Estimating the optimal relative density combination of two crops in an intercrop

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Abstract

A methodology is presented which enables the identification of the optimum density for planting two crops in a mixed stand. This approach requires (a) an additive experimental design, (b) the use of a regression model to measure the competitive effect of two species, and (c) the presentation of the net competitive effect on individual and total yields using a response surface. Results are presented for an experiment containing maize and beans. This approach is discussed in terms of its efficacy in managing plant competition between two or more crops in an intercrop.

Key words

Competition, experimental design, regression model

Introduction

Intercropping is attracting increasing interest in developed countries, primarily due to claims that it can provide increased yields in an environmentally sustainable manner. Research methodologies from the field of population ecology can be drawn upon to identify the optimum density combinations of two species in an intercrop design.

Materials and methods

The experiment consisted of fodder maize (*Zea mays)* and dwarf french bean (*Phaseolus vulgaris)* being grown at densities ranging from 8 to 39 plants/m^2, both in monoculture and a variety of mixtures. The experiment was a split-split-plot design that allowed for 20 treatment combinations and three replicate blocks. Intercropped treatments were produced by drilling a component crop between the main crop rows using an additive design. At each harvest six individuals of each species were removed. Dry weight measurements were taken after the plants had been oven-dried for a period of 48 hours at 80?C.

Analysis

Log transformation was used to stabilise the variance in the maize and bean data. The relationship between the mean plant dry weight, *w*, and density, *N,* of species *i* and *j* in a mixed stand was explored using the following two-species generalised linear reciprocal model (1, 2):

$$\bar{w}_i = w_{mi}(1 + a_i N_i + a_{ij} N_j)^{-1} \quad \text{(eqn 1)}$$

where w_{mi} is the mean dry weight of an isolated plant of species *i* at a given time and *a* is a density dependent feedback parameter. The competition coefficients a_i and a_{ij} measure the effect of increasing intraspecific densities (N_i) and inter-specific densities (N_j), respectively, on species *i*. As the *per capita* competition coefficient a_i has been shown to co-vary with w_{mi} (3, 4), the *per individual* equivalence coefficient ε_{ij} was also calculated:

$\varepsilon_{ij} = a_{ij} / a_i$ (eqn 2)

The equivalence coefficient measures how many individuals of species *i* have an equivalent competitive effect to one individual of species *j*. A value of $\varepsilon_{ij}<1$ indicates that the effect of intraspecific competition is greater than that of interspecific competition and the converse is the case for a value $\varepsilon_{ij} > 1$. A Levenberg-Marquardt estimation method was used to obtain a least squares estimate of the parameters log w_{mi}, a_i, and a_{ij}. The parameter estimates for maize and bean were then used to estimate the yields of the two crops grown in an intercrop at the full complement of density combinations. The Land Equivalent Ratio (LER) provides a comparative measure of the biological efficiency of pure and mixed species cropping systems calculated in units of land area and can be interpreted as the relative land area required under monoculture to produce the harvested yields achieved in an intercrop. The LER was calculated for the predicted yields in mixtures:

$$LER = \frac{y_{ij}}{y_i} + \frac{y_{ji}}{y_j} \quad \text{(eqn 3)}$$

where y_i and y_j are the yields of species *i* and *j* in monoculture and y_{ij} and y_{ji} the yields in mixture of species *i* and *j* respectively. LER values greater, and less than, unity identify intercrop combinations that are more, or less, biologically productive per unit area, respectively, than monocultures.

Results and discussion

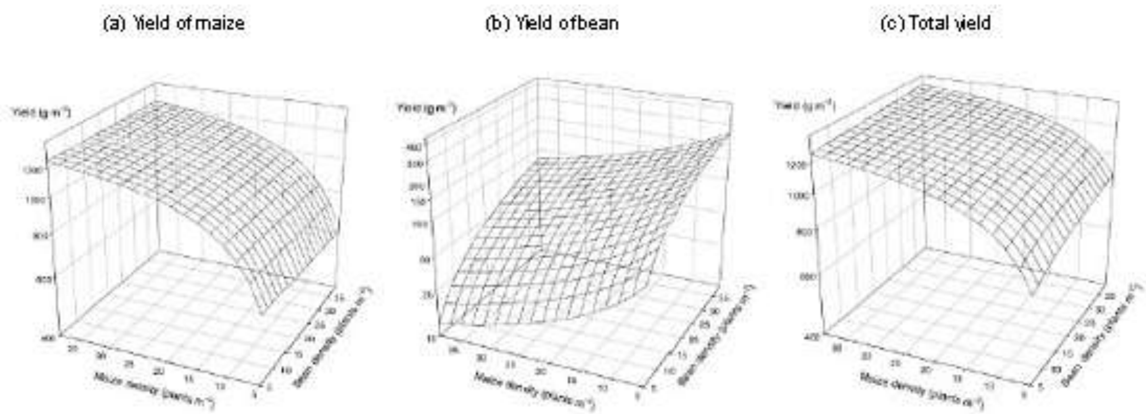

Figure 1. Estimated yields of (a) maize, (b) bean, and (c) maize and bean (log scale).

The reciprocal model accounted for 94% and 90% of the variation in the mean dry weight of maize and bean grown in intercropped stands, respectively. The response surfaces for the yield of maize (Fig. 1a) showed there to be little effect of increasing bean density on the yield of maize. The response surfaces for the yield of bean (Fig. 1b) showed that bean yield continued to increase with an increase in bean density, although increasing densities of maize significantly decreased the yield of bean. The response surface for the combined yield of the two species was produced by summing the individual maize and bean yields (Fig. 1c). The estimated LER values (not presented) suggest that the minimum density combination required to produce the maximum yield advantage comprises maize planted at 11 plants/m^2 and bean planted at 39 plants/m^2.

Conclusion

A single additive design coupled with regression analysis can be used to determine the optimal planting densities of crops in an intercrop. The dissociation of intra- and interspecific competition using the reciprocal model and the subsequent computation of the equivalence coefficient, illuminates the relative importance of intra- to interspecific competition on the individual crop yields in an intercrop. Further details of this research can be found in Park *et al*., (5).

References

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