Dragão FoL 03083

PRIORITIES AND GUIDELINES FOR INTERCROPPING RESEARCH IN NORTH-EAST BRAZIL 1/

M. R. Rao 2/

L. B. Morgado 3/

E. A. Menezes 3/

SUMMARY

The paper outlines the priorities and some guidelines for the future intercropping research in North-east Brazil. The importance of pulling together of all the available information is emphasised to identify promising intercrop situations as well as to understand their stability of performance. More studies are required in the area of crop physiology, genotype evaluation and intercrop response to nutrients, water and their interactions. Attention should be paid to pest and disease aspects in intercropping which so far have been ignored. Finally the need for coordinating the intercropping research in the north-east is stressed.

1/ A paper for presentation at the Ist Brazilian Symposium on Semi-Arid Tropics to be held at Olinda-PE, Brazil. 16-20 August 1982.

2/ Cropping Systems Specialist, Inter-American Institute for Cooperation on Agriculture (IICA), located at CPATSA (EMBRAPA), Petrolina-PE, Brazil.

3/ Researchers, CPATSA (EMBRAPA), Petrolina-PE, Brazil.

PRIORITIES AND GUIDELINES FOR INTERCROPPING RESEARCH IN NORTH-EAST BRAZIL

Intercropping has been an important traditional cropping system in North-East Brazil as in any other rainfed regions of the Semi-Arid Tropics. This is evident to some extent from a socio-economic study conducted by CPATSA in Ouricuri where more than 90% of farm holdings have been observed growing intercrops. As many as twenty seven combinations involving a variety of crops and spatial arrangements have been noted. However, intercropping has not received until recently as much attention as the irrigated cropping systems, mostly because of quick results from irrigated agriculture and the complexity of the traditional systems. However, it is now well recognised that crop production and consequently the living conditions of small farmers in the dry areas can not be raised unless the traditional systems are improved. With this realisation national institutes such as CPATSA and some state enterprises have been conducting intercropping research in the past five to six years,but there is still considerable scope for expanding it systematically. This paper outlines principles, priorities and a program of intercropping research for North-east Brazil in general.

CROP COMBINATIONS

What combinations to work with is often a puzzling question in intercropping because of the number and complexity of the systems seen in farming practice and the difficulty of developing all of them. A logical approach would be to select only a few combinations that are widely grown and possess good yield potential over the sole cropping. It is important to know for these systems the various traditional practices, resource base that determines their adoption and specific farmer objectives if any. Such information can be obtained by farm level surveys, and it would be useful for evaluating the improved systems at a later stage.

The most commonly grown combinations in North-east Brazil are: maize/cowpea, maize/beans, cotton (perennial)/maize/cowpea, cotton (annual)/maize/beans and cassava/others, other systems such as maize/rice, tobaco/cowpea, cotton/cactus, castor/cowpea/maize have regional importance (Willey et al 1981). For immediate benefit and wider applicability of results research programs should include the first five combinations at as many centers as possible on a cooperative basis. The regional centers may have to take up the specific systems relevant to that area simultaneoylsly. The strategy for improvement of any combination should be the same as for the sole crops; this requires crop physiological studies for understanding growth and resource use, agronomic studies to identify optimum populations, spacing, fertilisation and new genotypes and studies on pest problems. However, specific studies related to intercropping are the role of legumes and yield stability.

PHYSIOLOGICAL STUDIES

Intercropping research has fast expanded in many developing countries in the last decade, yet only a few studies have examined the detailed growth and resource use. Those that studied have generally shown that productive intercrops make efficient use of one or more of the growth resources such as light, water and nutrients (Willey 1979; Natarajan and Willey 1980; Reddy and Willey, 1981). Detailed crop physiological studies provide a good understanding of how the component crops grow, compete and complement each other for various resources over time and space. Such an understanding helps not only to know how a particular system outyields monocrops but also where the scope lies for further increasing its productivity by suitable agronomic techniques. To our knowledge, most experiments in the North-east have measured only final yield, and no experiment seems to have made growth analysis. It is high time that some experiments are initiated on 'key' combinations to monitor growth patterns of crops. These require periodical measurements on dry matter, leaf area patterns, rooting patterns, light interception, and water and nutrient uptake. Plant measurements and nutrient uptake can be determined without much difficulty. But light interception,particularly integrated measurements over time,require expensive equipment,and where such measurements are not possible frequent spot readings with simple solarimeters or a T - meter would be helpful. Root studies are laborious and involve the difficult task of separating out root systems of the component crops. If facilities are limited and separation between species is not possible at least one or two core samples may be taken for comparing the combined root growth of intercrops with those of the sole crops. Similarly if continuous monitoring of moisture is not feasible a few gravimetric samplings especially in periods of stress would be worth while.

