1093 92 - 4/136

Cropping systems
Africa, Nigeria, semi-humid region, savanna zone, maize variety, legumes, agroforestry

IITA

A NEW MAIZE MODERNIZES SAVANNA FARMING.

In: IITA 1990; Publ. of the Int.Inst. of Trop. Agriculture, (IITA), Nigeria, 1990, pp. 5-8

A new maize has broken the mode of agriculture in northern Nigeria, enabling farmers to begin modernizing their age-old practices with intensified farming.
Agricultural procutivity has improved markedly in the most savanna zone of northern Nigeria. Recent surveys there by IITA and the Institute for Agricultural Research (IAR) have shown increases in use of improved maize, fertilizer, and improved management practices, such as animal traction and effective weeding, as fallow periods have become abbreviated.
IITA has developed a high-yielding maize variety, TZB, by building on two composite breeding lines of Nigeria's Federal Department of Agricultural Research. In experimental trials the new variety yielded consistently one-and-a-half to two times as much as local varieties. Also, it was resistant to the fungal diseases of rust, blight, and ear rot, and highly adapted to growing conditions in the savanna.
The agricultural development projects introduced TZB to northern farmers and demonstrated how to obtain high yields.
Maize has become a major food crop in virtually all villages, and a major cash crop in more than two-thirds of them.
Sorghum, traditionally the favorite food crop, is still planted over a greater area than maize. However, since TZB outyields local varieties of sorghum and millet, the other staple cereals in the region, TZB can reduce the land requirement for feeding farmers' families. Many farmers have found that, by growing TZB for household consumption, they can free additional land for cash crops. With the surplus over food needs being marketed, farmers have increased their cash income which they can use to reinvest in cash crop production.
The characteristics which enabled TZB to make farming so commercially viable are its high yields and attractive appearance. Experiments on farmers' fields show that TZB, with moderate levels of fertilizer, yields 21-115% more than local maize. Its grain quality, with a white color and resistance to the ear rot, make it compatible with local food preferences.
The question of sustaining intensification, moreover, spotlights two distinct and critical issues: economic sustainability, in terms of the profitability of maize production; and environmental sustainability, in keeping up soil fertility and keeping down pests and diseases.

Environmental sustainability becomes a problem when cereals dominate the cropping regime, as sorghum and maize do in the savanna. Cereal dominance drains the soil of nutrients, because cereals demand a high level of soil fertility to be productive. And cereal dominance leads to a build-up of specific pests - insects, fungal diseases, nematodes, the parasitic weed striga, among others - because a similar pest and disease complex preys on all cereals. An ominous threat lies in the proximity of sorghum, historically striga's main host, with maize, also highly susceptible. The combination appears to be hastening the spread of the pest.
Several research institutes have joined to explore ways to help promote sustainability by expanding the role of nitrogen-fixing legumes in the cropping system. Legumes restore soil fertility with nitrogen from their residues or direct deposits.

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Cropping systems
Asia, Thailand, study, field trials, environmental effects, crop adaptation, genotype component, soybean varieties, yield evaluation

IVORY, D.A. et al.

ANALYSIS OF THE ENVIRONMENTAL COMPONENT OF GENOTYPE X ENVIRONMENT INTERACTION IN CROP ADAPTATION EVALUATION.

Field Crops Res., 28, 1991, pp. 71-84

In this paper, emphasis is given to the methodology of analysing and interpreting the environmental component of genotype (G) x environmental (E) interaction analysis using seed yield data from the on-farm evaluation of six soybean lines grown in 19 environments throughout the major soybean-growing areas in Thailand.
The relative performance of plant genotypes or lines is commonly found to vary in different environments, due to the interaction of genetic and non-genetic factors. This genotype by environment (G X E) interaction confounds comparisons of genotypes with the environments used for plant yield evaluation, and complicates the selection of lines for release as commercial varieties, recommendations of cultivars for particular environments or the definition of future breeding objectives. Effective plant improvement depends on an understanding of G X E interaction.
Various methods have been used for detecting and characterizing G X E interactions.
A basic objective of the regression approach is to identify systematic variation in performance in G X E matrices, but it is only informative where G X E interactions are linearly associated with an environmental index - often not the case in crop variety trials.
Another technique used for the investigation of systematic response or pattern in G X E matrices is cluster analysis, or numerical classification.
This method has been seen as useful in summarizing patterns of genotypic performance and environmental productivity.
There has been less attention given to the methodology used to improve or simplify the interpretation of the differential response of genotypes in different environments and the environmental factors which are causing differential genotype responses in different environments.
The use of genotype yield deviations from environmental mean yield as a measure of the G X E effect in pattern analysis, and their representation in bar graphs has proved very effective in separating differential soybean line responses in different environments in Thailand. The two methods enhanced the description of the way each of the line responses differed across the environments in which they were grown.

In the soybean farm trials, biotic factors had little influence on crop yield, due to the low incidence of diseases and insect pests, and the soybeans were irrigated in the dry season. In these circumstances, differences in environment mean seed yield should be mainly related to the fertility status of the location. The classification of environments based on mean seed yield showed no particular geographic distribution, which indicated that differences in mean yield were location-specific and probably due to differences in such things as soil fertility or the moisture environment.
It has been clearly demonstrated that recommendations can be made to farmers on the best line to grow in different regions, viz., CM60 in the north and northeast and 7608 in the lower north, west and central region. It is also apparent that the promising soybean line 7608 should be released as a new cultivar because of its widespread superiority to all other cultivars in the southern regions. In addition, regional recommendations can be made for a second "back-up" cultivar, where it is felt that there may be insufficient seed supplies of the premier cultivar available to farmers for planting.

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Cropping systems
Asia, India, review, semiarid tropics, ICRISAT, cropping systems, climatic analysis

VIRMANI, S.M.

CLIMATIC ANALYSES AND CROPPING SYSTEMS IN THE SEMIARID TROPICS.

In: Weather and Rice; Proc. of an Int. Workshop on the Impact of Weather Parameters on Growth and Yield of Rice; Publ. of IRRI, Los Baños, Philippines, 1987, pp. 215-220.

