APPROACHES FOR COMPETITION STUDIES[1/]

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Introduction

Economic weed management programs contemplating reductions in herbicide use must be able to predict the impact of weeds on crop yields. Crop loss estimations based on early assessments of weed infestations are required for adequate economic analysis of weed management. Economic use of inputs is achieved when weed control is restricted to the critical period when weeds can cause yield damage. Factors such as crop and weed density, species' proportions, and spatial arrangements are relevant to the outcome of crop-weed competition. An understanding of processes involved in competition is essential for deriving successful weed management approaches.

Different approaches that can be applied to study weed competition in rice are presented here. Examples belong to diverse weed-crop situations.

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Paired plots

As a first approach to assess weed competition paired plots, can be set in farmer' fields. One plot should be kept weed free, and another plot should represent the farmers' weed management practice. This is an excellent way to assess the efficiency of the farmers' weed management. A third, weedy, plot could be included when working in areas with different levels of weed infestation to perceive how yields vary under different weed pressures. Botanical weed composition and crop management should be similar in all plots. Crop yield and weed biomass in the plots should be recorded. A visual scoring, representing weed vigor and cover, is often used as a practical way to assess weed biomass.

Weed density experiments

Also known as additive experiments in which the density of the crop is usually held constant while the density of the weed is varied. Results follow the law of diminishing returns. (Figure 1). This approach is useful to study the effect of a predominant weed or one which escapes normal weed control (red rice). Can also be used to rank the relative competitiveness of different weed species grown individually with rice. The economical damage of weeds escaping weed control measures can also be assessed with additive experiments. Additive experiments are also often used to establish damage or economic thresholds of weed infestation. However, as weed density changes in the experiment so does the crop: weed proportion. Thus density and proportion (two relevant aspects affecting the outcome of competition) vary simultaneously, making the interpretation of the effects of either factor difficult.

Critical periods of competition

For a most economic timing of weed control the objective is to define when in the growing season do weeds reduce crop yields. A classic design is usually employed for this purpose (Figure 2). A series of treatments is left weedy during progressively longer periods after crop and weed emergence. In a complementary series of treatments the crop is kept weed free for different periods after emergence. Final harvest yields plot as in Figure 3, from where the critical period of competition can be established. This is a very useful approach that should be part of the first efforts of any weed research program. Best is to conduct this experiment under different levels of management inputs to infer what crop management approaches are useful to reduce the competitive impact of weeds. To assure uniform weed infestations weeds are often sown in these experiments. Usually, high saturating, weed densities are used to depict the most severe competition scenario, the critical period will vary at lower densities. This approach is ideal to determine what effects do late (and how late) weed infestations have on yield.

Response surface

Since effects of weed density and period of competition are not independent, an experiment combining both variables would be a realistic approach. Usually multiple linear regression models are used to describe crop yields as a response surface to weed density and duration of competition (Figure 4). This approach is ideal to assess competition with rice of weeds such as red rice.

Species proportions: Replacement series

In replacement series experiments two species are grown in mixtures at different proportions, while total density is kept constant.

Proportions	1:0	3:1	1:1	1:3	0:1
Density of species A	100	75	50	25	0
Density of species B	0	25	50	75	100
Total density	100	100	100	100	100

Results are commonly expressed as relative yields (RY).

$$RY_a = \frac{\text{Yield of } \underline{a} \text{ in mixture with } \underline{b}}{\text{Yield of } \underline{a} \text{ in monoculture}}$$

Where RY_a = relative yield of species a; a and b being the two species competing.

RYT (relative yield total) = $RY_a + RY_b$. Yields are expressed in terms of plant biomass or grain. Figure 5 illustrates some of the possible outcomes of replacement series studies. When RYT = 1, and the growth of one species is enhanced while the growth of the other species is depressed, a competitive interaction for the same growth resources takes place between a and b. RYT values less than 1, indicate an antagonistic interaction as could be the case of allelopathy. In the example of Figure 5 the antagonism is mutual (the growth of both species is depressed). Conversely, when growth in mixture is better than in monoculture (RYT>1) the species may partly avoid competition by having some degree of niche differentiation or of some sort of symbiosis. In associating crops for intercropping systems RYT>1 is sought. Thus replacement series provide a good indication of the type of interaction between two species. Conducted at different levels of given resources, this approach can help understand the role of such resources in competition.

Important criticism to replacement series is the fact that the information derived is mostly qualitative, competition is measured at only one total density, and is not suited to work with several species at one time.