PLANT POPULATION AND SPACING

This is the most important agronomic practice by which one can manipulate the competitive balance between the component crops in intercropping. Yield-plant population (/spacing) relationships in intercropping are not as straightforward as in sole cropping because of of
the presence of competition between dissimilar crops and changes in populations of both the crops. There are three different aspects of

population viz. total population (combined population of both crops), proportional population (population of each crop) and relative space allocation between the components, all of which are highly interrelated and interacting. Yet it is important to distinguish their effects independent of each other to identify which particular population factor is more important for a given combination.

This area, justifiably, has received more attention than any other area in intercropping research in the North-east Brazil. However, many experiments have used 'replacement series' designs; although these help to sort out the competitive effects, the main disadvantage is that these do not permit independent estimation of various population effects. Moreover, complete information is not always available from the past experiments either because enough treatments were not explored or more than one factor was confounded. But all those provide good basic information which must be pooled together to determine what conclusions can already be drawn and what questions remain to be answered. For population studies 'additive series' designs, where a range of populations of one crop are factorially arranged with a range of populations of the other crop, are much more useful. This is illustrated by the following simple example with castor/sorghum.

System	Populations of castor (plants/ha)		Populations of sorghum (plants/ha)		Treatments
	750	x	75.000		
Intercrop	1.500		150.000	=	9
	3.000		225.000		
Soles	1.500		150.000		2
					11

The row arrangement is constant i.e 1castor:8 sorghum at an uniform row spacing of 50 cm. The sole castor is planted at 4.5 m as in intercropping and sorghum at 50 cm. The populations are established by adjusting within the row spacing. Only two sole plots, one each for the components, are included at the respective sole crop optimum populations. Of course, where no information is available on sole crop optima it is necessary to examine a range of populations in sole cropping as well. Now the treatment setup allows to work out response to population of each component independent of changes in the other and determine optimum populations for both the components. Another advantage of this design is that where appropriate we can put different degrees of emphasis on each component. For example, we can have four populations of castor (750, 1500, 2250 and 3000 plants/ha) instead of three if we wish more precision on castor population curve. Similarly the intercrops can be examined at more than one row arrangement if desirable, and in our example it is worthwhile to study another arrangement of 1 castor : 5 sorghum with the same row spacing (i.e. 50 cm, castor row is at 3 m apart).

Where more factors are to be studied the number of treatments may be too unwieldy to be examined in the conventional experiments in which case systematic designs would be very handy. Many workers have used these designs for intercropping in recent years exploring a number of factors, but these are most appropriate for plant population and spatial arrangement studies. Of the various types of systematic designs available in the literature, parallel row designs are better to provide reasonable harvest area as well as represent normal sowing patterns (Willey and Rao, 1981). In the absence of randomisation analysis of variance (ANOVA) may not be strictly applicable to these designs. But one should not worry too much about ANOVA, and for factors such as population one can fit quantitative relationships using those already proposed for monocrops and/or intercrops to determine optimum populations (Willey and Heath, 1969; Wright, 1981). Of course, these designs require a uniform piece of land, and a newly cleared area would not provide an ideal site.