Climate and agriculture are intimately related. Both long-term meteorological factors (climate) and short-term meteorological events (weather) affect crop growth, development, and production. Studies of climate help understand crop production and other land use patterns that have evolved over a long period of time and assist in introducing new and more productive farming systems. At ICRISAT the relevance of climatic environment to the development of improved cropping systems for semiarid tropical areas are studied.
Semiarid tropical (SAT) areas are defined as those regions that have a mean annual temperature exceeding 18°C and mean monthly rainfall exceeding mean monthly potential evapotranspiration for 2-4.5 consecutive months in the dry SAT and 4.5-7 month in the wet/dry SAT.
Precipitation is characterized by annual and seasonal variability. the coefficient of variation for annual rainfall is 20-30%. Even within the rainy season, droughts of varying durations are common. The major climatic constraint to crops in the tropics is lack of adequate water. Against a continuing evaporative demand, the supply is discontinuous and variable, particularly in the drylands.
To cope with the variable climate, farmers tend to grow a mixture of crops. They usually include long-duration crops in their cropping systems.
Traditionally, the SAT areas have had agropastoral, silvipastoral, and agroforestry production patterns. Cultivation had been mainly restricted to dryland crops, with a crop or two of rice in the lowlands or where irrigation water is available. With large population increases in recent years, most of the land is now sown to crops; the area under forests and grasslands is rapidly decreasing. Soil erosion has increased tremendously and surface waterstorage systems have lost much of their effective storage capacity. Crop production is much more variable in both drylands and irrigated areas. Average crop production from the drylands does not exceed 0.7 t/ha a year in most of the SAT.
Agroclimatic analysis helps define the recommendation domain for transferring technology from the research center to farmers' fields.
An efficient cropping system is determined largely by climatic, and management factors. A more complete quantification of the

temporal and spatial distributions of natural resources is a key factor in assessing the agricultural production potential of a region. Mapping the agroclimate of an area in relation to its resources could give the recommendation parameters for improved cropping systems or farming systems technology.
A map of semiarid India showing the suitability of areas for the adoption of improved technology has been prepared.

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Cropping systems
Africa, tropics, review, book, field crops production, agronomic practices, climatic factors, soil fertility, irrigation, drainage, cereals, roots, tubers, grain legumes, oilseed crops, fibre crops, beverages, CTA

ONWUEME, I.C. and T.D. SINHA

FIELD CROP PRODUCTION IN TROPICAL AFRICA.

Publ. of the Centre Technique de Cooperation Agricole et Rurale (CTA), Postbus 380, 6700 A.J. Wageningen, Netherlands; ISBN 92-9081-086-6; 1991; available from CTA, Netherlands

A new CTA publication 'Field crop production in tropical Africa' by I.C. Onwueme and T.D. Sinha brings progress in scientific research and practice in crop production within the easy reach of students of agriculture. It provides a comprehensive text for an introductory course in field crop production and combines detailed treatment of agronomic principles with a crop-by-crop treatment of the major field crops of tropical Africa.
The authors explain that the most important phase in the history of the dispersal of crops from their centres of origin to other parts of the world followed the enormous expansion of world trade during the sixteenth and seventeenth centuries. During the sixteenth century New World crops (i.e. crops indigenous to the Americas) such as maize, groundnuts, sweet potatoes, potatoes, tomatoes and cassava were introduced to other parts of the tropics. The most recent developments in the dispersal of crops have been associated with the expansion of international agricultural research. Although there are relatively few indigenous plants of outstanding economic value in Africa, there are now many introduced crops which have been accepted and are grown on a large scale.
Part I of the book looks at agronomic practices generally and particularly at climatic factors, soil fertility and conservation, irrigation and drainage. Part II covers each crop in detail within categories such as cereals, roots and tubers, grain legumes, oilseed crops, and fibre crops. Sugarcane, tobacco, tea, coffee, cocoa and para rubber are also covered. Botanical descriptions of each crop are followed by details of cultivation and crop protection methods. The book is illustrated with line drawings and black-and-white photographs. Although the book is written mainly for undergraduate students, it may also be useful to postgraduate students of agronomy, research workers, agricultural extension officers and progressive farmers.

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Cropping systems
Review, book, tropics, subtropics, crops, plants, cultivation, economic value, utilization, IAT, CTA

REHM, S. and G. ESPIG

THE CULTIVATED PLANTS OF THE TROPICS AND SUBTROPICS.

Verlag Josef Markgraf, Weikersheim in cooperation with CTA, Wageningen; ISBN 3-8236-1169-0, 1991, 552 p.

This book is the translation of the well known original German edition: "Die Kulturpflanzen der Tropen und Subtropen".
The original German edition of this book was based on the lectures of the senior author (S.R.) at Göttingen University and on the documentation on tropical crops collected by G.E.
The number of plants which are cultivated in the tropics and subtropics is very large. About 2,500 species have been named, excluding ornamental and forest plants; this number includes the cultivated plants of the temperate zone, and some close relatives of the species cultivated.
The wealth of plants is far from being fully exploited and harbours genetic resources on a much larger scale than today used.
More than 1,000 plants are discussed in this pocket manual.
World trade, the drive for exports, and the transition to rational production procedures are nowadays the causes of rapidly progressing changes in plant cultivation in the tropics and subtropics.
The main concerns of the authors in this book are to comprehend these changes, to exclude obsolete plants, to indicate new developments, and to consider the economic importance of each plant.
With regard to the scientific nomenclature of plants, the authors endeavoured to use the names which are valid according to the International Code. Where plants are still frequently cited in the literature under a name which is no longer valid, the most synonym has been given and if necessary, two synonyms.
It seemed desirable to give the common names of plants also in several of the world's most important languages, because the scientific names of the plants are not always given in the foreign literatures.
Botanical particulars (morphology, anatomy, physiology) have been limited to the features which are important for the agronomist. It has been impossible to present the multitude of agricultural methods and possibilities. The book is limited to emphasizing the most basically important and generally valid aspects.
Detailed advice about fertilizers has been omitted because of the extraordinary differences in soil types found in the tropics and subtropics.
Diseases and pests have been reviewed in as much as they cause severe damage and are of more than regional importance.
The book is organized in the following way:

Each chapter begins with an introduction to the particular properties of the plant group, giving an overview on the economics, production trends, nutritional aspects, chemistry, and technological features. The major crops are treated in detail. With regard to these, the authors sought to cover all essential points: production, botany, breeding, ecophysiology, cultivation practices, diseases and pests, processing and utilization. The numerous minor or only locally important crops were collected in the tables; these give the valid botanical name of each plant, a selection of its vernacular names, and indicate its distribution, economic importance and uses. The drawings help to identify the plants and depict important morphological peculiarities. The diagrams illustrating the production during the last ten years are intended to offer visual information on the relative importance of a crop and on current trends.
As a key to available information, a large number of references to all the species included has been given. In selecting the quotations the authors aimed at covering all aspects of production and utilization, and all regions of the tropics and subtropics.
All information on the plants dealt with in this book is available off-line from a continuously updated data bank for cultivated plants and relevant literature.
The book will be of use to undergraduates, graduates and practioners involved in plant sciences or other looking to extend their general awareness of this exciting area.
Clearly written in a precise form and well illustrated, with an extensive bibliography, this book is an excellent source of information.
The book is therefore highly recommended to all interested in tropical agriculture.

