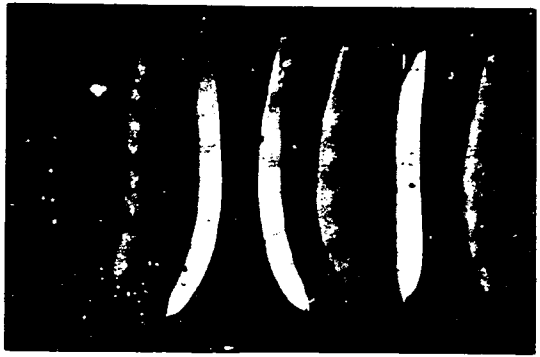

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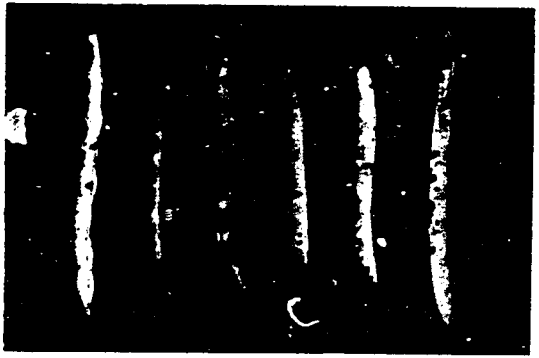

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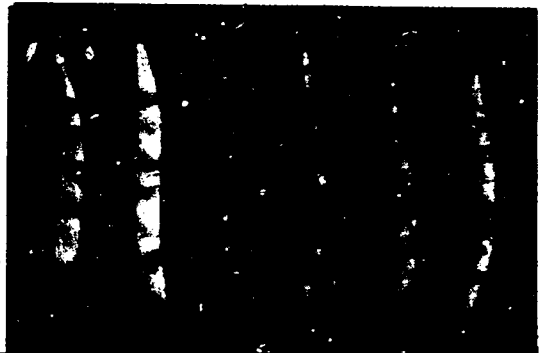

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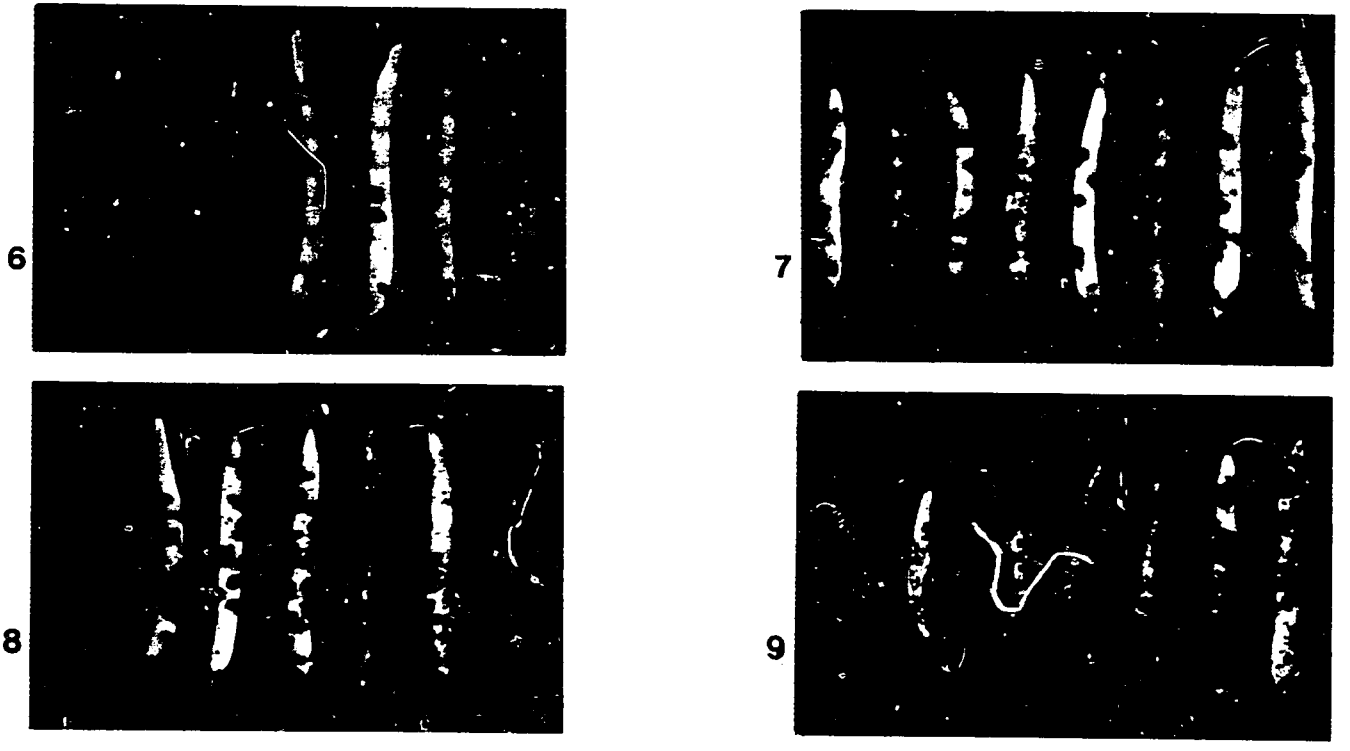