Improved agronomic practices at the farm level may have to be combined with the improved practices of land and water management(e.g.150-cm bed and furrow system) or a machinery system (e.g. tropicultor).Moreover, the farmer may not take up a particular spatial arrangement unless he can plant it with his traditional implement. Therefore, the crop management systems should interact with other production factor at some stage of development. It does not mean that all small-plot agronomic experiments have to be conducted on broad beds or planted with tropicultor but some consideration has to be given at planning stage itself such that when a promising practice is identified it can be easily adapted to broad beds or an implement without the necessity of being retested. The two row arrangements of castor/sorghum described earlier can be established on broad beds with tropicultor without much problem. Castor is placed at the center of the bed and sorghum is planted on either side at 45 cm, and such a bed can be alternated with one or two beds of three rows of sorghum to give 1:5 or 1:8 arrangements respectively.

Population requirements may change with the level of other inputs, particularly moisture and nutrients, and genotypes. Information should not be lacking when a new genotype is introduced or when the technology has to be extended to a new place. There is thus a need for conducting plant population/spacing studies in conjunction with moisture, nutrients and genotypes of different plant types. In this respect setting up of some cooperative multilocation studies with the state enterprises is ideal to build up information quickly for a range of situations in the North-east Brazil.

Intercropping with long season and semi-perennial crops such as cassava, castor, cotton, and cactus is very common in the dry areas but studies with these crops are few compared to maize/beans or cowpea. These crops require a wide spacing, though initially are slow growing. The inter-row space can be used for one or more intercrops as is the common practice. Of course,the there-crop systems are complex and should be pursued only if there is a definite advantage over two-crop system. Crops such as perennial cotton, castor and cactus are at present intercropped only in the first year, but the prospects of intercropping these in the subsequent years need to be examined. While initiating such long term studies it is very important to make room for new treatments as and when necessary. To sort out the seasonal effects and for quick results it is equally important to initiate the experiment in two consecutive years instead of waiting until the completion of first cycle of the experiment.

RESPONSE TO NUTRIENTS AND WATER

Soils in North-East Brazil are very low in nitrogen and phosphorus, yet responses to fertilisation have been very inconsistent. Of course these problems are of general nature and not specific to intercropping. Fertiliser studies are important to understand how intercrops respond to nutrients and at what fertility level the farmer is likely to get maximum intercropping advantage. The general beleif has been that intercropping is advantageous only under poorer fertility and it becomes less important at high fertility. Recent studies have dispelled such doubts; though the relative advantage showed some decrease, the absolute advantage still increased with fertilisation (IRRI, 1975; Rao _et al_ 1979, Rego, 1981).

Few studies have been conducted at CPATSA and even these have used limited levels of fertility. Future studies should examine more levels to work out response curves and determine optimum level of fertilisation.

When dealing with intercrops, we must also address the questions which crop has to be fertilised by what nutrient and how? These questions are particularly relevant when the fertiliser response of the component crops differ widely(eg. cereal/legume). The general observation is to apply phosphate basally to both the crops and restrict nitrogen to the non-legume component. Spatial arrangement x nitrogen studies may be useful to find out efficient method of N application to the non-legume. For example, nitrogen recovery by corn in a corn/soybean intercrop planted in an alternate double row system was 52% compared to 35% in an altermate single row system. The intercropped soybean in double rows recovered less than one fourth of that recovered by soybean in the alternate row system (3% vs 12%). This was because the double row system, unlike the alternate row system, permitted nitrogen application away from soybean between paired rows of corn (MacCollum, 1982).

A further question to be considered is the role of legumes in intercropping, especially to what extent legumes contribute to the nitrogen economy of the cereal. Legumes in intercropping may benefit the associated crop during the growing season (current effect) and/or benefit the subsequent crops in rotation (residual benefit). Though field-scale experiments have given contradicting results on current season transfer (Singh, 1977; Ahmed and Rao, 1982; Kassam, 1972; Agboola and Fayemi, 1972), many studies have shown substantial residual benefits of legumes (Agboola and Fayemi, 1972; Giri and De 1979, Lal et al 1978, ICRISAT 1980). However, intercropping with competitive crops can reduce N_2-fixation by legumes and consequently affect their residual benefits (Nambiar et al 1982). These aspects need proper quantification for working out judicious fertiliser shedules in legume/non-legume systems. N_2- fixation studies would require the active participation of a microbiologist but in his absence periodical observations on nodule number and nodule weights should be taken to get some information on this aspect.

