ASSESSMENT OF YIELD LOSS CAUSED BY BIOTIC STRESS ON BEANS IN AFRICA

by

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PREFACE

This volume is the fourth in a Working Document series that serves research on common beans (*Phaseolus vulgaris*) in Africa. This publication series forms part of the activities of the pan- African bean research network, which aims to stimulate, focus and co-ordinate research efforts on this crop.

The network is organized by the Centro Internacional de Agricultura Tropical (CIAT) through three interdependent regional projects, for the Great Lakes region of Central Africa, for Eastern Africa and, in conjunction with SADCC, for the Southern Africa region.

Working Documents will include bibliographies, research reports and network discussion papers. These publications are intended to complement an associated series of Workshop Proceedings.

Support for the regional bean projects comes from the Canadian International Development Agency (CIDA), the Swiss Development Corporation (SDC) and the United States Agency for International Development (USAID).

Further information on regional research activities on common beans in Africa, and additional copies of this publication, are available from:

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Charles S. Wortmann[1]

INTRODUCTION

In his review on the assessment of plant diseases and losses, James (1974) quoted the following statement made by Lyman in 1918: "How can we expect practical men to be properly impressed with the importance of our work and to vote large sums of money for its support when in place of facts we have only vague guesses to give them and we do not take the trouble to make careful estimates?"

Some 74 years later, the question is equally relevant. Quantification of yield losses due to specific causes is essential to the determination of the economic importance of pests (The word pest is used here to cover plant diseases, insect pests, nematodes and weeds). The relative economic importance of a pest should be considered in setting research priorities and allocating resources. Establishing the relationship between pest incidence at different stages of development and subsequent yield loss is needed for decision making on alternative pest control strategies. Crop loss assessment has received considerable attention (James, 1974; Walker, 1983; Teng, 1987), but the quantification of the effects of insect pests and diseases on seed yield of beans (*Phaseolus vulgaris* L.) appears to have been neglected. Scientists have opted instead to invest resources on studies of the biology and control of pests that are vaguely perceived as causing major losses of yield.

This paper is targeted at bean researchers who face many potential research topics amongst which they need to set priorities. The paper is presented in three parts. The first part is a review of research conducted in Africa on bean yield loss assessment due to biotic stresses. The second part presents techniques for appraising the importance of pests. The third part presents research proposals for quantifying the effects of specific pests on bean yield.

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SUMMARY OF FINDINGS ON YIELD LOSS IN BEANS GROWN IN AFRICA DUE TO DISEASES AND INSECTS

In this section, available research results relating yield losses in beans to incidences of biotic stresses are reviewed. Where possible, published results were re-analyzed to establish a quantitative relationship between incidence of the stress and yield loss. For diseases, this required conversion of the 1-9 evaluation system (CIAT, 1987, p. 17) to percent incidence. More freedom was taken in converting a 1-5 evaluation system (Mmbaga, 1984) to percent incidence. The regression analyses for the studies reported for anthracnose, angular leaf spot and rust were done using treatment means. In other cases, the analyses relied on plot values.

Quantitative assessments

Anthracnose (*Colletotrichum lindemuthianum*)

Fungicides were evaluated for the control of anthracnose in beans using a susceptible cultivar, Canadian Wonder (Gondwe, 1989). Four and two trials were conducted at Lambo and Lyamungu, respectively, in northern Tanzania. The results were re-analyzed to estimate the effect of varying the incidence of anthracnose on yield.

When the results of each trial were analyzed separately for disease scores made at 75 days after sowing, rates of loss ranged from 1.32 to 24.03 kg/ha for a 1% increase in incidence of anthracnose. When a combined analysis was done across all six trials, the estimated effect of incidence on bean yield was -9.1 kg/ha (R^2 = 92.5, intercept = 2248.5 kg/ha) for a 1% increase in anthracnose incidence. There was no distinct pattern of deviation from a linear relationship for any of the trials.

No mention was made of other fungal diseases which occurred in these trials and which the fungicides may have affected. It is probable that the estimator of 9.14 is high for anthracnose, as some of the yield loss may have been due to these other fungal diseases.