Figure 3. *Bean pods showing the nine disease categories (1 = no visible disease symptoms; 9 = very severe disease symptoms) used to evaluate the reaction of bean germplasm to the anthracnose pathogen* (Colletotrichum lindemuthianum).

Web blight
(Sexual stage: *Thanatephorus cucumeris*; asexual stage: *Rhizoctonia solani)*

Evaluation stages: V4, R6, R8.

Symptoms produced by the asexual stage differ from those produced by the sexual stage and generally cause more damage. Symptoms produced by the asexual stage first appear on the leaves as small, watery spots that later turn light brown with dark margins. These lesions generally coalesce, become gray or dark brown, and often result in necrosis of the total leaf area. Leaves are held together by the mycelial growth of the fungus resulting in a weblike appearance. Similar lesions develop on the pods.

Symptoms induced by the sexual stage on leaves are initially evident as necrotic, round, dark-brown spots with lighter-colored centers. Lesions may coalesce and often the necrotic tissues fall off leaving a hole known as 'cock eye.' Infected pods also develop necrotic spots with dark borders and light-colored centers.

An estimation of both disease severity and incidence should be considered but disease severity is generally more important. Under field conditions the unit of area measured is usually the row for single row plots, or the center row(s) for multiple row plots.

The percentage of infection on each plant is determined and then the average for the entire unit area is calculated. Diagrams provided in Figure 4 are used to determine the percentage of infection on individual plants.

Scale: (Figure 4).

1. No visible disease symptoms.

3. Approximately 5%–10% of the unit area evaluated is infected.

5. Approximately 20%—30% of the unit area evaluated is infected.

7. Approximately 40%—60% of the unit area evaluated is infected.

9. More than 80% of the unit area evaluated is infected.

White mold
(Sclerotinia sclerotiorum)

Evaluation stages: R8, R9.

Ratings should be directed primarily at the stem and main branches to reflect the area of the above-ground plant parts affected by the pathogen. For snap beans, pods should be evaluated using the same scale.

