COMPETITION BETWEEN A CROP AND UNDERSOWN PASTURE IN A WATER-LIMITED ENVIRONMENT - A SIMULATION STUDY

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Summary. A simple model of a maize/legume pasture intercrop was developed, validated and used to assess the performance of rainfed maize crops grown with an understorey of legume pasture at Katherine, NT. In over 80 of the 100 years for which the model was run, grain yield for maize grown with a legume understorey was lower than the yield of a sole maize crop. Whilst this system is unquestionably of benefit for soil conservation, acceptance by farmers will depend on the relative economic value of maize grain compared to dry season forage.

INTRODUCTION

McCown *et al.* (3) proposed a cropping system for the Australian semi-arid tropics where legume pastures are grown in rotation with crops of maize and grain sorghum. Crops are sown directly into chemically-killed legume pastures which provide both protection from high soil temperatures and a source of mineralizable nitrogen. An understorey of volunteer legume is permitted to establish from hard seed. Cattle graze native grass pastures during the wet season and the volunteer legume pasture and crop residues during the dry season.

While aspects of this proposed cropping system have been tested in agronomic experimentation over several years (3), it is difficult to estimate the cropping potential under this system due to the region's climatic variability. An operational research approach was therefore adopted in order to assess its potential benefits and to determine associated risks. Simulation models calibrated to this environment and run over 100 years of the climate record at Katherine, NT, have been used to demonstrate the overall benefits to crop yields because of pasture mulch protection against high soil temperatures during crop establishment (1). Quantative relationships describing the nitrogen supply to crops from leguminous pasture leys have been developed (J.P. Dimes, unpublished data) and are being used to assess the potential benefits. The competition between a legume pasture understorey and maize crop has been studied experimentally, but the expected yields of maize and legume have yet to be estimated.

In this paper, a model of a maize/legume pasture intercrop is described and tested, and simulations are conducted using 100 years of historical climate data to quantify production potential and risks of this cropping system at Katherine.

METHODS

Model development

A model of the growth and development of *Stylosanthes hamata* (cv. Verano) was developed from data collected from pure legume stands established in irrigated and dryland experimental treatments at Katherine in the 1986/87 wet season (P.S. Carberry, unpublished data). The model uses daily maximum and minimum temperature, incident radiation and rainfall. Potential daily increase in legume biomass (VCARB, g/m^2) is simulated as the product of a radiation use efficiency (0.61 g/MJ) and intercepted total solar radiation. The proportion of intercepted solar radiation is predicted from the light extinction coefficient (0.66) and pasture leaf area index (L). L is set to 0.02 at establishment and is subsequently calculated as the product of total legume biomass and a leaf area to biomass ratio (127.0 cm^2/g). L is reduced by leaf area senescence induced by water deficit (VSEN). Potential L is limited to a maximum value of 3.5.

To assess the effect of water deficit, the soil water balance under pure legume pasture is simulated as described for other crop models (1). Potential transpiration is predicted using VCARB, a transpiration efficiency coefficient (5.0 Pa) and the daily vapour pressure deficit estimated from temperature and radiation data. Plant extractable soil water is dependent on the drained upper limit (DUL) and a plant determined lower limit (VLL) of the soil, the vertical root front velocity (3.0 cm/d), and the maximum soil water deficit (MXSWD), which increases with days after sowing. While DUL remains unchanged for different crops, the legume VLL was considerably lower than for maize or sorghum. The value of MXSWD at flowering represents potential plant extractable soil water in the total soil profile (220 mm for the legume at Katherine). A soil water deficit factor for the legume (SWDFV) declines below a value of 1.0 when the fraction of actual available soil water falls below 30% of potential. Simulated daily transpiration and biomass accumulation are the products of their potential values and SWDFV. Daily increase in VSEN equals the product of (1-SWDFV) and a stress sensitivity coefficient (0.15).

The intercrop model was developed by adding the legume model to the maize crop growth model (1,2) using several assumptions. Firstly, the legume was assumed to establish at maize emergence. Secondly, the legume canopy was assumed to be below the green leaf canopy of the maize crop and so the legume does not shade the maize crop. This assumption is generally correct for experiments at Katherine (P.S. Carberry, unpublished data). Thirdly, the soil water extraction of each crop is simulated in turn, with the order of extraction alternated between maize and legume each day. Finally, at this stage of development, the model assumes the nitrogen status to be optimal for both crops.