Rust (*Uromyces appendiculatus*) and angular leaf spot (*Phaeoisariopsis griseola*)

Rust and angular leaf spot control were studied by Mmbaga (1984) in Tanzania. Field trials were repeated for three years. Yields per hectare were calculated from the reported plot yields, assuming plot size of nine square meters as given in the materials and methods. Yields were very low in some trials. Rust and angular leaf spot scores were highly correlated and similar in magnitude overall. Therefore the analyses were done using the mean of the two scores.

Estimates of yield loss per percent increase in disease incidence were calculated for each trial. These ranged from 2.9 to 5.6 kg/ha. When the combined analysis was calculated over the three trials, the estimator was -3.9 (intercept = 547.9, $R^2 = 0.925$). From the available data, the effects of the two diseases cannot be differentiated in these studies.

Research results of one season are available on bean yield loss due to rust in Ethiopia (Habtu, 1991). The trial included a susceptible and moderately resistant variety. The relationship estimated was 9.0 kg/ha yield loss per percent increase in incidence of rust (intercept = 1182.2, $R^2 = 0.905$). No mention was made of fungicidal effects on other diseases.

Bean flower thrips (*Megalurothrips sjoetedti*)

A single insecticide application for thrip control reduced thrip numbers from 15.2 to 4.0 per plant (approx. 30 flowers per plant) with yield increasing from 1448 to 1597 kg/ha (Uganda National Bean Programme, 1990). With regression analysis, the yield loss is estimated to be 14.5 kg/ha per thrip per plant (~30 flowers/plant) (intercept = 1879.4, $R^2 = 0.259$). Further investigation is needed to validate or improve this estimate.

Bean stem maggot (*Ophiomyia* spp.)

On-farm diagnostic trials were conducted in Uganda in 1988-9 in 12 clusters with 3-5 farms per cluster (Uganda National Bean Programme, 1988 & 1989). When seed was treated with endosulfan the yield was 5.1% higher then the untreated control over all trials (control -= 748.5 kg/ha). This is likely to be an under-estimate of yield losses due to this insect as the endosulfan reduced emergence and plant vigor in some of the trials.

Miscellaneous diseases

In the Uganda bean stem maggot trials, a treatment was included where seed was dressed with a combination of thiram and benomyl (Uganda National Bean Programme, 1988 & 1989). The fungicide treatment mean yield was 8.0% above the control mean over all trials. Information is lacking on which diseases were affected.

In an on-station trial, two applications of Dithane M45 resulted in a yield increase from 1715 to 1890 in Uganda (Uganda National Bean Programme, 1990), but information is inadequate to determine a relationship between yield and incidence of disease. Rust, angular leaf spot and floury leaf spot (*Mycovellosiella phaseoli*) were all reduced by spraying.

Qualitative assessments

In Zambia (Greenberg *et al*, 1986) and in Uganda (Uganda National Bean Programme, 1989), studies of yield losses due to diseases gave qualitative estimates of the relative importance of the various diseases. In each of these studies, data from variety evaluation trials were analyzed using multiple regression analysis to determine the estimators for each disease in each trial. The frequency of significant regression coefficients and their magnitudes, and the mean incidence levels of the diseases allow for estimates to be made of the relative practical importance of diseases.

Greenberg *et al* (1986) concluded that bean common mosaic virus (BCMV), angular leaf spot and scab (*Elsinoe phaseoli*) were the major diseases in terms of yield reduction. Common bacterial blight (*Xanthomonas campestris*), halo blight (*Pseudomonas phaseolicola*), ascochyta blight (*Phoma exigua*) and rust were determined to be of less importance. Anthracnose was not frequently observed, but it was often important when it occurred. BCMV was serious only in the hotter, drier areas (Chipata). Scab was important in the cooler, wetter areas. Angular leaf spot appeared to be important throughout the bean producing areas.

The study in Uganda (Uganda National Bean Programme, 1989) was limited to bimodal areas of 1200 to 1500 masl with generally adequate rainfall for bean production. Regression coefficients were most often significant, and large, for common bacterial blight and bean common mosaic virus. Rust and angular leaf spot were found to be of intermediate importance, and floury leaf spot of lesser importance. Anthracnose levels were always low and not significantly related to yield in any trial.