How the intercrop responses are affected by the availability of moisture is a pertinent question to be examined. in SAT. In combinations such as sorghum/pigeonpea,where the component crops mature at different times, the relative intercrop advantage is less likely to be affected by different levels of water compared to that in combinations such as raddish/sunflower, millet/groundunt etc,where both the crops mature very closely (Rao and Willey, 1980, Willey, 1979). The latter systems have in fact showed relatively high advantage under stress conditions compared. to non-stress conditions. In the North-east Brazil where drought is frequent relationships between intercrop performance and water application are crucial to understand i) whether intercrops offer any insurance against drought, ii) critical periods for supplemental irrigation and iii) what modifications the recommended practices require for irrigated conditions. The latter two points are particularly important in the context of watershed and runoff recycling concept that the CPATSA has been pursuing for this region. A worthwhile approach would be to examine different intercrops under a range of moisture regimes and derive water productions functions. The CPATSA center offers an excellent opportunity because of its locations in dry area, and the experiments can be conducted in both the rainy and summer seasons, though control on water application is much easy in summer. The line-source sprinkler technique to create a moisture gradient needs to be explored.

Response to nutrients and water can not always be treated indipendently for, nutrient responses are highly modified by water supply. For example, sorghum in a sorghum/pigeonpea intercropping study at ICRISAT responded upto 120 kg N/ha in a good year (1978) but the response was limited to 80 kg N in a near normal year (1979) and to a much lower level of 40 kg N in a dry year (1980) ICRISAT, 1980). In another ongoing experiment at ICRISAT, fertilised sorghum (100 kg N/ha) failed to produce any yield under severe stress whereas unfertilised crop gave at least some yield (unpublished data). Stress within a year at critical stage can affect crop response to nutrients. Lack of adequate moisture could be one of the reasons for poor responses in the North-east, though other factors might have also been involved. We strongly feel that some studies involving nutrients x water interactions should simultaneously be conducted with the above.

GENOTYPE EVALUATION

Genopype evaluation in intercropping is as important as in sole cropping. Genopypes for intercropping have to be selected not only based on their individual performance but also based on how they affect genotypes of the other component. Andrews (1974) observed greater yield advantage from short and improved genotypes than with the traditional cultivars in a sorghum/millet intercropping. Similarly intercropping of pigeonpea with new, short and early maturing sorghum cultivars was much more advantageous than with the traditional tall cultivars (ICRISAT, 1980). Wein and Nangju (1976) reported that erect and determinate cowpeas had less competitive effect on maize compared to some indeterminate cultivars.

Generally intercrop yield of the dominant species have shown good correlation with sole crop yields but correlations were poor for the dominated species (Baker, 1974; Finlay, 1974; Francis et al 1975). Characters that are not associated with yield reduction but would reduce competition on the other component are prefered for dominant species. On the other hand efforts should be to select genotypes with specific plant characters in the case of dominated species, e.g., spreading pigeonpeas for sorghum/pigeonpea, and erect, determinate and shade tolerant genotypes of low canopy legumes (cowpea, groundnut etc) for intercropping with tall cereals.

Few studies have used large numbers of genotypes, but majority of them have emphasised the need for genotype evaluation in intercropping. Rao et al (1981) observed that selection of pigeonpeas under sole cropping at a pressure of, say 33%, was only 55% effective for intercropping, i.e only 55% of the genotypes identified in sole cropping were those identified in intercropping. Similarly, in another study at ICRISAT center that examined twenty five sorghum genotypes in sole and intercropping with cowpea, the system x genotype interaction was highly significant indicating the need for selecting sorghums specifically for intercropping (ICRISAT unpublished data). On the contrary, Francis et al (1978 a & b) emphasised the advantage of sole crop selection for beans because of high yields and greater yield differences and for convenience.