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Cropping systems
Review, software system, package, starter data-files, handbook, plant growth, growth prediction, plant species, soils, climates, lesser-known crops, trees

CSIRO

SOFTWARE SYSTEM FOR PLANT GROWTH PREDICTION.

CSIRO Publications, 314 Albert Street, East Melbourne, Victoria 3002, Australia; 1992

Farmers have predicted plant growth according to their experience for thousands of years. Now a new software system, PLANTGRO, combines this experience with modern scientific techniques to provide new ways of predicting the growth of hundreds of plant species, including some lesser-known plants.
The PLANTGRO package, which was designed by the Division of Tropical Crops and Pastures of the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO), comes with a handbook which uses a simple skill-rating system.
It encourages users to go at their own pace. In this way, people who have a strong feeling for plants but have little contact with computers or formal plant science, quickly realise that their expertise is valuable and can be recorded. The package provides starter data-files for 60 plants, 30 soils and 40 climates.
PLANTGRO can be used in numerous contexts. For farmers, foresters and rural advisers, it provides an on-the-spot means of thinking about new land-use options. For planners at higher levels who use computerized resource information systems, it represents an add-on package which can give life to soil and climate data held in store. And for those struggling to integrate scraps of information about lesser-known plants, it provides procedures for almost every situation.
Crops covered include banana, cashew, cassava, cocoa, coconut, coffee, cowpea, kenaf, lentil, maize, oil palm, pineapple, potato, rubber, soybean, sugarcane, sweet potato, taro, wheat and yam. Trees include *Acacia* spp. and tropical hardwoods.
Software programme language is GWBASIC (not supplied), System: MS DOS 3.2 or higher. Total access is given to software. Editing and upgrading of data-files can be performed by using a simple word processing package.
The price is $A65 for the handbook only and $A40 for disks only.

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Cropping systems
USA, Florida, study, wetlands, flood-tolerant crops, low-input agriculture, soil conservation strategies, alemangrass, sugarcane, rice, taro, crop management, water management, economics

PORTER, P.S. et al.

FLOOD-TOLERANT CROPS FOR LOW-INPUT SUSTAINABLE AGRICULTURE IN THE EVERGLADES AGRICULTURAL AREA.

J. of Sust. Agriculture, 2, (1), 1991, pp. 77-99

The objective of this paper is to describe potential crops for production in reflooded wetlands and present yield and resource use data (water, nitrogen, and phosphorus). The crops in the study include a tuber (taro, *Colocasia esculenta*), three grasses (alemangrass, *Echinochloa polystachia*, flood tolerant sugarcane, *Saccharum* sp., and rice, *Oryza sativa*).
Wetlands have traditionally been viewed as wastelands; now vast areas of such lands have been converted to agricultural production worldwide. This has often been done in the past without regard for potential environmental consequences or long term sustainability of agricultural production. Recently, wetlands have become appreciated for, among other things, their role in environmental quality and stability. This greater appreciation for wetlands, combined with extensive wetlands loss, has recently led to concerted efforts to protect these areas and, in some cases, has led to confrontations with agricultural interests.
Wetlands are often highly fertile when initially drained. This is the result of rapid oxidation of a soil which had accumulated in a flooded environment. During this oxidation process, nutrients which had accumulated in the soil organic matter over an extended period of time are released to the soil solution at a high rate. Eventually, the stocks of nutrients and soil organic matter are depleted, leading to poor native soil fertility, low agricultural production, and in some cases, abandonment of the now depleted wetland.
Studies of wetland cropping systems have been conducted at the Everglades Research and Education Center (EREC).
The crops in this study vary widely in yield and nutrient uptake. Rice, for example, thrives in water with very low phosphorus contents. Alemangrass is a tremendous phosphorus sink, but may require supplemental phosphorus fertilization. Crops which thrive in oligotrophic conditions, as well as those which require large amounts of nutrients, are useful in water quality management. For example, alemangrass could be effective in reducing the phosphorus content of drainage from fields previously cultivated with crops which leave behind a large amount of fertilizer phosphorus, as do some vegetables. Rice can further reduce phosphorus contents to levels found under natural conditions. In addition, operating costs in a flood-tolerant cropping system may be lower for flooded

crops because periodic flooding aids in the control of some pests and weeds.
Results from this study pertaining to crop management, water and nutrient budgets are encouraging. More information is neded about soil formation and nutrient dynamics in a flood-tolerant system. For example, the balance between soil formation and soil loss for the crops in this study is not well understood. A desirable feature of flood-tolerant crops may be a reduction in nitrogen and phosphorus fertilization over that required by upland crops, however, nutrient mineralization rates and availability to crops when fields are flooded for long periods of time are not well understood in the EAA either.
Economic viability is a complex topic as well.
Currently, upland crops are profitable to the extent that it is not economically sensible to make meaningful investments in soil conservation.
Successful expansion of wetland agriculture in the EAA imlies reversal of soil loss, reduction of nutrient levels in drainage, compatibility with natural hydrologic cycles, and economic viability. Long term sustainability has been experienced in similar systems in other parts of the world. For example, it has been reported that aquatic crops have been grown for more than 400 years in the same organic soil without fertilization in Malaysia.
The development in the Everglades Agricultural Area (EAA) of sustainable agriculture in a former wetland can serve as a model for the many countries which have undertaken or contemplated wetland conversion. Indonesia, for example, is draining parts of 27 million ha of organic soils, much of it along coastal areas.