Crop density and spatial arrangement

Density and spatial arrangement are key factors affecting competition. Spatial arrangements refers to the dispersal of plants in a field. Usually a crop is least affected by weed competition when it is planted in a square or hexagonal (equidistant) pattern. Two systematic experiments (density varies systematically in the experiment with no randomization) were proposed to determine the optimum crop density under two different planting arrangements (intraspecific competition is thus assessed). Figure 6 illustrates an approach for equidistant planting, while Figure 7 represents row planting at fixed row width. If these experiments are conducted under a uniform weed infestation the most competitive crop density and planting pattern can be determined. The results of such work with corn showed the equidistant distribution to be superior over row planting (Figure 8). The systematic experiments allow to test a wide range of crop densities with considerable space economy. Critics to the systematic approach are the relative small size of the plots, and the lack of randomization. However the systematic technique may be an invaluable approach in preliminary density screening.

Competitiveness of multispecies weed infestations: an approach

In most cases rice fields are infested by mixtures of several species at different densities and proportions. Therefore, the ultimate goal in competition work should be to develop a working tool for fieldmen to make economic decisions about weed control in such (usual) field situations.

Addition Series

This is an approach based upon de linearization of the basic intraspecific relationship between individual plant weight and density (Figure 9):

If: w = biomass of one individual, then w is a function of density that can be linearized as: $1/w = a + b \times \text{density}$ (1)

This relationship has been empirically determined, and in fact other linearizations are possible (such a by using Ln(w)). The linearization allows the use of multiple linear regression to predict the effect of species mixtures (at different densities and proportions) on the growth of crop and weeds. Thus the model in equation (1) can be expanded:

$$1/w = a + bD_{12} + cD_{21} \qquad (2)$$

For: W_{12} = biomass of an individual of species 1 growing in mixture with species 2.

D_{12} = density of species 1 in mixture with species 2.

D_{21} = density of species 1 in mixture with species 2.

a = intercept (maximum biomass of sp. 1. in absence of intra- or interspecific competition).

b and c = regression coefficients (expressing intra- and interspecific competitive effects respectively.

Extending equation (2), more species can be considered. The assumption with this model is that competitive effects are additive.

Addition series offer a useful approach that has been widely used. It has the additional advantage of its coefficients indicating how different management practices affect intra- or interspecific interference. One would clearly want to manage a crop so as to maximize its interspecific competitive ability against weeds, and at the same time, reduce the intensity of intraspecific interference among rice plants. The unique property of separating intra- and interspecific competition is especially valuable to crop-weed competition studies. Addition series also allow us to determine the most adequate crop density to compete with a given weed infestation. Finally the crop growth (1/w) estimated by the model can be related to grain yield using a yield vs biomass (w) relationship established with data from the experiment.

The experimental design can be considered as a sequence of replacement series conducted for a range of total densities. Alternatively, it can also be conceptualized as all possible combinations of species mixtures for a range of densities and proportions.

Evaluations

To just know the effects on crop yield of weed competition is only a very preliminary step. It is important to gain some understanding of the competition process itself, in order to be able to derive useful management implications. Therefore, besides measuring crop yield, other evaluations should be conducted to help understand how crop and weeds interact. It will be useful to monitor crop and weed growth over time, thus sequential determinations of leaf area, dry biomass (usually aerial portion), height, and tillering can be considered. It is important to determine crop and weed emergence over time to know when do weeds responsible for yield losses emerge with respect to the crop (how much do late-emerging weeds compete ?). Crop and weed density should be established, usually counts within quadrants placed several times within each plot are satisfactory. Visual estimations of ground cover by weeds can be a useful and quick, though subjective, way of assessing levels of weed infestation. Basic, season-long weather parameters such as temperature, rainfall, and perhaps luminosity are helpful to understand competition responses to environmental changes. Cumulative growth degree days (average daily temperature-12) usually relate very well to competition effects over time.

Conclusions

Predictions of yield losses by weed competition provide an economic and rational approach to manage weeds, since weed control expenses can be closely matched to the expected benefits. Economic thresholds* of weed infestation and critical periods for weed control can also be derived from competition studies, to help adjust the economics of weed management.

Competition studies can be quite site specific, therefore, they are valid under similar cropping conditions and weed species. Experiment must be conducted for more than one season. Ecophysiological modelling approaches can account for the effects of key environmental and management variables, and thus remove much of the site and season specificities. In studies to assess the competitive effects of weed density on crop yields, using relative leaf area (Weed leaf area index/crop + weed leaf area index) instead of density counts, as independent variable, can be helpful to remove some of the variation caused by environmental differences.