To date genotype studies in North-East Brazil are few, and at CPATSA studies have confined only to maize/cowpea. The approach has been to evaluate a range of genotypes of one crop against a standard genotype of the other crop. Similar studies have to be extended to other combinations of genotypes and all of them should include more number of genotypes having contrasting characters. There is also a need for some combined evaluation of genotypes of both crops in order that interactions between genotypes are not neglected. All these studies should aim to identify i) the scope of genotype selection for intercropping ii) plant characters associated with better intercrop performance and iii) whether sole crop selection is valid for intercropping or genotypes have to be specifically bred for intercropping. This would involve more detailed characterisation of genotypes as well as attempts to correlate different plant characters with intercrop performance to gain an understanding of which charactes are involved and what their relative importance is likely to be. If specific characters are identified they can be useful for selection of genotypes even under sole cropping. The genotype studies require establishing links with the crop improvement programs of different commodity centers(e.g. cotton, maize, beans etc) so that improved material can freely become available for evaluation in intercropping before final release.

YIELD STABILITY IN INTERCROPPING

It is frequently mentioned that greater stability of yield is one of the major reasons why farmers in the semi-arid tropics practise intercropping. A few studies have examined this aspect in mixtures of genotypes (Trenbath, 1974) but there is very limited understanding of intercrop systems having dissimilar crops. This is because of (i) the lack of enough experimental data for any given combination covering a range of agroclimatic situations and (ii) the lack of appropriate methods for evaluating the complex intercrop systems. Recently Rao and Willey (1980) have studied the stability of sorghum/pigeonpea intercrop adapting some of the breeder's techniques of commomly used in genotype evaluation. Their method of calculating the probability of failure of different systems to produce a specified 'disaster' level of income has been particularly useful in quantifying the risk associated with different systems. Their studies on sorghum/pigeonpea showed that, for an example level of Rs 1000/ha, sole pigeonpea would fail approximately one year in five, sole sorghum one year in eight, shared sole system one year in thirteen, but intercropping one year in thirty six. Similar studies in maize/beans (Francis et al 1978) and sorghum/groundnut (Baker, 1980) have indicated greater stability for intercropping.

The intercrop may acheive greater stability by one or more of the follwing: (i) if one crops fails because of stress, pest or disease the other crop may compensate and at any time there may not be a total crop failure (ii) by producing heigher yield advantage under stress conditions (water or nutrients) and iii) by acting as a buffer against pest and diseases i.e, one crop acts as a barrier for the spread of pests or diseases of the other. Fisher (1976) has reported a clear case of compensation in maize/beans; when maize at one site had suffered from hail damage and disease the beans compensated and resulted in a LER of 1.87. At two other sites where normal conditions prevailed LERs were only 1.08 and 1.24. However, ever, Harwood and Price (1975) expressed doubts about greater stability in intercropping because crop failure in their experiments was observed after considerable competition had occurred leaving less scope for compensation.

In any case there is an urgent need to study how much stable the current intercropping systems are and how the different improved practices compare with the stability of the traditional practices. At present studies in this direction are under way in the Northeast Brazil. However, there is a wealth of data already available from the past research could provide a useful basis for future work. Therefore the approach could be:

1) collect available data on 'key' combinations that have been examined in the past 5-6 seasons (eg. maize/beans, maize/cowpea) and make use of that data for stability analysis. These studies may have the limitation that some times basic information on soil and climate may not be available or there is no uniformity in varieties, populations, arrangements and general management across experiments.

2) initiate simple multilocation experiments involving major intercrop systems. These need to be conducted for atleast 4-5 seasons over a range of widely differing locations in cooperation with the state enterprises. It is essential to collect in these experiments a 'standard set of data' at all locations to enable pooled analysis and proper interpretation. The combinations that can be considered are cereal/legume, and two-and three-crop systems based on castor, cotton and cassava. The cereal could be maize or sorghum and the legume could be cowpea or beans depending on the local importance.