1100 92 - 4/143

Cropping systems
Review, book, tropics, crop production, environmental factors, plant population density, crop productivity, physiological process, CAB, ODA

SQUIRE, G.R.

THE PHYSIOLOGY OF TROPICAL PRODUCTION.

CAB INTERNATIONAL, UK.; ISBN 0-85198-677-3; 1990, paperback, £13.95

This is an excellent book that examines the way the physiological processes of tropical crops are influenced by environmental factors, namely solar radiation, temperature, photoperiod, saturation deficit, soil water and nutrients.
The effects of plant population density are also considered. The work is based largely on the research funded by the UK Overseas Development Administration which examined the physiological control of yield of pearl millet, grain sorghum and groundnut by temperature and drought. The subject matter in this book is extended to cover more physiological processes and environmental factors (e.g. nutrients) and more tropical crops (including maize, sugarcane, pigeon pea, cassava, tea and oil palm). To keep the book to a workable size, the research presented is selective, with examples largely from developing countries in the tropics. This does not detract from the value of the book, and it is a valuable contribution to tropical crop physiology.
The physiology of yield is examined in terms of four types of process - development, expansion, productivity (both in terms of solar radiation intercepted and water transpired) and partitioning of dry matter. Throughout the text, the effects of solar radiation, temperature, water and nutrients on these processes are examined in terms of a duration and a mean rate. For example, leaf canopy development is examined in terms of an expansion rate governed largely by temperature and a duration governed largely by temperature and photoperiod. Then, restrictions to the rate and duration of leaf canopy development due to solar radiation, saturation deficit, water and nutrient supply are considered.
The first five chapters of the book consider the key physiological processes. The chapter titles are: 1. Control of Development; 2. The Leaf Canopy and Root System; 3. Dry Matter Production by Interception and Conversion of Solar Radiation; 4. Transpiration and Dry Matter Production; and 5. Partition of Assimilate. The final chapter (6. Environmental and Physiological Control of Yield) attempts to draw together the responses of crops to environment and cultivation. Yield is analysed in terms of supply-limitation (water-limited) and demand-limitation (radiation-limited). Then, the physiological responses to nutrients, plant population density and mixed cropping are considered, and finally, species are compared in terms of their main physiological attributes.

Perhaps one disappointment with the book is its lack of application of the physiological understanding to the solution of agricultural problems. The main value of the physiological understanding, described so well in the book, is in the development of crop growth simulation models. Given that most crops in the tropics are grown under variable and relatively unpredictable environmental conditions, it is impossible to sample sufficient growing seasons to obtain the mean response and assess the climatic risk to production, using conventional field experimentation. Consequently crop physiologists should view crop simulation as an adjunct to field experimentation. It would have rounded the book off nicely if a final chapter had been devoted to the application of this physiological knowledge.
Abstract by R.C. MUCHOW, shortened

1101 92 - 4/144

Cropping systems
Asia, Indonesia, study, cropping systems, labour requirements, mulch rotation system, sustainable systems, deforestation

LORENZ, C. and A. ERRINGTON

ACHIEVING SUSTAINABILITY IN CROPPING SYSTEMS: THE LABOUR REQUIREMENTS OF A MULCH ROTATION SYSTEM IN KALIMANTAN, INDONESIA.

Trop. Agric. (Trinidad), 68, 3, 1991, pp. 249-254

The present paper demonstrates that the Mulch Rotation System has another major advantage over more traditional systems since its labour requirements more closely match labour availability on the settlement units. It thus demonstrates the importance of including a systematic assessment of labour requirements and labour availability in the field trials of any new farming system.
In order to overcome the considerable problems of replacing rainforest with sustainable agricultural systems, IITA has developed a 'Living Mulch' system. The results have shown that in contrast to a conventional till system, in which yields decline rapidly after six seasons, sustainable yields of food crops can be achieved under a live mulch which tends to take over most of the functions of the natural vegetation.
A somewhat different approach described as a 'Mulch Rotation" System has attracted considerable interest in Indonesia.
The system starts with a one-year fallow when a legume cover crop - *Pueraria javanica* Benth. - is grown on the land cleared of rain forest. After one year the cover crop is cut by hand and food crops are sown into the decomposing mulch. This continues for three seasons (one year) and the cover crop is again planted (as cuttings) into the last food crop - upland rice - after which the land is left under the legume cover crop fallow for a further year.
In addition to plant nutrients, however, the sustainability of a farming system depends on the availability of a whole range of other inputs. Labour is a major constraint. However, both the Living Mulch and the Mulch Rotation Systems use no-till methods; and because the mulch, whether living or dead, tends to suppress weed growth, two of the most labour-intensive operations, soil tillage and weeding, are markedly reduced.
This paper shows how labour profile techniques can be used to evaluate this aspect of the Mulch Rotation System.
The introduction of the Mulch Rotation System can reduce the labour peaks dramatically. All the data for this system show a profile with less severe peaks and some extended troughs giving time for social activities and leisure. It should be noted that the Mulch Rotation System does include a one-year fallow. This implies the need for some additional land though the actual amount required depends on the yield improvement of food crops grown after a legume cover crop. Trials' work to date suggests that this yield improvement may be substantial but further work needs to be

done to establish whether the introduction of the Mulch Rotation System would in fact need to be accompanied by a change in the standard size of settlement farm (from 2 to,say 2.5 ha).
Labour requirement data of the type used in this study must be validated under different climatic and soil conditions and further data gathered on other food crops. On the labour supply side, more reliable information is needed on the relative contribution of different family members in order to include appropriate weighting factors in the analysis.

1102 92 - 4/145

Cropping systems
Asia, Philippines, IRRI, green manure, legumes, biomass, nitrogen accumulation, nitrogen substitution, rice yield, residual effects

MEELU, O.P. et al.

GRAIN YIELD RESPONSES IN RICE TO EIGHT TROPICAL GREEN MANURES.