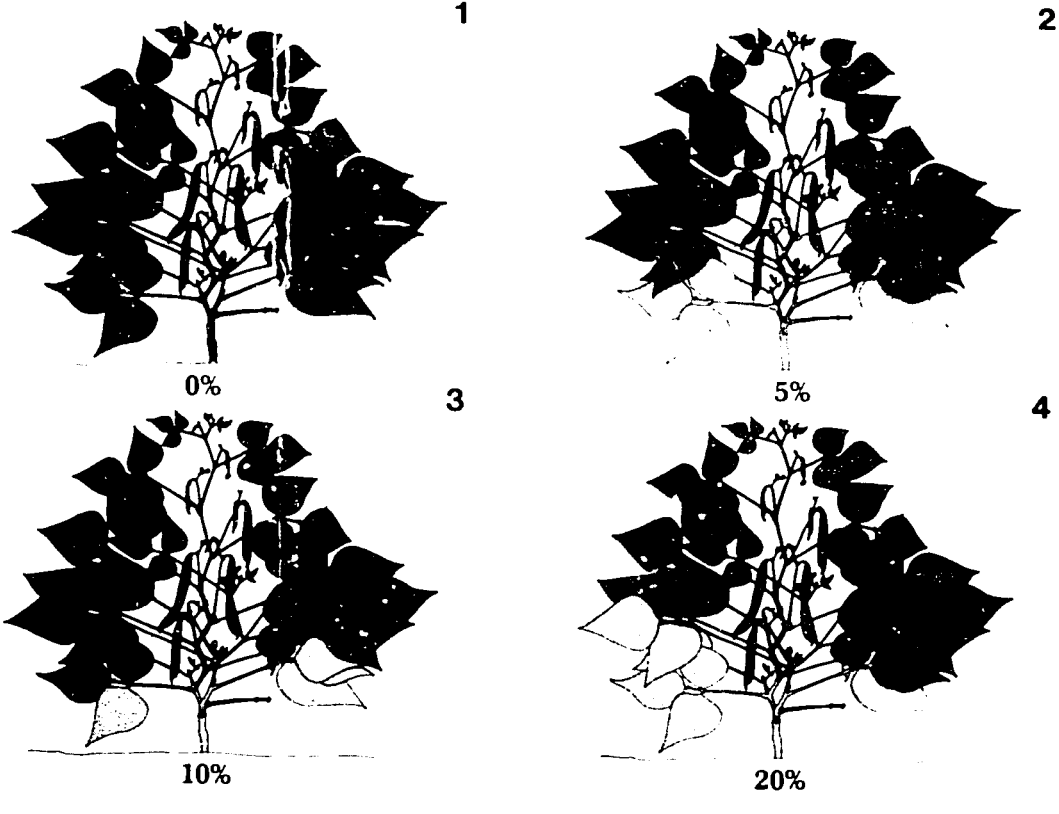
An estimation of both disease severity and incidence should be considered but disease severity is generally more important. Under field conditions the unit of area measured is usually the row for single row plots, or the center row(s) for multiple row plots.

The percentage of infection on each plant is determined and then the average for the entire unit area is calculated. Diagrams provided in Figure 4 are used to determine the percentage of infection on individual plants.

Scale: (Figure 4).

1. No visible disease symptoms.

3. Approximately 5%–10% of the unit area evaluated is infected.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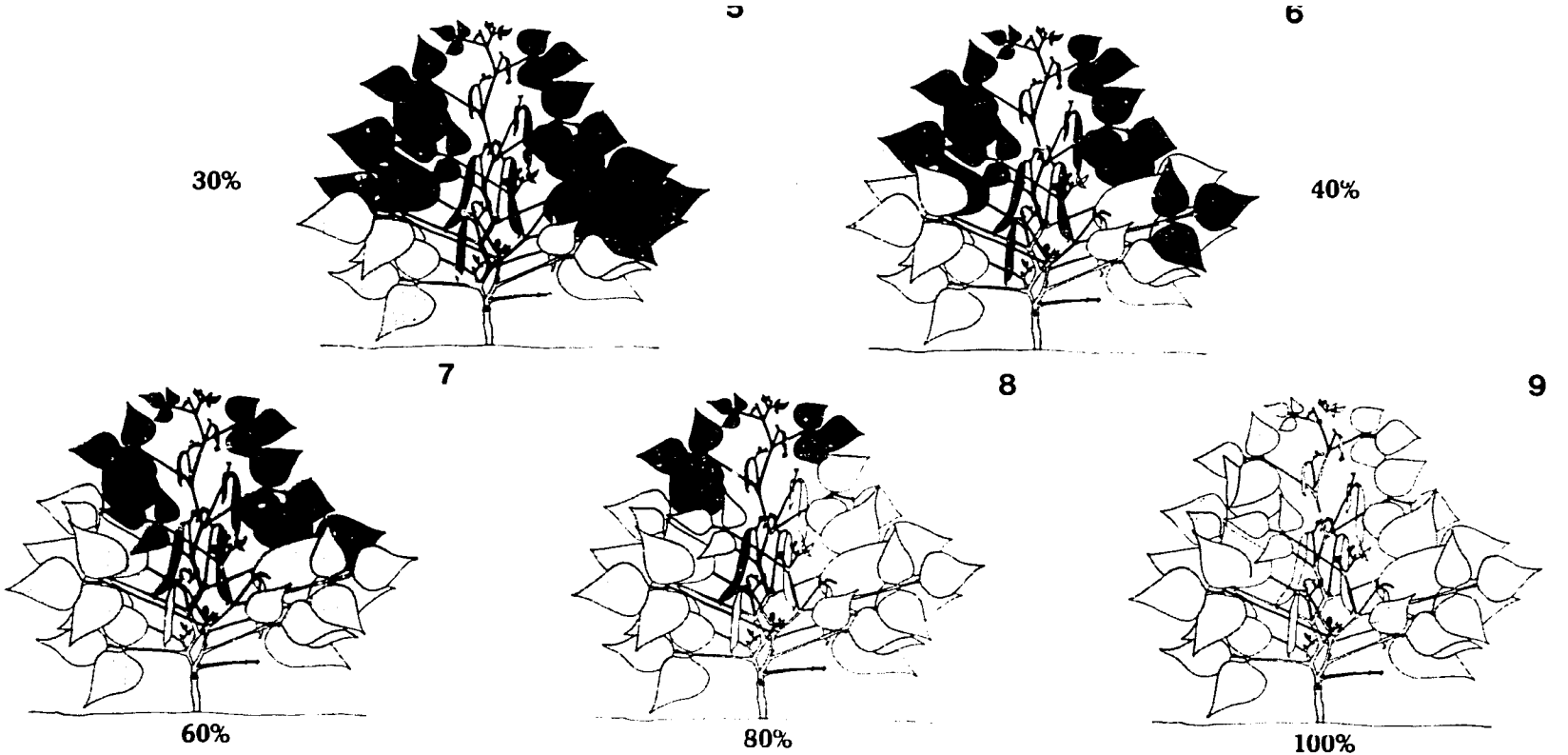