PLANT PROTECTION

There is very little information in Northeast Brazil on how intercropping affects the incidence of pests, diseases and weeds. Many of the rainfed crops here do not have major pest problems, but still this area in relation to intercropping can not be completely ignored because the experience in other parts of the world suggests that intercropping can substantially modify the pest problems (Willey et al 1981). It is important to identify the beneficial situations to fully exploit them particularly in places such as Northeast Brazil where chemical control methods are beyond the reach of small farmers. To begin with separate experiments may not be required on pests but entomologists and pathologists should be encouraged to take observations in the already established agronomic experiments. For the purpose of observations under natural infestation, one or two additional replications without any plant protection may be included in such trials. Where specific problems are identified separate field studies may be required to deal with them.

POTENTIAL OF NEW CROPS/CROP COMBINATIONS:

Maize is the only staple cereal grown throughout the Northeast but this being a sensitive crop to moisture stress fails often in the very dry areas. Sorghum and parlmillet seem to be good alternatives for poor and unstable rainfall area of 'sertão'. Some work carried out in other parts of the Northeast has indicated that maize can be substituted by sorghum in the traditional systems (Mafra *et al* 1981). Sorghum and millet may not be readily accepted by farmers as food crops but still they are better than maize to ensure at least stable feed and fodder to the animals which is equally an important issue. Among other arable crops, early to medium maturing pigeonpeas (120-150 days, *Cajanus cajan*), mungbean (60-70 days, *Phaseolus aureus*) guar or cluster beans (70-80 days, *Cyamopsis tetragonaloba*) sesame (70-80 days, *Sesamum indicum*), Chickpea (90-120 days, *Cicer arietinum*) and safflower (100-110 days, *Carthamus tinctorius*) may have some potential. Chickpea and safflower prefer cool season, so these may be possible only where there is some available moisture during the winter period. The best answer to these possibilities is to examine them in preliminary experiments.

experiments.

COORDINATION OF INTERCROPPING RESEARCH IN NORTHEAST BRAZIL

At present manycenters are conducting intercropping research in Northeast Brazil indépendently; while some have good programs others have not progressed so well. We feel that there is much to gain if all the centers work together cooperatively under one umbrella. A center like CPATSA with its national importance and logistic facilities should be able to shoulder the responsibility of coordinating the work. Such a coordination is advantageous to:

1. initiate multilocation experiments on a common program,the results of which can be pooled and summarised for broadbased recommendations,
2. build up information quickly covering a range of situations on any particular area of research, and
3. share the expertise, resources and results of the participating centers.

For the coordinated work to be successful intercropping specialists of all the centers should be involved in the program from planning stage itself.and they in turn should cooperate fully. An annual meeting with all the cooperators is desirable to disscuss previous results and develop work plans for the future. The coordinated program may not satisfy the needs of all the agroclimatic enviroments in the Northeast. In such cases, as mentioned earlier, the region-specific problems have to be met by the respective state institutes.

REFERENCES

AGBOOLA, A.A. and FAYEMI, A.A., 1972. Fixation and excretion of nitrogen by tropical legumes. Agron. J. 64: 409-412.

AHMED, S. and RAO, M.R. 1982. Performance of maize-soybean combination in tropical and semi-arid areas. Field Crops Research (In press).

ANDREWS, D.J. 1974. Responses of sorghum varieties to intercropping Expl. Agric. 10: 57-63.

BAKER, E.F.I. 1974. Research on mixed cropping with cereals in Nigerian farming systems - a system for improvement. In: Proc. International Workshop on Farming Systems.18-21 November, ICRISAT, Hyderabad. pp. 287-301.

BAKER, E.F.I. 1980. Mixed cropping in Northern Nigeria. IV. Extended trials with cereals and groundnuts. Expl. Agric. 16: 361-370.

FINLAY, R.C. 1974. Intercropping soybeans with cereals. In: Proc. Regional Soybean Conference. 14-17 October, Addis Ababa, Ethiopia.

FISHER, N.M. 1976. Experiments with maize-bean and maize-potato mixed crops in an area with two short seasons in the highland of Kenya. In: Proc. Symposium on Intercropping in Semi-Arid Areas, 10-12 May. Morogoro, Tanzania.

FRANCIS, C.A., FLOR, C.A. and TEMPLE, S.R. 1975. Adapting varieties for intercropped systems in the tropics. In: Proc. Multiple Cropping Symposium. American Soc. of Agron. Annual Meeting, Knoxville, Tennesse 24-29 August.