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* An economic threshold weed population is that at which the cost of controlling it would equal the value of expected crop yield and quality losses. According to this weed populations below the threshold would not be worth while controlling.

Weed competition needs to be managed, and weed management refers to the integration of practices that will render growing conditions more favorable to the crop than to the weed. Thinking of weed management just as chemical control is too expensive and dangerous. To manage weed competition, an understanding of the factors involved is essential. Thus competition studies need to consider besides crop yield losses other parameters related to crop and weed growth.

Approaches to study competition should be carefully selected to answer specific questions, using the simplest possible design. Competition work can otherwise become very laborious. For cost effectiveness and an integrated management perspective, competition experiments should be shared with other disciplines for data collection.

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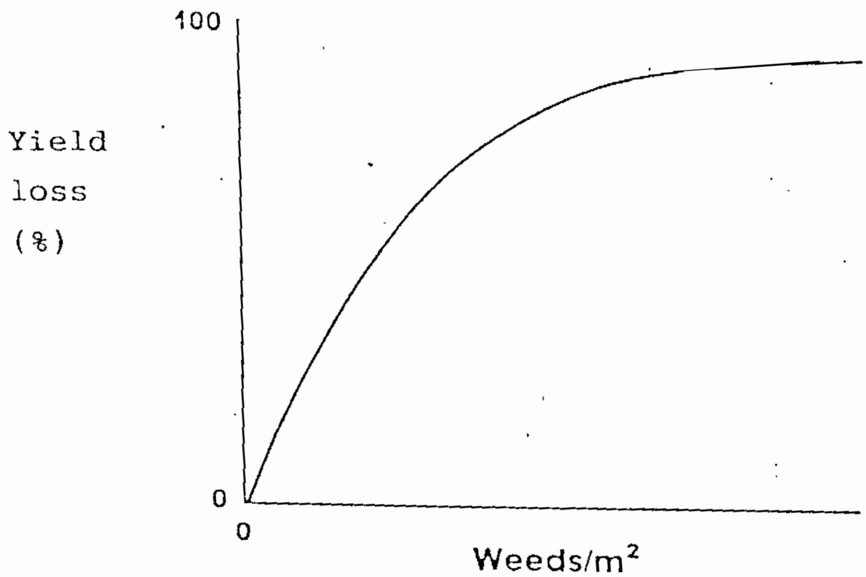

Figure 1. Schematic representation of a typical weed density-yield loss relationship.