Conclusion

Available information on bean yield losses due to biotic stresses is inadequate to determine the economic importance of any disease or insect pest of beans in Africa. The estimate of 9.1 kg/ha yield loss for a 1% increase in anthracnose is perhaps the most useful estimate (Gondwe, 1989), but this may be high as some of the effect was probably due to other diseases. The estimate obtained for rust and angular leaf spot (Mmbaga, 1984) is useful for setting a minimum level (yields were very low), but the effects of rust cannot be separated from those of angular leaf spot. The diagnostic work in Uganda resulted in an estimate for yield losses caused by bean stem maggot which is probably lower than the actual losses.

Habtu's (1991) work in Ethiopia is continuing and is expected to establish a reliable yield loss model for rust, and Opio's (1991) work in Uganda is expected to result in a reliable model for common bacterial blight. Once such models have been determined and validated, results of surveys of disease incidence and insect population levels occurring in farmers' field can be used to estimate the economic losses liable to result from various pests.

TECHNIQUES FOR THE ASSESSMENT OF YIELD LOSS DUE TO BIOTIC FACTORS

Quantification of pest induced yield loss for crop producing areas is important for efficient allocation of research resources. For some problems, this can be done quite easily with simple on-farm trials in which the yields with disease or insect pest control are compared to those without pest control. In other cases, control may be difficult, or it may not be possible to partition the effects of a single pest from those of other factors. This section presents several yield loss assessment techniques and discusses the situations in which the techniques may be applied.

Yield Loss Trials

The simplest approach to estimating yield loss due to a pest is to conduct simple trials in which yields are compared in treatments with and without pest control. It is important that the control measure does not affect yields due to factors (e.g. phytotoxicity, or reduced effectiveness of natural enemies) other than the pest of concern. These trials often are done on farmers fields. This may not be necessary however, if the occurrence of the pest and its strains, fecundity and virulence are similar on the research stations to that on farmers fields. Pest control may be only partial, in which case observations on levels of infestation are needed, and the results interpreted accordingly. As an example, bean stem maggot is a major pest of beans throughout Eastern Africa. Where bean stem maggot is a major pest and can be controlled by dressing seed with a selective insecticide, quantitative yield loss data may be obtained by comparing yields in protected and unprotected plots. If bean stem maggot effects are confounded by insecticide effects on other beneficial or harmful insects, or by phytotoxic effects, the confounding must be considered in the interpretation of the results. Alternatively, other methods of assessing yield loss must be considered.

Regression of the effect of a single disease on yield

Experimental conditions can be created in which variation is controlled so that yield is primarily affected by a single factor. In such trials, the objective is to obtain varying levels of a single pest while holding all other factors constant. Yield is then related to pest level. Field experimentation should be done in uniform fields with all plots similarly managed, including soil amendments and measures to control other pests. Other diseases and insects may be present, but their effects on yield should be constant across the field. Plots deviating greatly from the norm for a biotic or abiotic stress (as indicated by observations on symptoms of the causal agent), may be excluded from the final analysis or the effects accounted for in the regression model. For certain plant diseases, within field variation can be obtained by varying the frequency, timing and concentrations of inoculum applications, or by manipulating levels with selective fungicides. When more than one important pathogen strain exists in an area, account must be taken in the inoculation due to possible synergistic or antagonistic effects between strains.

Two or three well-adapted and commonly grown varieties should be included to increase confidence in the extrapolation of results. Regular scoring of the levels of the pest may be needed, possibly every 10 to 14 days once symptoms appear. Other pests, and possibly vectors of virus diseases, may be monitored to ensure that these do not vary greatly among the plots.

Replication of the treatments is not required, but there should probably be 30 or more plots with varying levels of the pest. The number of plots is dependent on the expected magnitude both of the pest effect on yield and of experimental error.