FRANCIS, C.A. PRAGER, M.; LAING, D.R.; FLOR, C.A. 1978a. Genotype x environment interactions in bush bean cultivars in monoculture and associated with maize. Crop Science 18: 237-242.

18: 237-242.

McCOLLUM, R.E. 1982. Dynamics of soil nutrients in multiple cropping systems in relation to efficient use of fertilisers. Presented at F.A.O. Meeting 'Expert Consultation on Fertiliser Use Under Multiple Cropping Systems' March 1982. New Delhi.

NAMBIAR, P.T.C.; RAO, M.R.; REDDY, M.S.; FLOYD, C.N.; DART, P.J. and WILLEY, R.W. 1982. Nitrogen fixation by groundnuts in intercropping with cereals. Experimental Agriculture (In press).

NATARAJAN, M. and WILLEY, R.W. 1980. Sorghum-pigeonpea intercropping and the effects of plant population density. 2. Resource use. J. Agric. Sci. Camb. 95; 59-65.

RAO, M.R.; AHMED, S.; GUNASENA, H.P.M. and ALCANTARA, A. 1979. Multi-locational evaluation of productivity and stability of some cereal-legume intercropping systems. A review of INPUTS trial III In: Proceedings of III INPUTS Review Meeting September 1979. East-West Center, Honolulu, Hawai.

RAO, M.R. and WILLEY, R.W. 1980. Evaluation of yield stability in intercropping: studies with Sorghum/pigeonpea. Expl. Agric. 16: 105-116.

RAO, M.R.; WILLEY, R.W.; SHARMA, D. and GREEN, J.M. 1981. Pigeonpea genotype evaluation for intercropping. In: Proc. International Workshop on Pigeonpeas. Vol. 2: 263-270. 15-19 Dec. 1980.

REDDY, M.S. and WILLEY, R.W. 1981. A field technique for separating above and below ground interactions in intercropping: An experiment with pearlmillet/groundnut. Expl. Agric. 17: 257-264.

REGO, T.J. 1981. Nitrogen response studies of intercropped sorghum. In: Proc. International Workshop on Intercropping. 10-13 Jan. ICRISAT. Hyderabad, India. pp. 210-216.

SINGH, S.P. 1977. Intercropping and double cropping studies in grain sorghum. Presented at the International Sorghum Workshop, March 6-12, ICRISAT, Hyderabad, India.

TRENBATH, B.R. 1974. Biomas productivity of mixtures. Advances in Agronomy. 26: 177-210.

WEIN, H.C. and NANGJU, D. 1976. The cowpea as an intercrop under cereals. In: Symposium on Intercropping in Semi Arid Areas, 10-12, May, Morogoro, Tanzania.

WILLEY, R.W. 1979 - Intercropping - its importance and research needs. 1. Competition and yield advantages, 2. Agronomy and research approaches. Field Crops Abstracts 32: 1-10, 73-85.

WILLEY, R.W., LAL, R. and FARIS, M.A. 1981. Relatório de consultoria: Empresa Pernambucana de Pesquisa Agropecuária, Recife, Pernambuco. 18 pp.

WILLEY, R.W. and HEATH, S.B. 1969. The quantitative relationships between plant population and crop yield. Advances in Agron. 21:281-321.

WILLEY, R.W. and RAO, M.R. 1981. A systematic design to examine effects of plant population and spatial arrangement in intercropping, illustrated by an experiment on chickpea/saffower. Expl. Agric. 17: 63-73.

WILLEY, R.W.; RAO. M.R. and NATARAJAN, M. 1981. Traditional cropping systems with pigeonpea and their improvement. In: Proc. International Workshop on Pigeonpeas. Vol. 1, 15-19 Dec. 1980. ICRISAT Center, Patancheru, A.P. India.

WRIGHT, A.J. 1981. The analysis of yield-density relationships in binary mixtures using inverse polynomials. J. Agric. Sci. Camb. 96, 561-567.

MRR/mia.