Trop. Agric. (Trinidad), 69, 2, 1992, pp. 133-136

This study was undertaken to compare eight green manure legume species for biomass production, N accumulation and as substitutes for fertilizer N in rice.
Crop residues and organic manures are common sources of humus and soil N. During the past few decades, organic manures were abandoned in favour of inorganic fertilizers that came with modern varieties of rice, maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.), but owing to fertilizer input cost and concern for sustainable agriculture, interest in organic manures has been renewed. Farmyard manure, compost and green manure are commonly used organic manures, but farmyard manure and compost are limited in supply and generally low in nutrient content. Hence, re-examination of legume crops as a source of organic matter and N for rice is justified.
The treatments were arranged in strip plots with strips of green manures in one direction and N levels in the other. Eight green manure species were grown: dhaincha (*Sesbania cannabina* (Retz) Poir.); sunhemp (*Crotolaria juncea* L.); soybean (*Glycine max* (L.) Merrill); lablab (*Lablab purpureus* (L.) Sweet); indigo (*Indigofera tinctoria* L.); pigeonpea (*Cajanus cajan* (L.) Millsp.); cowpea (*Vigna unguiculata* (L.) Walp.); and mungbean (*Vigna radiata* (L.) Wilczek).
No fertilizer was applied to the green manures.
The green manures were incorporated in situ 60 DE by a tractor-mounted rototiller and by a power tiller-drawn mouldboard plough in 1985.
The above-ground biomass of *Sesbania cannabina* accumulated mean maximum N (84-199 kg ha^{-1}) and indigo accumulated the least N (8-84 kg ha^{-1}) in 30-60 days. Mungbean and cowpea, which produced grain and crop residue, are potential dual-purpose grain and green manure species. Regardless of species, mean rice grain yield from green manures was 4.0 t ha^{-1} in 1984 and 4.6 t ha^{-1} in 1985, comparable with 4.1 t ha^{-1} from 50 kg fertilizer N in 1984 and 4.7 t ha^{-1} from 105 kg fertilizer N ha^{-1} in 1985. In both years, 50-day *Sesbania* and *Crotolaria* acumulated N in excess of the rice crop requirement. Residual effects from green manures on dry season (DS) rice were not significant in 1984 but were significant from *Sesbania* green manure in 1985. Soil organic C and total N were also significantly higher after *Sesbania* and *Crotolaria* than after other green manures or fertilizer N treatments.

1103 92 - 4/146

Cropping systems
Asia, Philippines, study, field trials, intercropping, maize, mungbean,nitrogen,utilization efficiency, inoculation, land equivalent ratio

CHOWDHURY, M.K. and E.L. ROSARIO

UTILIZATION EFFICIENCY OF APPLIED NITROGEN AS RELATED TO YIELD ADVANTAGE IN MAIZE/MUNGBEAN INTERCROPPING.

Field Crop Research, 30, 1992, pp. 41-51

This study was undertaken to examine the effects of rhizobial inoculation and applied nitrogen on growth and performance of intercropped maize (*Zea mays* L.) and mungbean [(*Vigna radiata*(L.) Wilczek] and to relate nitrogen utilization efficiency of the component crops to the yield advantage.
The experiment was conducted to determine the effects of rhizobial inoculation and nitrogen applied at 0, 30, 60 and 90 kg ha^{-1} on growth and performance of intercropped maize and mungbean.
Inoculation decreased both dry matter and grain yield of intercropped maize and mungbean. Applied N at levels above 30 kg ha^{-1} increased the dry matter and the grain yield of maize but reduced that of the associated mungbean. Intercropping drastically reduced the dry matter yield of mungbean but maize showed negligible reductions;the reductions were evident when the crops flowered. Inoculation increased the land equivalent ratio (LER) by increasing the partial LER of maize. Applied N at high levels also increased the partial LER of maize but this failed to increase LER due to corresponding reductions in partial LER of mungbean. Nitrogen at 30 kg ha^{-1} produced the highest LER (1.40).
Applied N increased N uptake of maize but decreased that of mungbean. Inoculation increased the N uptake of both mungbean and maize at 48 days and onward. Large reduction in N uptake of intercropped mungbean was observed when it flowered at 33 days but maize was affected 2 weeks later at the tasseling stage. Thus, the competition for N was acute when the crops were at the reproductive stage.
The LER analysis in terms of N utilization efficiency showed that N absorption efficiency of both maize and mungbean was reduced due to intercropping, and mungbean was more affected than maize.
Intercropping severely depressed N uptake in mungbean compared to maize but mungbean utilized the absorbed N relatively more efficiently than maize producing a higher quantity of grains per unit of absorbed N compared to sole mungbean.

1104 92 - 4/147

Cropping systems
Africa, Ethiopia, study, greenhouse trials, underseed cropping, legumes, wheat, soil erosion

PÜLSCHEN, L.

EFFECTS OF TWO UNDERSEED SPECIES, *MEDICAGO POLYMORPHA* L. AND *SCORPIURUS MURICATUS* L.,ON THE YIELD OF MAIN CROP (DURUM WHEAT) AND SUBSEQUENT CROP (TEFF) UNDER HUMID MOISTURE REGIMES IN ETHIOPIA.

J. Agronomy & Crop Science, 168, 1992, pp. 249-254

The objective of the study was to record quantitative effects of two underseed species - *Medicago polymorpha* L. and *Scorpiurus muricatus* L. - on the shoot and grain dry matter of main crop (competitive effects) and succesive crop (residual effects). Both species are abundant annual leguminous weeds in the Ethiopian highlands.
Depending on the site factors, agronomic and technical measures at hand, mixed cropping systems may serve widely differing purposes: In vast areas of the Ethiopian highlands (>1500 mm NN) which are mainly characterized by semipermanent cropping systems they could especially contribute to erosion control and to restoration or stabilization of soil fertility.
The highlands are exposed to a considerable population density and its continuous increase leads to declining proportions of pasture fallows and to the cultivation of steep slopes which in turn drastically increases the risk of soil erosion.
Apart from a lowering of soil erosion risks and a preservation of the soil's N- and C-pool leguminous underseed species are suggested to increase water permeability due to an improved soil structure.
Two successive greenhouse trials have been carried out in two factorial designs with three replications.
The leguminous weed species which are widely distributed in annual crops of the Ethiopian highlands have been studied with varying coverage with regard to their suitability as underseeds and with wheat (*Triticum turgidum* [L.] Thell. var. *durum* [Desf.] MacKey) as a main crop. The competitive effects of *Scorpiurus muricatus* L. on the grain yield of wheat were smaller than those of *Medicago polymorpha* L. (-14.1% and -23.6% respectively, compared with the underseed free control) which is mainly ascribed to differences in their speed of development and shoot height. The residual effects of the underseed's root masses on the grain yield of the successive teff crop (*Eragrostis tef* [Zucc.] Trotter) were significantly higher with *Scorpiurus muricatus* (+99.3%) than with *Medicago polymorpha* (+63.6%).
Leguminous underseed species adapted to the above described environments should be able to perform in waterlogged sites. This could possibly also have some ameliorative effects, if the combination of main crop with underseed species leads to an

increased evapotranspiration rate compared with single crop cultivation and if it improves soil aeration through increased soil organic matter content.
per se *S. muricatus* fits better as an underseed partner than *M. polymorpha*, due to its lower competitive power and due to its even stronger positive residual effects on the successive teff crop.
Moreover it was found out by inquiries of Ethiopian farmers that both species serve as a feed for livestock and that *S. muricatus* is preferably grazed on harvested fields.