The data are normally analyzed using uni-variate regression analysis, with the pest level as the independent variable and seed yield as the dependent variable. The model is $Yi = a + bXi$, where Yi is the yield of the *i*th plot, a is the intercept of the y axis, b is the regression coefficient for disease level and Xi is the disease level of the *i*th plot. If the relationship is quadratic, the model will be $Yi = a + b1Xi + b2Xi2$ If disease levels were assessed using a standard numerical rating system, conversion of scores to percent incidence (CIAT, 1987, p.17) is likely to improve the analysis. Separate analyses may be done for each variety and for each time of observation to determine the relationship between yield and a change in pest level at a particular growth stage. When variation in yield occurs due to factors independent of the pest, it can be accounted for by including additional independent variables in the model. Full use of these results requires that they be related to the situation in farmers fields. The determination of this is discussed below. The proposal in section 3 for yield loss assessment due to common bacterial blight is an example of this approach.

Multiple regression analysis of multi-location trials

Data collected from trials, such as multi-location variety evaluation trials, can be used to obtain estimates of the effects of diseases on yields. The advantage of this approach is that the data can be obtained with no added cost. Using multiple regression analysis, estimates can be obtained for the relationships between the incidences of the target pests of interest and yield.

A serious problem with this approach is that the data often cannot be analyzed easily across sites to estimate reliably the actual yield loss associated with an increase in disease level. The environmental variation encountered between multi-location trials affects both the pests as well as the yield, with the result that the pest levels are not truly independent of yield, nor of each other. A more reliable analysis can be done within environments if the management practices, soils, rainfall and other environmental factors are uniform throughout the trial area, although correlations between incidences of two or more pests may present a problem. The variation that occurs in the levels of the pests is probably independent of non-pest factors affecting yield and therefore pest levels can be assumed to be independent of yield. Unfortunately, the estimates obtained from this analysis hold true only for that particular location and season and results from several locations cannot be reliably combined to quantify the relationship between the levels of a pest and yield. However, it can give a qualitative assessment in which the impact on yield of one pest can be compared to that of another.

Use of isogenic lines or near isogenic populations

For some plant pests, resistance is controlled by a single gene. When pathogenic variation occurs, a gene-for-gene relationship between the host and parasite may exist. In cases of monogenic inheritance, iso-genic lines can often be bred in which the essential genotypic differences occur only at the loci involved in conferring resistance. For example, the "I" gene confers resistance to mosaic inducing strains of BCMV, but has a hypersensitive reaction to a necrotic strain. The "bc3" gene conveys resistance to all strains (Morales, 1989). Comparison of isolines with and without the "I" gene, and with the "bc3" gene in numerous environments within a zone will give an estimate of the yield losses occurring due to the necrotic and non-necrotic strains.

Iso-genic lines are produced by backcrossing with a well adapted line as the recurrent parent. Difficulties with strong linkages may prevent the development of truly iso-genic lines. The effects of linkages between resistance genes and other genes on yield can be detected through observation of consistent yield differences in disease free environments. When linkages have significant effects, these "iso-genic" lines may still be useful for yield loss assessment, but the differences in yield potential of the lines needs to be considered.

Often resistance to biotic stresses is a polygenic trait, as against ascochyta blight in beans. Presence of some but not all genes for resistance may give only partial resistance. Development of iso-genic lines is not feasible for polygenic traits. An alternative is to develop near iso-genic populations with varying levels of resistance. Populations are formed by selecting under pest pressure within the progeny of a cross between a susceptible and a resistant parent. Seed of severely affected plants is bulked to form the susceptible population while seed of unaffected or slightly affected plants is bulked to form the resistant population. The populations are assumed to have similar distributions of all genes except for those involved in the conference of resistance. Yield differences between the 'susceptible' and 'resistant' populations are attributed to the disease. The proposal for ascochyta blight in section three is an example of the use of near isogenic populations

Determination of economic loss due to decline in seed quality

Economic loss can occur due to decreased yields as well as reduced grain quality. Seed discoloration due to insect or disease damage results in reduced market value. The economic losses which occur can be easily determined by presenting samples with differing levels of damage due to the various pests to traders, and determining the differences in market values. These results can then be related to the damage levels typically occurring in farmers' harvested grain.

Farm Surveys

The results of yield loss studies must be related to the occurrence, severity and timing of the pest in farmers' fields. Surveys may be conducted to determine this.