Figure 4. *Bean plants showing different percentages of disease severity caused by either white mold (*Sclerotinia sclerotiorum*) or web blight (sexual stage:* Thanatephorus cucumeris*; asexual stage:* Rhizoctonia solani*) pathogen.*

5. Approximately 20%–30% of the unit area evaluated is infected.

7. Approximately 40%–60% of the unit area evaluated is infected.

9. More than 80% of the unit area evaluated is infected.

Root rots

Root rot of beans can be caused by a single organism or any combination of the following organisms acting as a complex of pathogens:

Rhizoctonia root rot (*Rhizoctonia solani*);

Fusarium root rot (*Fusarium solani* sp. *phaseoli*);

Black root rot (*Thielaviopsis basicola*); and

Phythium root rot (*Phythium* spp.).

Evaluation stages: V1, R6, R8.

Pathogens causing bean root rot are not evenly distributed in the soil and frequently affect seed germination and radicle emergence. It is therefore important to record disease incidence by determining the number of emerged seedlings and the number of healthy and productive plants at harvest. Infection of the tap root is more serious and damaging than infection points on the lateral roots.

In contrast, many infections are superficial causing limited damage to cortical tissues as is the case with Fusarium cortical rot caused by *F. solani* f. sp. *phaseoli*. The whole hypocotyl tissues may be discolored and covered with superficial cortical lesions; however, unless the stem and root tissues exhibit rotting symptoms the

plant may not suffer damage. Accordingly, the reaction of certain germplasm may show high disease symptoms but with little damage. Adjusting the disease severity rating to include the degree of damage is required in this case. Evaluations often require destructive sampling because above-ground symptoms are generally not evident. Plants should be dug up carefully and the soil around the roots removed by mild shaking or by washing with water.

The percentage of infection on each plant is determined and then the average for the entire unit area is calculated. A bean accession exhibiting only discoloration symptoms should not be classified as susceptible. In the absence of rotting symptoms the rating should be 5 or less.

Scale: (Figure 5).

1. No visible disease symptoms.

3. Light discoloration either without necrotic lesions or with approximately 10% of the hypocotyl and root tissues covered with lesions.

5. Approximately 25% of the hypocotyl and root tissues covered with lesions but tissues remain firm with deterioration of the root system. Heavy discoloration symptoms may be evident.

7. Approximately 50% of the hypocotyl and root tissues covered with lesions combined with considerable softening, rotting, and reduction of the root system.

9. Approximately 75% or more of the hypocotyl and root tissues affected with advanced stages of rotting combined with a severe reduction in the root system.