1105 92 - 4/148

Cropping systems
Latin America, survey, Honduras, intercropping, beans, sorghum, maize, environment, management practices, on-farm research, rainfall, temperature, soils, planting, cultivars, CATIE

DIAZ, D.R.E.

CARACTERIZACION Y RELACIONES AMBIENTE-MANEJO EN SISTEMAS DE FRIJOL Y SORGO ASOCIADOS CON MAIZ EN HONDURAS. (CHARACTERIZATION AND ENVIRONMENT-MANAGEMENT RELATIONSHIPS IN BEANS AND SORGHUM INTERCROPPED WITH MAIZE IN HONDURAS.)

Tesis Mag. Sc. Turrialba, Universidad de Costa Rica; Centro Agronomico Tropical de Invest. y Enseñanza; 1982, 130 p.

Using a modification of the area characterization methodology developed in farming systems research, cropping systems involving beans and sorghum associated with maize (M + B, M + S, M + B + S) were studied in Honduras. By means of a survey of 378 farmers, selected at random from different areas of the country, data was collected of the farm, the soil, the predominant cropping systems and their management. This data was used with secondary information of climate and soils to characterize the three cropping systems and analyze their relationship with different environments. Seventy-five percent of the farms studied were less than six ha in size, and 63 percent less than four ha. The area planted to the cropping systems was even smaller; 75 percent, 50 percent and 61 percent of the M + B, M + S and M + B + S plots respectively were less than 1.4 ha. The majority of the farmers were owner-occupiers, although share-cropping (where the farmer gives part of the harvest and the sorghum straw as payment to the landowner) was evident in the M + S and M + B + S systems. Seventy percent of the farmers utilized all their produce on-farm and only 5 percent sold more than 50 percent of their produce. The use of bought inputs was minimal: only 19 percent used fertilizers and practically none used herbicides, insecticides or fungicides. It was found that the physical environment influenced both the localization of the cropping systems and also their management. As an example of this influence it was showned that the three cropping systems were concentrated at different altitudinal ranges: M + S at less than 750 m; M + S + B at 500 - 1250 m; and M + B between 500 and 2000 m. Using principal component analysis it was shown that the most variable management practices of M + B were those relating to spatial arrangement of the crops and choice of variety (especially grain color in maize and growth habit in beans). By means of contigency tables and multiple regression it was demonstrated that these management factors were influenced principally by altitude (temperature) and rainfall (quantity and distribution). As the present study only utilized a part of the data collected, it is recommended that further analysis be undertaken to improve our understanding of these cropping systems which are of such influence both in Honduras and Central America.

1106 92 - 4/149

Cropping systems
Asia, India, field trials, on-farm research, rainfed condition, sandy loam soil, flooding occurrence, intercropping, pigeonpea, pearl millet land equivalent ratio

SINGH, R.A. et al.

PRODUCTION POTENTIAL OF PIGEONPEA/PEARL MILLET INTERCROPPING SYSTEM IN RAINFED DIARA (FLOODPRONE) AREAS OF EASTERN UTTAR PRADESH, INDIA.

In: Pigeonpea Newsletter (IPN), 14, 1991, pp. 14-17

Most of the agricultural land of Diara regions are small and marginal units, and farmers adopt mixed cropping of pigeonpea and pearl millet during monsoon with poor yields.
Farmers of the area mix seeds of pigeonpea and pearl millet in about equal proportion of the required seeds of both the crops and broadcast them in the field along with a small amount of fertilizers (about 9 kg N and 10 kg P ha^{-1}).
Two experiments were conducted. The experiments were laid out in a randomized-block-design with four replications having five treatments of pigeonpea.
Sole crop treatments of both the crops were grown at their optimal plant population.
Intercropping of one row of pearl millet in between two rows of pigeonpea was done and plant populations of pearl millet were maintained by reducing within-row spacing.
Intercropping of pigeonpea (100% plant population) with various plant populations of pearl millet in additive combinations was more productive than growing them as sole crops, as total land-equivalent ratio (LER) values were greater than 1.0 for these treatments.
With the increasing plant population of the intercrop pearl millet, the pigeonpea yield decreased, probably because of increasing competition from pearl millet. In the pigeonpea pearl millet intercropping system, partial LERs for pigeonpea were less than those for pigeonpea grown alone. This indicates suppression of pigeonpea growth by pearl millet. The total partial LERs of pearl millet, however, were greater than pearl millet alone up to 100% plant population, but it decreased at 150% plant population of pearl millet. Thus, the overall efficiency of pigeonpea/pearl millet intercropping system was optimal with a pigeonpea plant pupulation of 100% and pearl millet plant population of 50%. It seems that pearl millet better utilized space and resources between two rows of long-duration pigeonpea up to 100% plant population.
At 150% plant population of pearl millet between two rows of initially slow-growing, long-duration pigeonpea, both the crops were put under stress for space, light, and other resources resulting in reduced yields of both crops.

1107 92 - 4/150

Cropping systems
Asia, Bangladesh, field trial, rainfed conditions, silty loam, mixed cropping, lentil, barley, sole cropping, land equivalent ratio, monetary returns

ISLAM, M.N. et al.

EFFECT OF MIXED CROPPING LENTIL WITH BARLEY AT DIFFERENT SEEDING RATES.

