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EVALUATION OF YIELD STABILITY IN INTERCROPPING:† STUDIES ON SORGHUM/PIGEONPEA

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SUMMARY

Data from 94 experiments on sorghum/pigeonpea intercropping were examined for evidence that the stability of yield is greater with intercropping than sole cropping. Stability of the major component (sorghum) was examined by calculating the distribution of yields; stability of the overall intercropping system was examined by calculating coefficients of variation, by computing regressions of yield against an environmental index, and by estimating the probability of monetary returns falling below given 'disaster' levels. All these approaches have some merit; taking the last as an example, it was found that for a particular 'disaster' level quoted, sole pigeonpea would fail one year in five, sole sorghum one year in eight, but intercropping only one year in thirty-six. Intercropping gave yield advantages under a wide range of environmental conditions and there was no significant evidence that advantages were greater under stress. This is discussed in relation to possible mechanisms contributing to greater yield stability.

It is often suggested that improved stability of yield is one of the major reasons why intercropping continues to be an extremely important practice in many developing areas of the world, especially those areas of greater risk (Aiyer, 1949; Jodha, 1979; Norman, 1974). But as yet there is little quantitative information on the magnitude or practical importance of this improvement; indeed, in many situations there is still considerable doubt as to whether improved stability is actually achieved.

Several mechanisms might bring about improved stability - e.g. if one crop fails, or grows poorly, the other to some extent may compensate; such compensation clearly cannot occur if the crops are grown separately. Fisher (1976) observed such compensation when the maize in some maize/bean intercrops suffered damage due to hail and disease. However, Harwood and Price (1976) have questioned this compensation effect, reporting from their experiments at the International Rice Research Institute that if crop failure occurs later in the season, the subsequent compensation may not offset the earlier intercrop competition, thus arguing that sole cropping might often be a more stable system.

Intercropping could also provide greater stability if its yield advantages, compared with sole cropping, were greater under stress than non-stress conditions, since this would mean that intercropping yields in seasons of stress would not decrease as much as yields of sole crops. Greater yield advantages under stress have often been suggested as a probable effect of intercropping but very little information is available on this aspect and its possible relation with yield stability. This is considered in some detail in the data presented later.

A further mechanism for improving stability could occur where intercropping

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provides a buffer against pests and diseases, for example where one crop acts as a barrier against the spread of a pest or disease of the other crop. The limited available information indicates that pest and disease incidence can be less in certain situations, but greater in others where, for example, the presence of one crop alters the microclimate of the other in a way that favours a pest or disease (Trenbath, 1975). This is a very complex field, in which generalizations are difficult, but it is not considered in any further detail in this paper though it is potentially very important in farming practice.

Most of the quantitative work on stability has been limited to mixtures of genotypes within a given crop, mainly examining the possible benefits of a 'multi-line' approach in what is essentially still a sole crop situation. Trenbath (1974) summarized this work and found that, at best, the improvement in stability was only marginal. Greater improvements might however be expected in a genuine intercropping situation where there are bigger differences between crops; for instance, this seems more likely to give rise to situations where the effects of an adverse environment on the two crops are sufficiently different to allow meaningful compensation by the better growing one. This suggestion is supported by evidence of improved stability in oats/barley intercropping (Daniel, 1955; Morrish, 1934) and in cereal/legume intercropping (Gliemeroth, 1950; Papadakis, 1941).

A further problem of past stability studies is that only limited data have been available. The present paper examines a large body of available data on sorghum/pigeonpea intercropping, which is an extremely important combination in many parts of India (Aiyer, 1949). The farmer's objective with this combination is usually to produce a 'full' yield of sorghum (i.e. as much as a sole sorghum crop) and some 'additional' yield of pigeonpea (Krishnamurthy *et al.*, 1978), which has also been the objective in most of the experimental work.

In general, the concept of improved stability is relatively straightforward and can be fairly simply defined as less variability over different seasons or situations. But quantification of the degree of stability is far from straightforward, and the intercropping system itself poses some special problems. In addition to examining the stability of the important sorghum/pigeonpea combination, therefore, the purpose of this paper is to illustrate some of the methods that might be of general use in intercropping studies.

MATERIALS AND METHODS

Results from 94 experiments carried out during the years 1972–78 were collected from a number of sources (Appendix 1). Fifteen of the experiments did not include sole pigeonpea and another 14 did not include sole sorghum. The optimum intercropping population for each crop is generally held to be the same as its sole crop optimum (Krishnamurthy *et al.*) but only 51 of the experiments

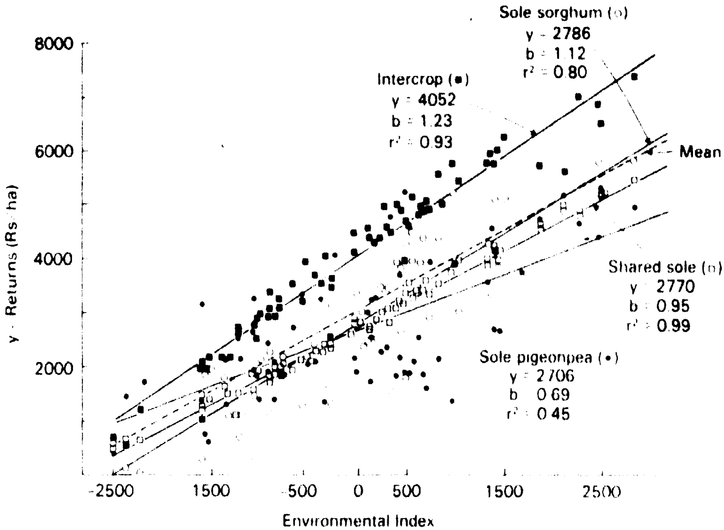

Fig. 6. Regressions of returns on environmental index for sorghum and pigeonpea in different cropping systems (market value Rs 1/kg sorghum, Rs 2/kg pigeonpea).

best aggregate indication of environmental effects. But where the environmental responses of intercrops and sole crops are very different, it can be argued that intercropping effects would be more precisely indicated by using an index based only on the sole crops, since these essentially represent the situation with which intercropping is being compared.

This then raises problems of whether to use only one or both of the sole crops. Where one of the crops has to maintain an intercropping yield equivalent to a full sole crop yield, and where this sole crop is thus effectively the practical alternative to intercropping, it seems reasonable that the index could be based only on this crop. On the other hand, both crops should presumably be included where intercropping aims to achieve some balance of the two crops. It is suggested that in this instance the index should logically be the 'shared sole' situation described above, so that the two crops are given the same weighting as their relative importance in intercropping. As an example, Table 2 gives the regression parameters obtained by fitting the present sorghum/pigeonpea data in this way; comparison with the parameters in Figs 4–6 shows that this approach was little different from basing the index on all the cropping systems.

Despite the possible usefulness of these first two approaches, they leave much to be desired because they still do not indicate in simple practical terms what a given level of 'statistical' stability means to a farmer. On the assumption that a farmer's major concern is to avoid 'disaster' situations, a third approach estimated the probability of each cropping system failing to provide