The complexity and extent of the surveys depends on the researchers' objectives. For many pests, however, these could be quite simple. The major bean diseases, for example, could be surveyed by simply scoring the diseases in a cluster of 25-50 fields when the beans are in the pod elongation and filling stages. A cluster should be surveyed in each of the major bean producing areas and the survey should be conducted for 3-4 seasons, choosing clusters in different locations in each season. As the ratings are subjective, all ratings for a disease should be done by one person, who also does the ratings for the yield loss trial. Fields may be at different growth stages, but the growth stages should be recorded. The survey will give estimates of the mean levels of occurrence, as well as the variation in levels. The results then can be related to the results obtained from the yield loss trials.

Summary

Procedures for estimating yield and economic losses to insect pests and diseases are discussed.

1. Yield loss trials in which paired comparisons are made of yields of protected treatments with unprotected treatments are the easiest to conduct and to interpret. They are appropriate when control measures are selective and easy to apply, and do not significantly affect yield through direct or indirect means other than through control of the pest of interest. Such trials should probably be conducted on farmers' fields, unless on-station occurrence and severity of the pest is representative of the farmers' situation.

2. Relating the level of a pest to yield using regression analysis is an alternative technique when paired comparison yield loss trials are not appropriate and when the pest levels can be varied without affecting other yield- influencing factors.

3. Use of iso-genic lines to determine yield losses due to a pest is an appropriate method when resistance to one or more of the strains of the pest is governed by a single gene.

4. Use of near iso-genic populations offers a fourth option for estimating the effect of a pest on yield. It is appropriate for pests that cannot be specifically controlled, whose levels cannot be varied without varying other yield affecting factors, and where resistance is quantitatively inherited.

5. Multiple regression analysis of data from multi- location trials, such as national variety trials, can give a qualitative assessment of the relative importance of the various pests, but it may not give reliable estimates of the yield losses actually occurring to the individual pests.

6. Economic loss due to reduced grain quality can be determined by relating the market value of samples with different damage levels to the damage levels typically found on farm.

7. Results of surveys on the occurrence, severity and timing of pests in farmers' fields are needed to extrapolate the assessments of yield and economic losses to the farmers' situation.

PROPOSALS FOR YIELD LOSS ASSESSMENTS

In this section, research proposals are presented for the determination of the economic importance of various insect pests and diseases of beans in Africa.

For most of the pests, a two phase approach is proposed. Field experiments are conducted in the first phase to characterize the relationship between the pest levels and loss in yield. This is to develop a reliable method for estimation of the loss in yield associated with any pest level under a range of environmental conditions. In the second phase, diseases and insect pests are assessed on farmers field's to determine frequencies of occurrence and levels of incidence.

Bean Common Mosaic Virus (BCMV)

Objective: To relate yield loss to levels of non-necrotic and necrotic strains of BCMV, and to determine the disease's economic importance.

Procedure: Plant isogenic lines, or near-isogenic populations, of two widely adapted cultivars, with a) resistance to all strains of BCMV; b) I gene protected; c) no I gene protection, but immune to the necrotic strains.

Conduct trials in 6 locations for 2 seasons with no more than 2 locations per country.

Treatments consist of 2 varieties x 3 isolines x 3 inoculation levels (no inoculation and 4 & 7 weeks after planting (WAP) with necrotic or non-necrotic strains as appropriate). Use four replications in a randomized complete block design (RCBD) with 1 x 4m plots of 2 rows.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer if it will reduce the variability of the experimental material. Fungicides and insecticides may be applied to protect the crop and to reduce variability in yield due to fungal diseases and insect pests.

Observations: BCMV and other disease scores every 10 days beginning at R6; seed yield.

Survey farmers fields for 2 seasons to determine mean levels and frequencies of occurrence of the levels of the disease.

Analyses: direct comparison of yields of resistant with non-resistant lines; multiple regression analysis to determine the yield loss function for levels of non-necrotic BCMV, and for numbers of necrotic plants; and determination of the economic importance of BCMV strains using survey results and the yield loss functions.

Halo blight

Objective: To relate yield loss to levels of halo blight and to determine the disease's economic importance.

Procedure: Grow 2 widely adapted cultivars with moderate tolerance to commonly occurring races of halo blight under conditions to obtain varying levels of halo blight infection. Vary levels of infection by varying applications of inoculum of the major races in the area and by using less infected seed and heavily infected seed.