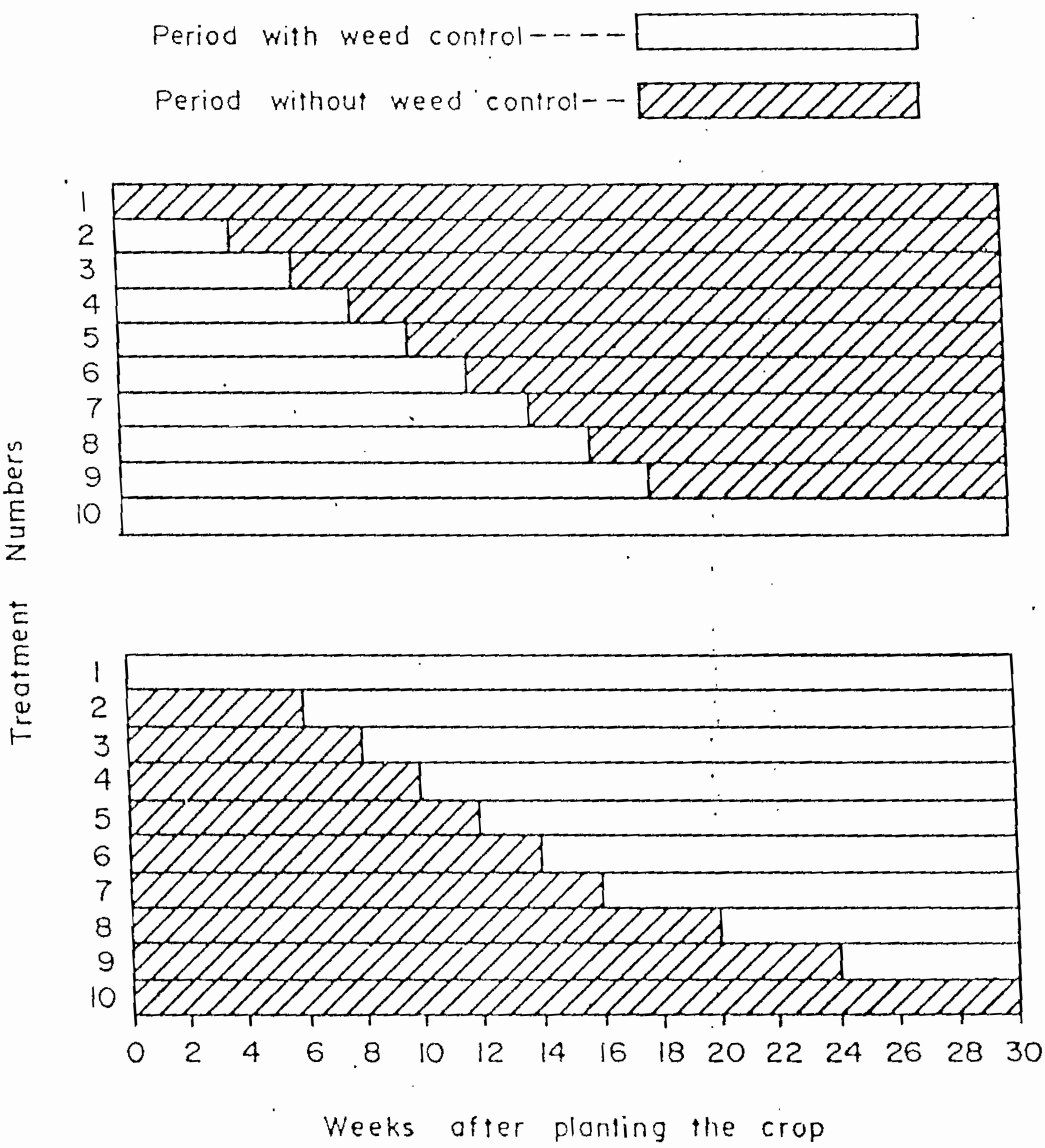

Figure 2. Graphic presentation of treatments in studies critical periods of weed competition.