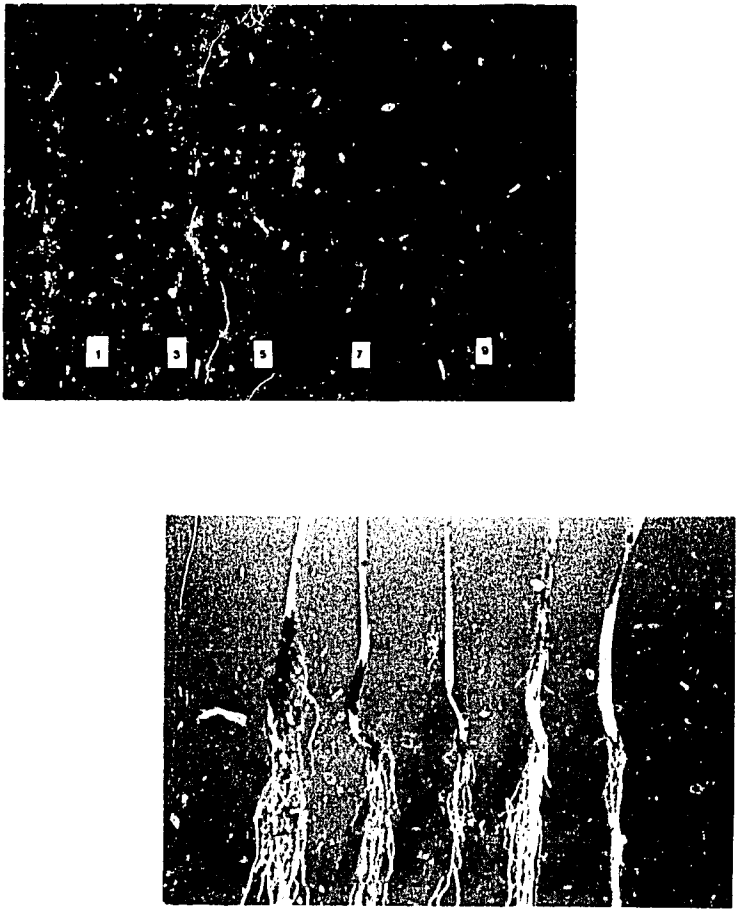


Figure 5. *Bean roots showing the disease categories (1 = no visible disease symptoms; 9 = advanced rotting) used to evaluate the reaction of bean germplasm to: top, Rhizoctonia root rot (*Rhizoctonia solani*); and bottom, Fusarium root rot (*Fusarium solani sp. phaseoli*). Also used for evaluating bean germplasm reaction to other root rot pathogens (see text).*

Charcoal rot and southern blight
(Macrophomina phaseolina and *Sclerotium rolfsii)*

Evaluation stages : V3, R8.

Scale:

1. No visible disease symptoms.

3. Disease symptoms for charcoal rot are restricted to the cotyledons. For southern blight, this rating refers to approximately 1% of the hypocotyl with symptoms. Lower stem tissues are covered with small and superficial lesions.

5. Approximately 10% of the hypocotyl and lower stem tissues covered with lesions and often combined with fruiting structures of the fungus.

7. Approximately 25% of the hypocotyl and lower stem tissues covered with lesions and often combined with fruiting structures of the fungus.

9. Approximately 50% or more of the hypocotyl and stem tissues covered with lesions and with a large number of fruiting structures of the fungus.

Fusarium wilt
(Fusarium oxysporum f. sp. *phaseoli)*

Evaluation stages: R6, R8.

Scale:

1. No visible disease symptoms.

3. Very few wilted leaves (1-3 leaves representing no more than 10% of the foliage) combined with limited

vascular discoloration of the root and hypocotyl tissues.

5. Approximately 25% of the leaves and branches exhibit wilting and chlorosis.

7. Approximately 50% of the leaves and branches exhibit wilting, chlorosis, and limited necrosis. Plants are stunted.

9. Approximately 75% or more of the leaves and branches exhibit wilting, severe stunting, and necrosis with premature defoliation often resulting in plants dying.

Common bacterial blight
(Xanthomonas campestris **pv.** *phaseoli)*

Evaluation stages: R6, R8.

Scale: (Figure 6).

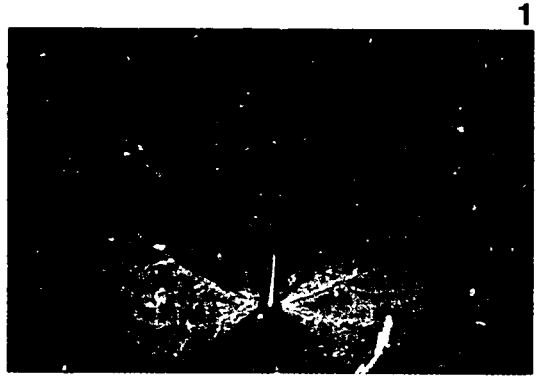
1. No visible disease symptoms.