LENS (Newsletter), 1991, pp. 24-26

The experiment explained in this paper was conducted to determine a suitable seeding ratio for lentil and barley sown in a random mixture.
In a mixed cropping experiment, three combinations of lentil (*Lens culinaris* Medik.) and barley (*Hordeum vulgare* L.) were compared to corresponding sole crops.
The experiment was conducted under rainfed conditions.
The treatments consisted of three combinations of lentil and barley (100:10, 100:30, and 100:50) plus the monocultures of the two crops as checks. The design was randomized complete block with five replications.
The results of this study revealed that yield and yield parameters of lentil were lower in mixture with 50% barley than in monoculture. Grain yield, plant populations/m^2, number of pods/plant, number of seeds/pod, and 1000-seed weight of lentil in mixed cropping were statistically identical to sole lentil (1.05 t/ha) up to addition of 30% barley seeds. Due to higher competition of nutrients, moisture, space, and light, the number of pods/plants, number of seeds/pod, and seed size, i.e., yield/plant of lentil were reduced.
Grain yield and number of spike/m^2 of barley differed significantly mainly due to different amount of seeds used in the combinations. Sole barley produced highest grain yield (2.58 t/ha) and the highest number of spikes m^2. In mixed cropping, the yield/plant of barley was significantly higher over sole barley, as were the yield components, i.e., number of spikes/plant, number of grains/spike, and 1000-grain weight. The increase in yield/plant might be for beneficial effect of lentil on barley.
Relative yields of barley showed that barley yields were higher than the expected yields (on the basis of seeding percentage) in the mixtures. That is 10%, 30%, and 50% barley seeds produced 11%, 36%, and 51% yield of monoculture, respectively.
From the above results, it may be concluded that 30% barley seed did not reduce lentil yield significantly, producing highest LER of 1.29. Highest monetary return was also obtained from the same combination.
Summarizing, it may be stated that 30% barley seeds can be mixed in normal lentil without substantial yield loss and with high monetary return in the region.

1108 92 - 4/151

Cropping systems
Europe, Italy, study, intercropping, wheat, pea, yield performance

PAOLINI, R. et al.

YIELD PERFORMANCE AND COMPLEMENTARITY IN MIXTURES OF BREAD WHEAT (*TRITICUM AESTIVUM* L.) AND PEA (*PISUM SATIVUM* L.).

Publ.of the Inst. of Agronomy, Univ. of Tuscia, 01100 Viterbo, Italy, 1991

Intercropping of cereals and grain legumes often gives higher resource use efficiency compared to homologous sole crop systems. Complementarity between bread wheat and grain pea can derive from their different growth habits, earliness, and ability to use different sources of N and/or, presumably, other nutrients owing to root stratification in the mixture. As to plant morphology and growth habits, consistent variation also occurs among pea cultivars. Results are reported of a study carried out during two cycles (1989/90 and 1990/91) at Viterbo (central Italy) where four pea varieties (the early "leafy" cv. 'Stehgolt' and the early "semileafless" cv. 'Consort'; the medium early "leafy" cv. 'Frijaune' and the medium early "semileafless" cv. 'Countess') were intercropped with the medium early bread wheat cy. 'Pandas' under two different inorganic N conditions (9.0 g/m^2 and 16.1 g/m^2). Both wheat and pea intercrops were compared with their respective sole crops under the same conditions. Complementarity clearly occurred in both years in two cases out of four (mixture of wheat with the early cvs. Consort and Stehgolt), only under the lower N availability conditions. LER values were about 1.20 for both Pandas/Consort and Panda/Stehgolt mixture; partial LERs showed a great yield advantage of wheat and a moderate yield disadvantage for pea. In the most balanced mixture (Pandas/Consort), grain yields of wheat and pea intercrops compared to sole crops were 7180 vs 4380 kg ha^{-1} and 3340 vs 4380 kg ha^{-1}, respectively. Both medium-early cultivars (cv. Countess and cv. Frijaune did not show complementarity with wheat, and components did not give yield advantages. Under high N availability conditions (16.1 gm/m^2), complementarity between wheat and pea never occurred. Wheat was more competitive than the early cultivars of pea (cv. Stehgolt and cv. Consort), but equally competitive against the medium-early ones (cv. Frijaune and cv. Countess). Intercropping of wheat with early, standing pea cultivars represents a promising solution to obtain yield advantages under low to moderate N input conditions.

1109 92 - 4/152

Cropping systems
Asia, Philippines, study, rice, green manure, economic feasibility, azolla fertilizer

ROSEGRANT, M.W. and J.A. ROUMASSET

ECONOMIC FEASIBILITY OF GREEN MANURE IN RICE-BASED CROPPING SYSTEMS.

In: Proc. of a Symp. on Sustainable Agriculture - Green Manure in Rice Farming; IRRI, Philippines, 1988, pp. 11-16

In this paper the authors discuss the key concepts, issues, and methods of determining the economic feasibility of green manure; employ these concepts in a case study of the economics of azolla as a green manure in Philippine rice production; and draw a number of general conclusions regarding the economic feasibility of green manuring in rice-based farming systems.
Increased use of fertilizer, with development and dissemination of improved varieties and expanded and improved irrigation, has been a key factor in the growth of rice production in Asia and elsewhere.
The increase in fertilizer use has been remarkable by any standard. Between the first and second halves of the 1970s, average fertilizer consumption grew by 50% in South Asia, 39% in Southeast Asia, and 53% in East Asia.
The rapid growth in fertilizer use has been due almost entirely to increased use of chemical fertilizers. Organic fertilizers (green manure crops, animal manure, and compost), traditionally important sources of nutrients, declined in relative importance with the rapid increase in use of chemical fertilizers.
Although data on use of organic fertilizers is scarce, there is at least some evidence that their use has declined in absolute, as well as in relative terms.
Despite (or because of) these trends, interest in the potential for expanded use of green manure has been renewed.
Concern also has been rising over possible long-term adverse effects of heavy use of chemical fertilizer on soil structure, crop productivity, and off-farm pollution. Green manure and other organic fertilizers can maintain and improve soil structure.
Increased use of chemical fertilizers may also incur long-term environmental costs. In areas where chemical fertilizers are heavily used, drainage runoff contributes to eutrophication of rivers and lakes.
Green manure and other organic fertilizers have a number of apparent agronomic and environmental advantages.
The case study results suggest that azolla usually is not a cost-effective substitute for urea fertilizer. Green manuring is uneconomic, largely because of the opportunity cost of land used to grow azolla. Use of land for azolla incurs a substantial cost of alternative cropping opportunities forgone. Compared to using N

from urea, using azolla as an intercrop is profitable only with good irrigation.
High labour costs, high opportunity costs of land, and poor water control are major constraints to the economic feasibility of green manure. Given the current stage of azolla technology and its relatively poor economic feasibility, policy support for widespread investment in technology dissemination is not appropriate. Instead, strong support should be given to a research program designed to overcome the constraints to economic feasibility. Improvements in azolla technology that increase nitrogen yield and pest resistance or reduce the opportunity costs of labour and land could make azolla economically feasible in a greater number of environments.