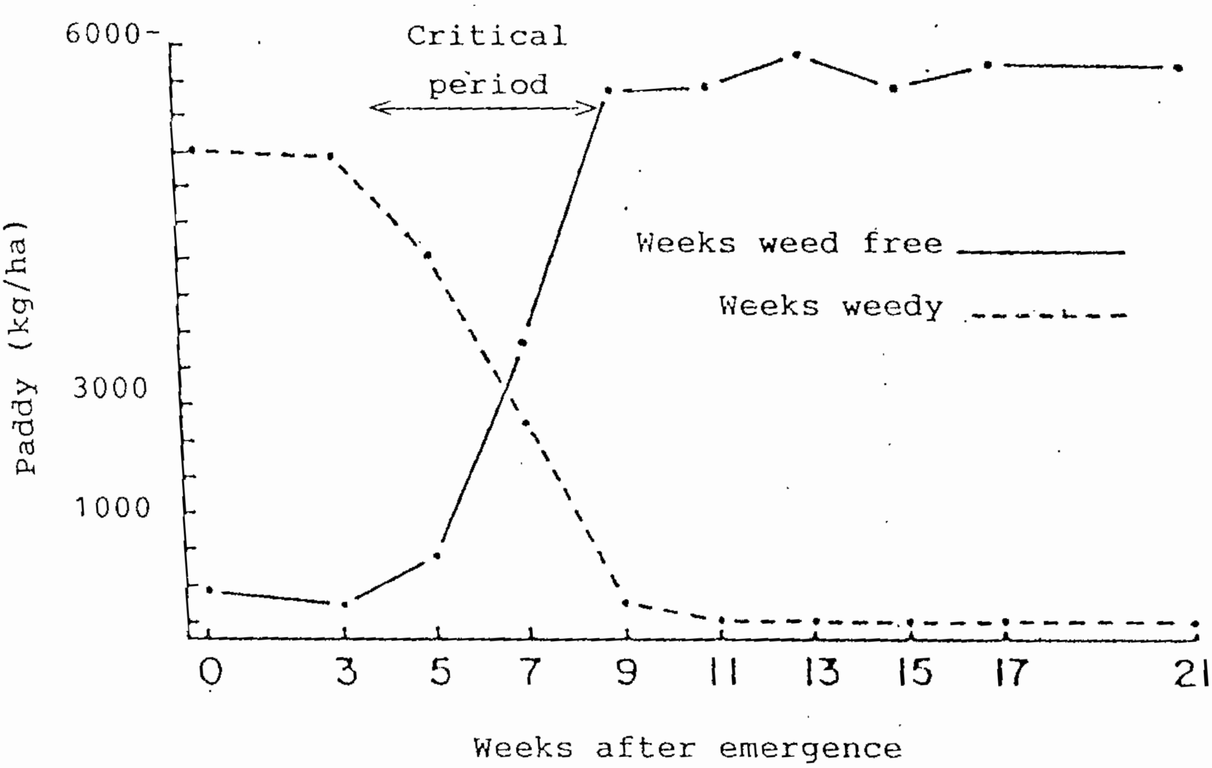

Figure 3. Results from an experiment to determine the critical period of competition with weeds.

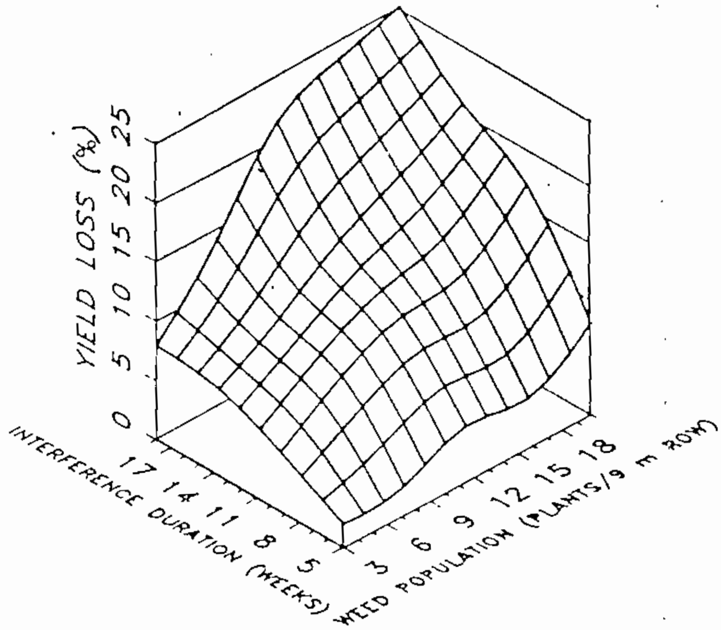

Figure 4. Effect of common lambsquarters population density and interference duration on soybean yield reduction in 1986 and 1987 (combined data). The regression equation is $Y = 15.3451 + 3.3247T - 0.1040T^2 + 0.0039D^2T$, where Y = predicted soybean yield reduction (%), D = weed population density (plants/9 m row) and T = interference duration (weeks after emergence). For the model, $r^2 = 0.86$.