Treatments are of a factorial arrangement: 2 varieties x 2 seed sets ('clean' vs. heavily infected) x 6 inoculation regimes (no inoculation, and inoculation at 3, 5, 7, 3 + 5, 3 + 5 + 7 WAP) using a mixture of prevalent races.

Use three replications in a RCBD with 1 x 4 m plots of 2 rows per plot and plots separated from adjacent plots by two rows of soybeans.

Conduct trial in four halo blight prone locations for two seasons with no more than two locations per country.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer if it will reduce the variability of the experimental material. Fungicide and insecticide may be applied to protect the crop and to reduce variability in yield due to fungal diseases and insect pests.

Observations: Halo blight and other disease scores every 10 days beginning at R6 growth stage; seed yield.

Survey farmers fields for 2 seasons to determine mean levels and frequencies of occurrence of the levels of the disease.

Analyses: multiple regression analysis to determine the yield loss function for halo blight; and determination of the economic importance of the disease using survey results and the yield loss function.

Common bacterial blight

Objective: To relate yield loss to levels of common bacterial blight (CBB) and to determine the disease's economic importance.

Procedure: Grow 2 widely adapted cultivars with moderate tolerance to commonly occurring strains of CBB under conditions to obtain varying levels of CBB infection. Vary levels of infection by varying applications of inoculum of locally occurring strains and by using less infected seed and heavily infected seed.

Treatments are of a factorial arrangement: 2 varieties x 2 seed sets ('clean' vs. heavily infected) x 6 inoculation regimes (no inoculation, and inoculation at 3, 5, 7, 3 + 5, 3 + 5 + 7 WAP) using a mixture of prevalent races.

Use three replications in a RCBD with 1 x 4m plots of 2 rows. Separate plots from adjacent plots with two rows of soybeans.

Conduct trial in four CBB prone locations for two seasons with no more than two locations per country.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer if it will reduce the variability of the experimental material. Fungicide and insecticide may be applied to protect the crop and to reduce variability in yield due to fungal diseases and insect pests.

Observations: CBB and other disease scores every 10 days beginning at R6; seed yield.

Survey of farmers fields for 2 seasons to determine mean levels and frequencies of occurrence of the levels of the disease.

Analyses: multiple regression analysis to determine the yield loss function for CBB; and determination of the economic importance of the disease using survey results and the yield loss function.

Aschochyta blight

Objective: To relate yield loss to levels of aschochyta blight and to determine the disease's economic importance.

Alternative 1.

Use a procedure similar to that proposed for CBB and halo blight if inoculation can be successfully used to vary aschochyta levels in the field.

Alternative 2.

Procedure: Use two 'susceptible' and two 'resistant' near iso-genic populations formed from segregating generations derived from crosses between resistant and susceptible lines (Fig 1). Early generations are grown under low disease pressure. The F3 generation is grown under moderate aschochyta pressure to enable identification and selection of relatively resistant (as well as escapes) and relatively susceptible plants to form bulks of "resistant" and "susceptible" genotypes. F4 seed of the bulks is increased under typical disease pressure with further selection for resistance or susceptibility in the respective populations. Trials are conducted using the F5 populations.

Use six replications in a RCBD with 1 x 4m plots of 2 rows.

Conduct trial in four aschochyta prone locations for two seasons with no more than two locations per country. (5000 seeds will be needed. Assuming a multiplication factor of 10, 15-20 F1 plants will be needed.)