3. Approximately 2% of the leaf surface area covered with a few small lesions. Pods are generally free of lesions.

5. Approximately 5% of the leaf surface area covered by small lesions that are beginning to coalesce and sometimes encircled by yellow halos resulting in minor blight. Lesions on the pods are generally small and not coalescing.

7. Approximately 10% of the leaf surface area covered with medium and large lesions which are usually accompanied by yellow halos and necrosis. Lesions on pods are large and coalescing and often show bacterial exudate.

9. More than 25% of the leaf surface area with large coalescing and generally necrotic lesions resulting in defoliation. Lesions on pods coalesce to cover extensive areas, exhibit abundant bacterial exudation which sometimes causes pod malformation and empty pods.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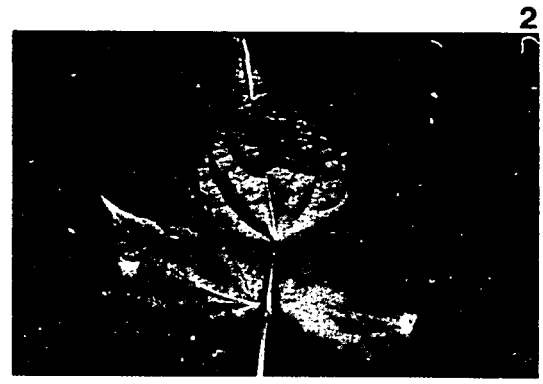
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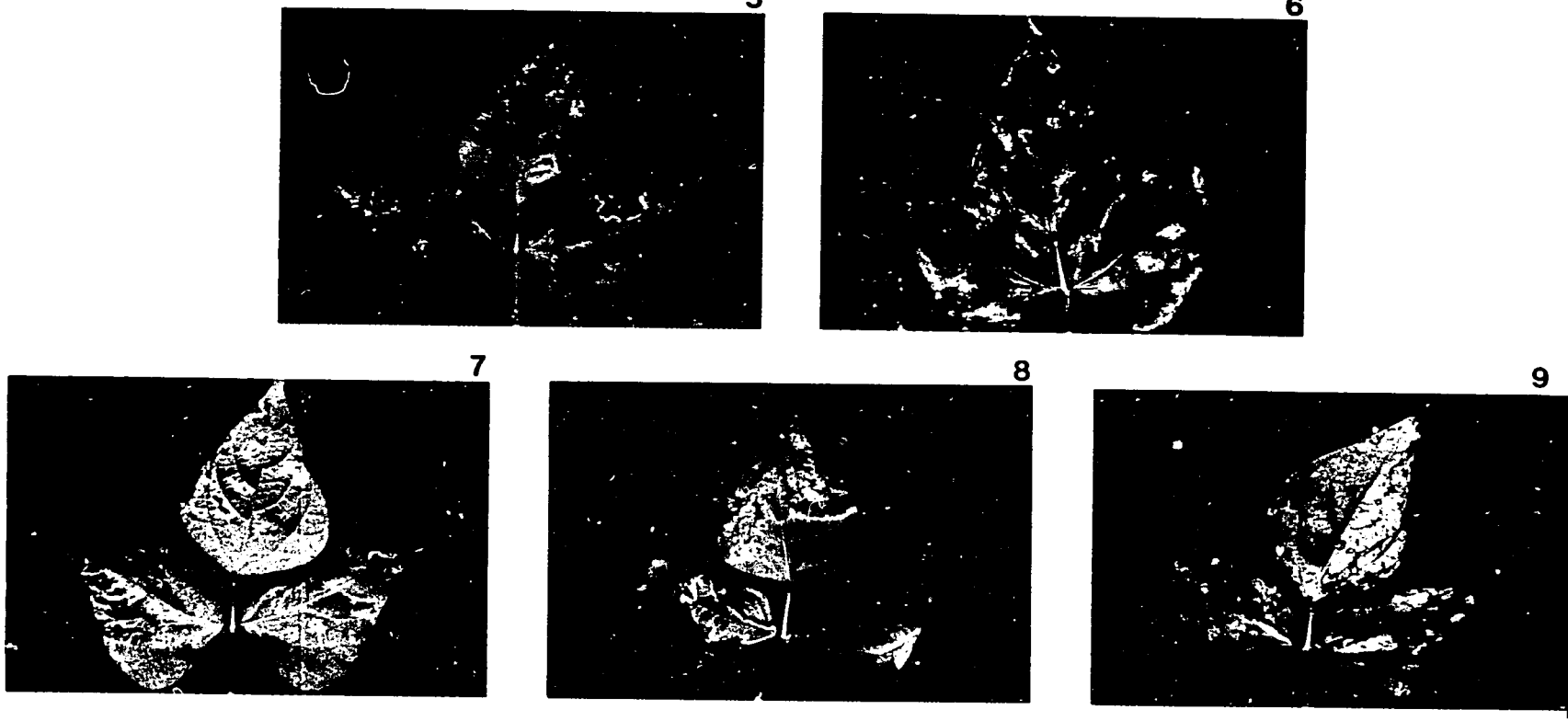