Model validation

Predicted grain yields of maize (15.5% moisture) and biomass yields of legume are compared in Figure 1 to observed yields for both intercrop, sole crop and pasture treatments under irrigated and rainfed conditions and for maize populations of either three or six plants/m^2. Essentially, all predictions are true independent validations except for the sole legume treatments which were used to develop the sole legume model. The prediction of maize yields are comparable to previous validations of the maize model (1) and simulations predicted the reductions in yield due to competition from understorey legume (Fig. 1). Predictions of legume biomass were generally close to observed values with intercrop legume biomass correctly predicted at values less than 3000 kg/ha, compared to the irrigated biomass of the pure legume stand of 9000 kg/ha.

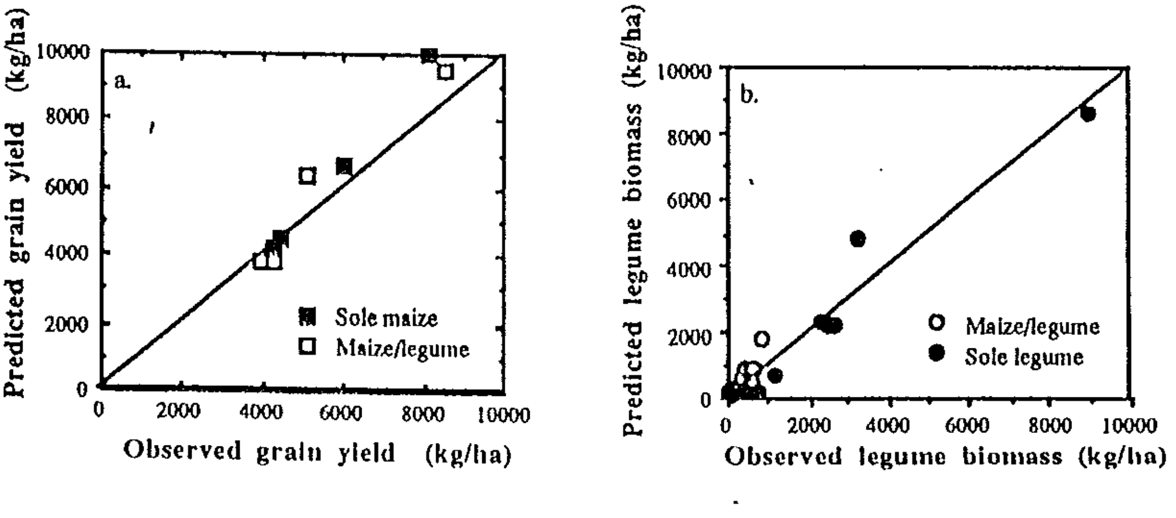

Figure 1. (a) Grain yields predicted for maize grown at two populations and two moisture regimes and as both sole crops and in intercrops versus observed grain yields. (b) Dry weight predicted for legume grown as a pure stand and as an understorey to maize planted at two populations and two moisture regimes *versus* observed biomass.

Model application

The intercrop model was run for the 100 years of Katherine climatic record using the strategy specified in previous risk analysis runs for this environment (1). Briefly, the rule for sowing was 30 mm rainfall in a five day period after 15 December each year. Separate runs were made for sole legume, sole maize and intercrop maize/legume at two maize populations, either three or seven plants/m^2. All runs were conducted under rainfed conditions and reductions in maize plant population, due to either water deficit or high soil temperatures, were simulated. Maize grain yields are reported as oven dry weight. Simulation results are presented as cumulative distribution frequency (CDF) plots which specify the probability (y-axis) of obtaining less than the specified outcome (x-axis).

RESULTS AND DISCUSSION

The yields for sole maize predicted for the years 1889 to 1988 at Katherine varied greatly (mean yield 3770 kg/ha, c.v. 62%). The grain yield distribution for maize crops at Katherine showed the expected response to population with yields greater in good years at the higher population but lower in the poorer seasons (Fig. 2a). The changes in yield for maize grown in an intercrop relative to yield in the same year for sole maize are presented in Figure 2b. In over 80% of years, there was a yield penalty for maize grown with a legume understorey compared to a sole crop. Yield reductions were mostly greater at the lower maize population than at the higher density, due to the higher transmission of radiation to the legume understorey which increased its competitiveness in low maize populations. This conclusion is supported by Figure 3a where the probability distributions for legume biomass increased as the competition from maize is sequentially reduced.