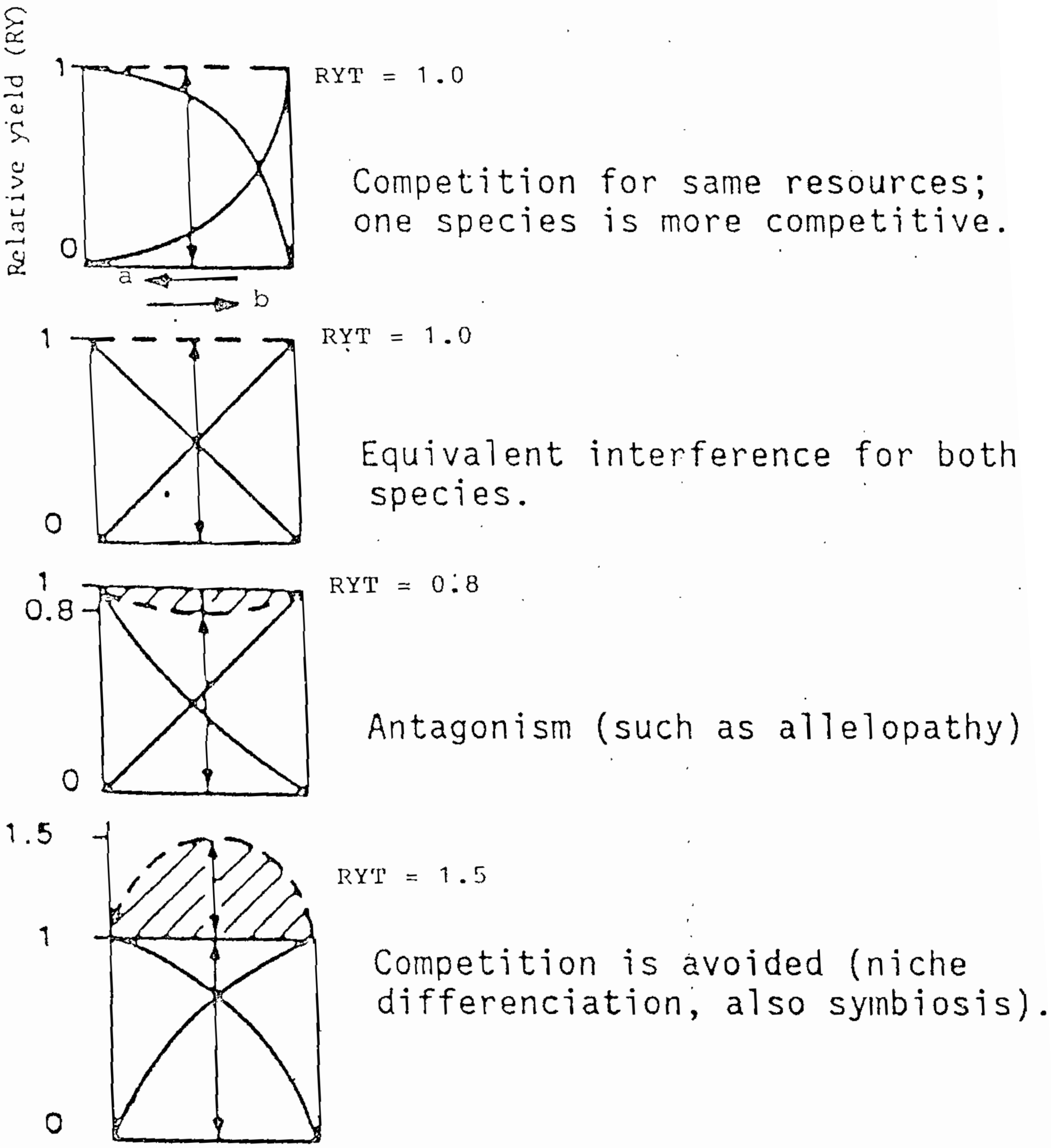

Figure 5. Models to interpret results in replacement series experiments with mixtures of two species: a and b (adapted from Harper, 1977).

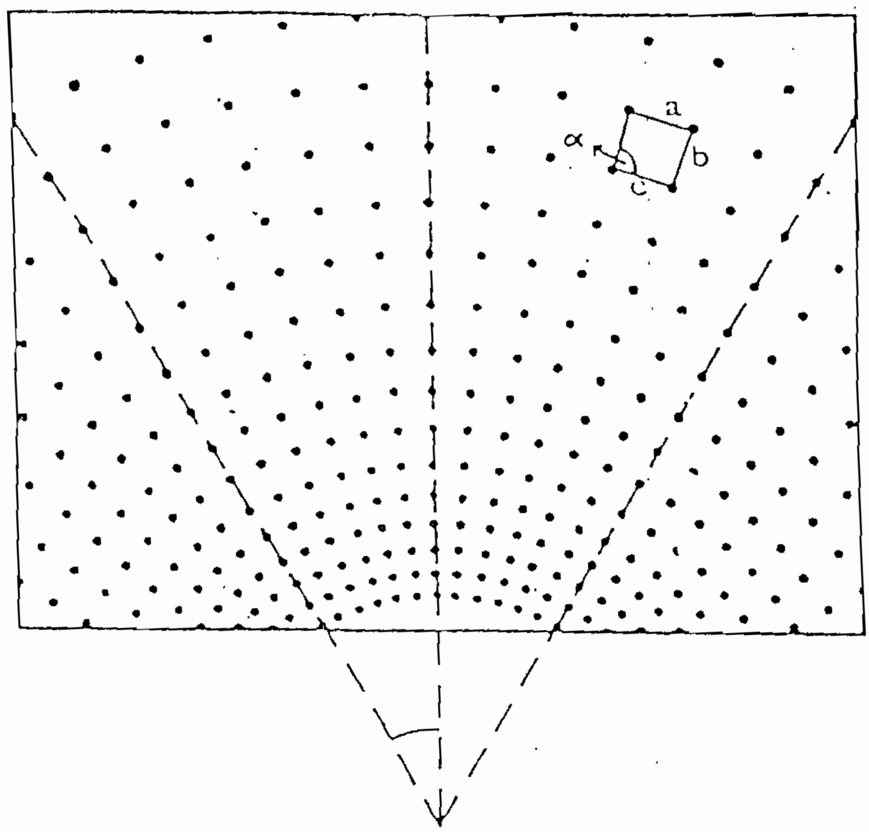

Figure 6. A systematic fan design with an approximately square plant arrangement. The plant positions are represented by dots (From: Bleasdale, J.K.A. 1967. Systematic designs for spacing experiments. Expl. Agric. 3(1):73-84.).