Figure 6. *Bean trifoliates showing the nine disease categories (1 = no visible disease symptoms; 9 = very severe disease symptoms) used to evaluate the reaction of bean germplasm to the common bacterial blight pathogen* (Xanthomonas campestris *pv.* phaseoli).

Halo blight (and bacterial brown spot) [*Pseudomonas syringae* **pv.** *phaseolicola* (**and** *Pseudomonas syringae* **pv.** *syringae*)]

Evaluation stages: R6, R8.

Scale:

1. No visible disease symptoms.

3. Approximately 2% of the leaf or pod surface area covered with round lesions. Very slight systemic chlorosis may be evident.

5. Approximately 5% of the leaf or pod surface area covered with round lesions of about 5 mm in diameter. Limited systemic chlorosis may be present on growing points.

7. Approximately 10% of the leaf tissues affected either by lesions or by the resulting chlorosis. Limited leaf distortion is present and the pods generally show a bacterial exudation on coalescing lesions that can be about 10 mm in diameter.

9. Twenty-five percent or more of the leaf tissues affected by lesions and chlorosis. Severe leaf distortion and coalescing lesions covering large areas on pods cause deformation and empty pods.

Measurement of Damage Caused by Nematodes (*Meloidogyne* spp.)

Evaluation stages: R6, R8.

Infection of the root system by plant parisitic nematodes, such as the root-knot nematodes, is often also accompanied by discoloration and necrosis, resulting from activities of associated soil microorganisms. The same scale can be used to evaluate the degree of discoloration and necrosis associated with nematode infections.

Scale:

1. No galling or necrosis symptoms.
3. Approximately 10% of the roots are galled or accompanied by necrosis.
5. Approximately 25% of the roots are galled or accompanied by necrosis.
7. Approximately 50% of the roots are galled or accompanied by necrosis.
9. Approximately 75% or more of the roots are galled or accompanied by necrosis.

Measurement of Damage Caused by Arthropods

Bean flies
(*Ophiomyia phaseoli* and *O. spencerella*)

The uniformity of *Ophiomyia* infestations is low. Replications are required to evaluate bean germplasm for resistance to *Ophiomyia*. The reaction of bean germplasm to both species (*O. phaseoli*, yellow-brown pupa; and *O. spencerella*, black pupa) could be different. For this reason pupal color must be recorded.

Scale:

Two characteristics are evaluated in the V4 stage:

Incidence (number of plants with pupae): The number of plants with and without pupae are counted and the percentage of infested plants is the infestation rating; and

Severity (vigor of infested plants): Only measured if there are infested plants.

1. Infested plants are as vigorous as uninfested plants. The bean fly apparently causes no considerable damage.

3. Infested plants with slight growth delay.

5. Infested plants with considerable growth delay.

7. Infested plants with severe growth delay.

9. Infested plants dead or almost dead.

Aphids
(*Aphis fabae* and other species)

Scale:

This scale is used to measure foliar damage which, when present, usually occurs before the flowering stages V4 and R5.

1. No damage.

3. Leaves slightly cupped.

5. Leaves moderately cupped with some leaf yellowing.

7. Severe distortion of leaves with considerable yellowing combined with honeydew production.

9. Very severe foliar distortion and yellowing combined with abundant honeydew production.

Red spider mite
(*Tetranychus* spp.)

Foliar damage is measured during natural infestation or at 8 and 15 days after plot infestation. The artificial infestation method consists of placing an infested trifoliate on each plant. Artificial infestations are recommended in developmental stages V4 and R5.

Scale:

1. No damage.

3. The upper surface of the leaves in the middle portion of the plant show slight mottling with white-colored spots.

5. The mottling, covering approximately one-third of the leaf area, extends to all of the intermediate and terminal leaves.