The biomass production of understorey legume is plotted in Figure 3b against the corresponding changes in the grain yields of intercropped maize at three plants/m^2. Large reductions in the grain yield of intercropped maize were generally compensated for by higher levels of legume biomass. For smaller changes in maize yield, the production of legume biomass was quite variable. In a considerable number of years, maize yields remained unchanged and the intercropped legume was able to take advantage of excess resources. In other years, minimal biomass of legume was produced. At seven plants/m^2, reductions in maize yield and production of legume biomass were small in most years (data not presented).

Completion of this assessment of the maize/legume intercrop system requires the assignment of economic values to both products (maize grain, legume forage) to enable comparisons with the alternative sole crop or pasture systems. This will be reported elsewhere.

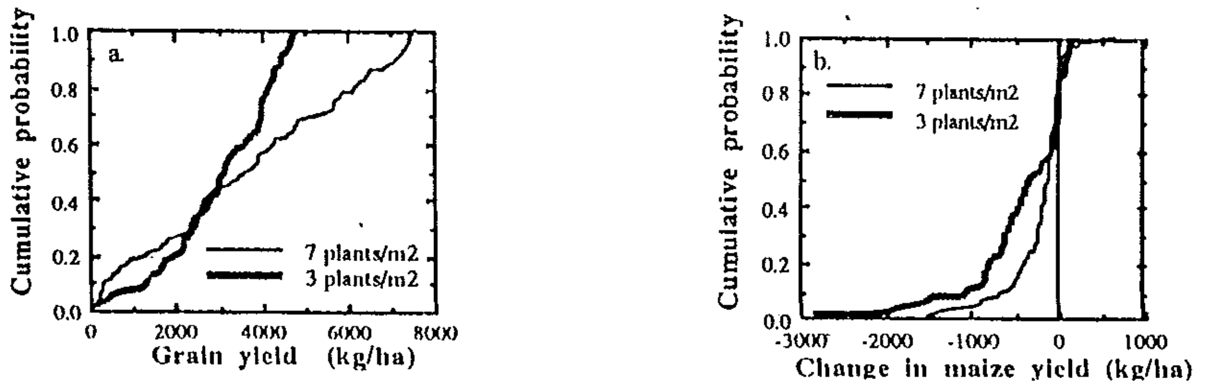

Figure 2. Cumulative disstribution frequencies for (a) grain yield of sole maize, and (b) change in grain yield of intercrop maize relative to yields of sole maize, grown at Katherine at populations of three and seven plants/m^2.

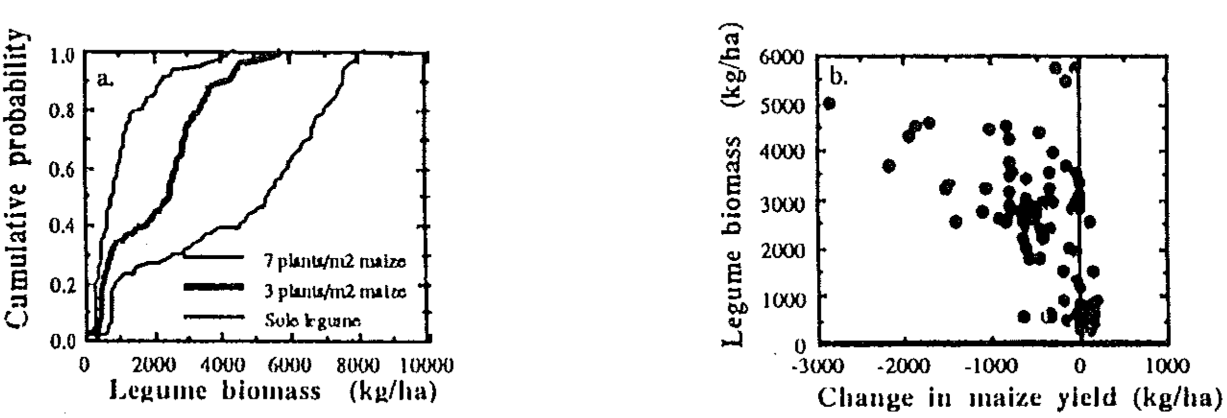

Figure 3. (a) Cumulative distribution frequencies for legume biomass when sown as either a pure stand or as an intercrop at maize populations of three and seven plants/m^2; and (b) understorey legume biomass production *versus* the corresponding changes in the grain yields of intercropped maize sown at three plants/m^2 respectively.

ACKNOWLEDGMENT

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