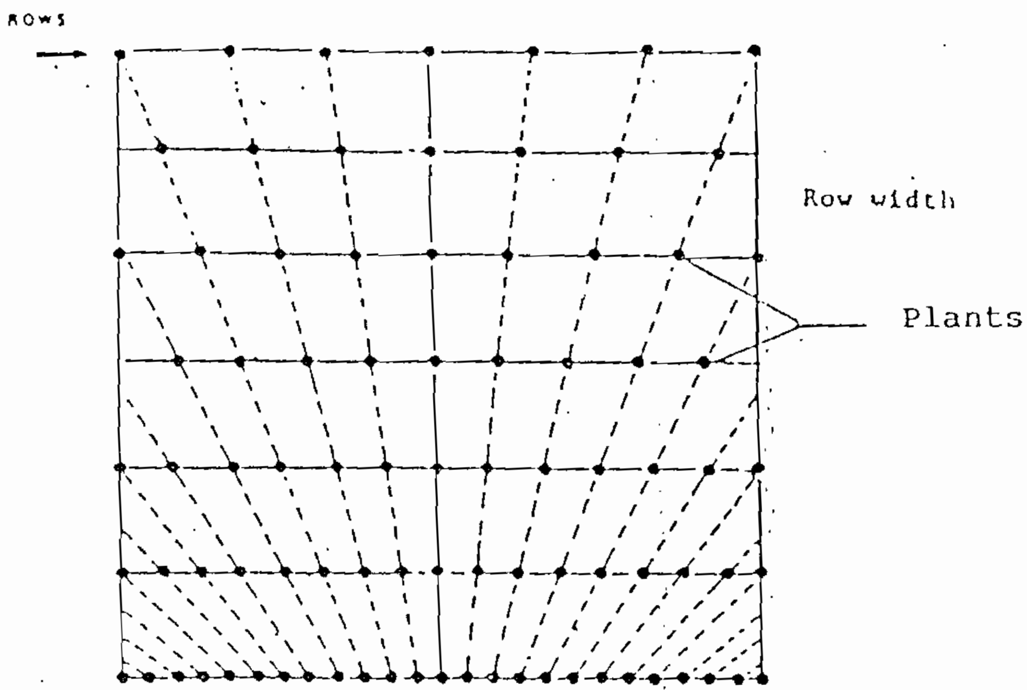

Figure 7. A fan design for spacing experiments with set row widths. The plant positions are represented by asterisks (adapted from Freyman and Dolman, 1971).