7. A white-dotted mottling covers approximately two-thirds of the leaf area.

9. All leaves show mottling that covers almost all of the leaf. Severe leaf yellowing and necrosis combined with defoliation and weblike structures occur.

White spider mite
(Polyphagotarsonemus latus)

Plants can be artifically infested by placing infested leaves on plants during R5. Attacks generally occur at full flowering (R6). Two or more evaluations should be carried out at weekly intervals.

Scale:

1. No damage.

3. Terminal leaves with an upward curling of the margins.

5. The leaves in the upper third of the plant show upward curling of the margins. The lower surface of the terminal leaves show bronzing.

7. Approximately two-thirds of the plant show leaf curling. Bronzing of the lower-leaf and even upper-leaf surface of nonterminal leaves is combined with abscission of the terminal leaves.

9. Almost all of the plant is affected. Foliage bronzing results in a coriaceous texture. Considerable defoliation with pods showing bronzing.

Leafhoppers (*Empoasca* spp.)

Evaluate foliar damage when it occurs but before the end of R8.

Scale:

1. No damage.
3. Slight downward or upward curling of leaves in some plants.
5. Moderate curling and some leaf yellowing. The plant has stunted growth.
7. Increased leaf curling, yellowing, and plant stunting.
9. All leaves show yellowing and curling. The plant is observed completely stunted with very low flower and pod production.

Leaf feeders

This scale is used for insects such as the Mexican bean beetle (*Epilachna varivestis*), Lepidopterans, Chrysomelids, slugs, etc.

First, the responsible pest is identified. Defoliation intensity is evaluated under conditions of natural infestation when the damage occurs.

Scale:

1. No defoliation.

3. Less than 10% of the leaf area consumed.
5. Between 10% and 25% of the leaf area consumed.
7. Between 25% and 50% of the leaf area consumed.
9. More than 50% of the leaf area consumed.

Bean pod weevil
(Apion godmani)

Replications are required to evaluate bean germplasm for resistance to or damage by *A. godmani*. At the beginning of R9, 30-50 pods per material per replication are taken, opened, and checked for the number of healthy and damaged pods. A pod is considered damaged if it has at least one damaged seed. The insect does not have to be present for the pod to be considered damaged.

Damage evaluation: the percentage of damaged pods is calculated. Late-maturing materials could escape infestation.

Bruchids
(Zabrotes subfasciatus and *Acanthoscelides obtectus)*

Fifty seeds of each material are artificially infested with five sexual pairs of *Z. subfasciatus* or 100 eggs of *A. obtectus*. After 30 days the new adults are counted on a daily basis until the final stage of plant emergence. Oviposition by *Z. subfasciatus* on the seeds can be counted.

Infestation evaluation: the total number of adults emerged per 50 seeds (emergence percentage) is the rating value. In the case of *Z. subfasciatus* oviposition can also be calculated as well as the average period required for adult emergence.

Measurement of Tolerance to Soil and Climatic Factors

Drought

A standard scale for drought tolerance is not possible due to the great variation in the effects caused by drought (depending on climatic and soil conditions). The scales for vegetative adaptation and reproductive adaptation (in developmental stages R5 and R9) are normally used. Because of 'escape' problems in early materials, evaluators should be careful when a nursery presents a wide range of dates for physiological maturity. In some cases evaluations of specific symptoms are justified, e.g., leaf wilting, leaf orientation to avoid over-heating and flower drop, leaf malformation, and difficulty to pull out plants from the soil.

Acid soils

The scales for vegetative and reproductive adaptation are normally used. When there are specific symptoms of phosphorus (P) deficiency, and aluminum (Al) or manganese (Mn) toxicities, additional evaluations should be carried out to differentiate the materials.

In screening trials that use applications of lime or P or both, evaluators must take into account the multiple responses that can be obtained:

Efficient responsive plant: a plant that yields high under both P stress and adequate P supply.

Efficient unresponsive plant: a plant that yields well under P stress but production is not greatly increased under conditions of optimal P availability.

Inefficient responsive plant: a plant that yields less under P stress but yields the same amount or more than the efficient plant with an adequate P supply.

Efficient low responsive plant: a plant that produces less under P stress but its yield increases with an adequate supply of P.

Inefficient unresponsive plant: a genetically inferior plant that does not yield well under adequate or inadequate P conditions.

Note: These responses should not be interpreted as a scale.

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