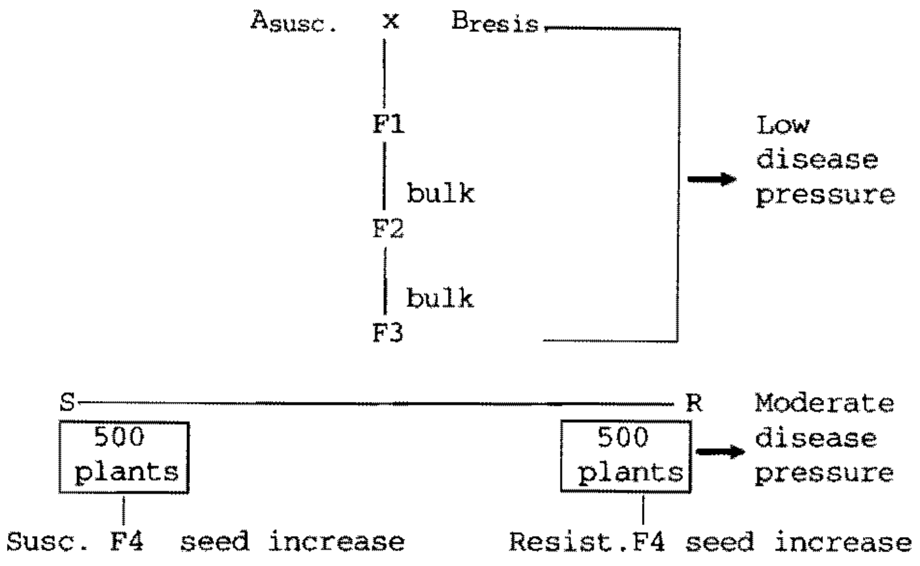

Figure 1. Procedure for formation of near-isogenic populations.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer and pesticides to reduce variability in yield due to variations in soil fertility, bacterial diseases and insect pests.

Observations: Aschochyta and other disease scores every 10 days beginning at R6; and seed yield.

Survey of farmers fields for 2 seasons to determine mean levels and frequencies of occurrence of the levels of the disease.

Analyses: Do an analysis of variance for yield and compare 'susceptible' populations with 'resistant' populations using orthogonal comparisons; attempt to establish a yield loss function relying on variation in disease levels due to different degrees of resistance, natural variation in the distribution of the diseases and differences across sites; and determine the economic importance of the disease using survey results and the yield loss function.

Angular leaf spot

As for aschochyta.

Bean flower thrips (*Megalurothrips sjostedti* (Trybom))

Objective: To relate yield loss to bean flower thrip number per blossom and to determine the insect pest's economic importance.

Procedure: Grow 2 widely adapted, determinate cultivars under conditions to obtain varying densities of thrips. Vary levels of density by varying time of insecticide applications.

Treatments are of a factorial arrangement: 2 varieties x 3 contact insecticide treatments (no insecticide, at 50% flower, at 3 days after 50% flower).

Use eight replications in a RCBD with 2 x 4m plots of 4 rows (2 harvest rows).

Conduct trial in four locations for two seasons with no more than two locations per country.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer if it will reduce the variability of the experimental material. Fungicide may be applied to protect the crop and to reduce variability in yield due to fungal diseases and insect pests. Observations: Count thrips per 50 blossoms per plot at 5 days after 50% flower; disease scores at R7; and seed yield.

Survey farmers fields for 2 seasons to determine mean levels and frequencies of occurrence of the levels of the disease.

Analyses: Multiple regression analysis to determine the yield loss function for bean flower thrips; determination of the economic importance of the pest using survey results and the yield loss function.

Bean stem maggot

Objective: To establish a estimate of bean yield loss occurring due to bean stem maggot (BSM).

Procedure: Grow two widely adapted cultivars in paired treatments, i.e. protected by seed dressing with a non- phytotoxic, systemic insecticide and unprotected.

Treatments include 2 varieties, protected and unprotected.

Conduct five on-farm trials per cluster with 1-4 clusters in each important bean growing area in which BSM is a problem. (Conduct these trials together with on-farm trials conducted for other purposes to reduce the cost of implementation.) Use two reps per farm in a RCBD and a plot size of 3 x 3m plots. Conduct trials for 2 seasons.

Management: Manage for good crop performance and to minimize the heterogeneity of the site. Apply fertilizer if it will reduce the variability of the experimental material. Fungicide and insecticide may be applied to protect the crop and to reduce variability in yield due to fungal diseases and insect pests.

Observations: Total BSMs (larvae, pupae or adults) 3 WAP after planting on 10 plants per plot; disease scores during R7; and seed yield.

Analyses: multiple regression analysis to determine the yield loss function of BSMs per plant at 3 WAP; economic analysis of the difference between protected and unprotected treatments; and application of the yield loss function to BSM levels observed in the unprotected plots to determine the economic importance of the pest.

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