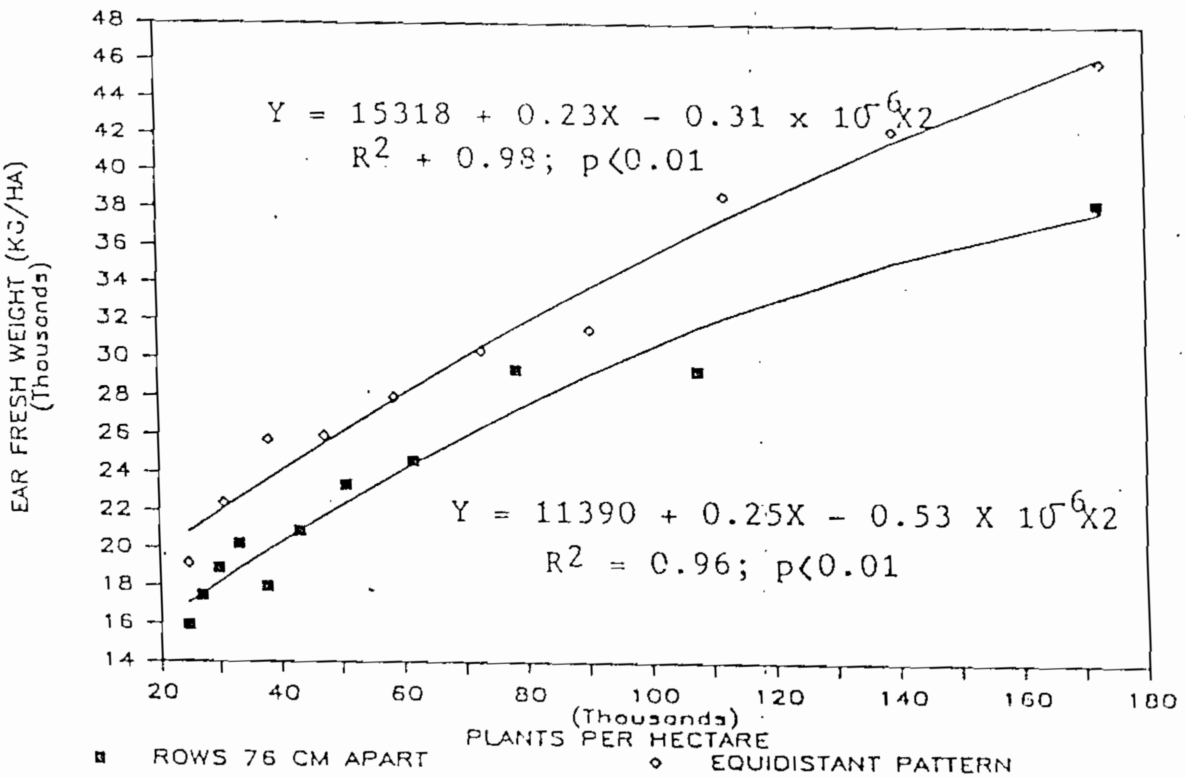

Figure 8. Yields of marketable sweet corn ears when planted at different densities, in a nearly equidistant pattern or in rows 76 cm apart (The regression lines are statistically different ($p<0.01$) according to an F test comparing all the coefficients in the models).

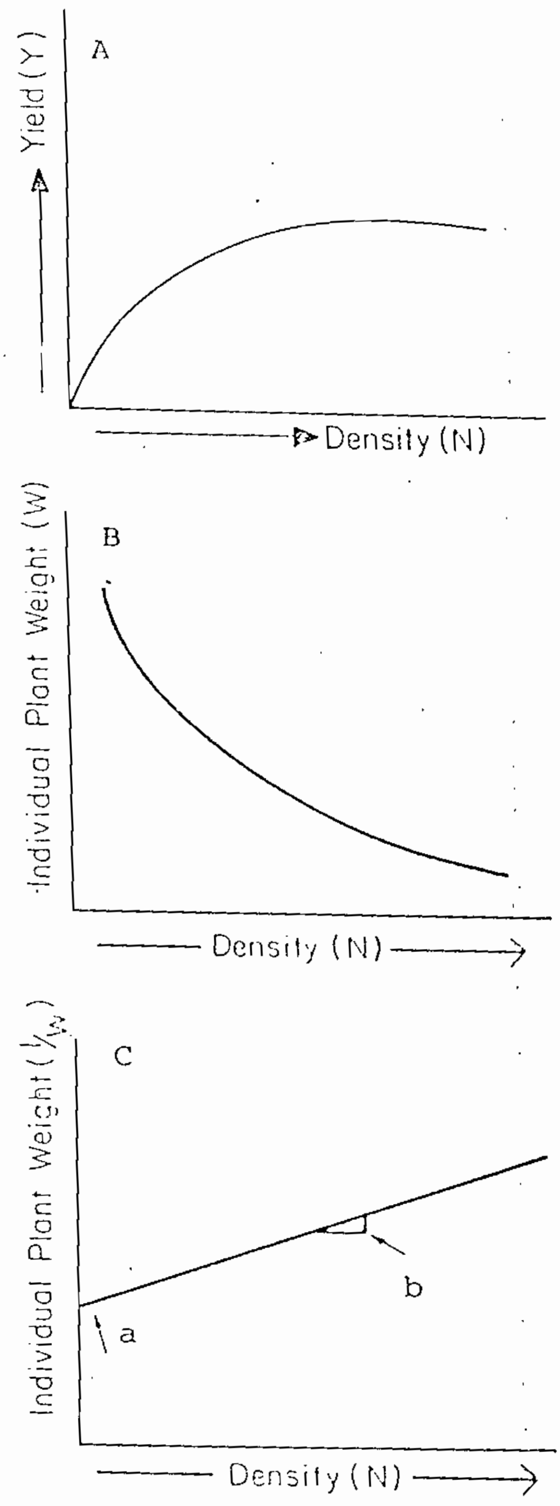

Figure 9 A. Theoretical yield of plant biomass per unit area as a function of density.
B. The relationship of individual plant weight to density.
C. Linearized (inverse) relationship.