1110 92 - 4/153

Cropping systems
Asia, India, study, field trial, intercropping system, pigeonpea, rice, nitrogen economics

MAHAPATRA, P.K. et al.

EFFECT OF NITROGEN ON PIGEONPEA (*CAJANUS CAJAN*) AND RICE (*ORYZA SATIVA*) INTERCROPPING SYSTEM.

Indian J. of Agric. Sc., 60, 1990, pp. 519-522

An experiment was conducted under rainfed situation to assess the legume advantage under varying levels of N in a pigeonpea [*Cajanus cajan* (L.) Millsp.] - rice (*Oryza sativa* L.) intercropping system. The experiment was conducted during the rainy seasons in a randomized block design with 4 replications in the rainfed upland. The soil was lateritic with a sandy -loam texture.
N was applied through urea 30, 45, 60 and 75 kg/ha. Of the total N applied, 10 kg/ha was given in lines uniform to all the treatments at sowing along with 18 kg P/ha and 17 kg K/ha. The remaining amount of N for each treatment was top-dressed to rice in 2 equal splits, at 20 and 40 days after sowing. The sole pigeonpea received a fertilizer dose of 28, 18, 17 kg N, P, K/ha at the time of sowing.
The land-equivalent ratio was calculated for each fertilizer N level by adding the proportion of rice yield in the intercrop to that in the sole crop with the proportion of pigeonpea yield in the intercrop to yield of sole pigeonpea. The energy input and energy output were also calculated.
The transfer of N during the rice-growing period from pigeonpea to rice was negligible. Application of 30kg N/ha to rice in the intercrop gave the optimum economic return. This could recover 59 and 90% of the grain yields of sole rice and pigeonpea with an yield advantage of 49%, net profit of Rs 4432, energy output of 129400 MJ/ha, and energy output-input ratio of 16.59. Sole rice was an inefficient user of energy input.
It can be concluded that pigeonpea can adjust well with rice in the rainfed upland in an intercropping system at different levels of N. Optimum economic returns with high energy-use efficiency were observed when only 30 kg N/ha was applied to rice in the intercropping system.

1111 92 - 4/154

Cropping systems
Africa, Togo, cropping practices, cotton, yield, smallholder, production systems, extension, research topics

COUSINIÉ, P. and K. DJAGNI

SMALLHOLDER COTTON CROPPING PRACTICES IN TOGO.

Coton Fibres Trop., 46, 1991, pp. 285-290

The work described here was undertaken over the period 1980-1990 in five villages in Togo and provided an understanding of the ways cotton growing has developed: smallholder responses to recommendations and the main obstacles to increase cotton yields. The analysis of production systems was completed by experiments in the smallholder sector, destined to test innovations developed by research or to expand on the agricultural survey.
The cotton development operation in Togo was one of the most spectacular in West Africa in the 1980s.
Many smallholders in Togo have only recently started to grow cotton, and are small-scale producers, with an average area of 0.5 ha of plantings each.
The low cotton productivity levels observed are partly explained by the use of lower quantities of inputs than recommended.
Despite the low productivity observed, cotton is still an attractive crop, by virtue of the income it provides and the fact that it can be used to fund inputs for food crops.
By linking the behaviour of cotton smallholders with the various constraints mentioned above, it is possible to characterize various smallholder strategies. Four main types of situation are described in this paper.
The main causes of these low yield levels are essentially linked to the logic behind smallholder cropping practices, which consists in deliberately growing cotton extensively so as to reduce the risk of failure.
Concluding, it can be said that extension activities should be based on priority topics, taking acount of technical constraints encountered in the field. It would be beneficial if detailed technical responses could be drawn up depending on the region and the existing production system, to ensure more effective valorization of the inputs purchased by the smallholder. A considerable effort should be made to pass on messages to farmers, since the main obstacle to intensification is not so much developing new techniques as encouraging smallholders to adopt existing ones.
For its part, agricultural research should take account of the difficulties encountered by smallholders in applying recommended techniques. Hence agronomists should be able to propose techniques more adapted to conditions in the rural environment, and it is essential to redefine research topics with a view to minimizing the technical constraints facing smallholders in Togo.

The final aim is to eventually produce specific recommendations, where the supervisor would move from his current role to that of advisor. It has to be said that the current state of cotton growing in Togo (numerous small-scale producers and low yields) makes this a difficult target.
In addition, cotton development cannot be dissociated from other agricultural or livestock activities. It would be no good concentrating on cotton in view of the fact that food crops are often the smallholder's priority and govern his behaviour with respect to cotton. Cotton intensification should therefore be looked at in overall terms, i.e.in terms of integrated development, taking account of all the constraints encountered by smallholders in Togo.

1112 92 - 4/155

Cropping systems
Africa, Uganda, study, highlands, field trials, intercropping, sorghum, finger millet, row arrangements, yield advantage

SSEKABEMBE, C.K.

EFFECT OF ROW ARRANGEMENT ON YIELD AND YIELD ADVANTAGES IN SORGHUM/FINGER MILLET INTERCROPS.

Trop. Agric. (Trinidad), 68, 1991, pp. 19-22

A study was conducted to determine the effect of row arrangement on the yield and yield advantages in a sorghum-finger millet mixture grown at four different plant population densities.
The study was carried out at an altitude of approximately 1200 m. Most of the soils are oxisols and highly weathered, but are deep, firmly heavy and well drained. The mean daily maximum and minimum temperatures of the area are approximately 27 and 17°C. The annual rainfall averages 1300 mm and is bimodal in distribution.
The results indicated that the yield of each species increased with increase in planting density. The sorghum yield and the total yield of the mixture were reduced when a proportion of sorghum was replaced by an increasing number of millet rows. However, the total yield of the mixture was increased when pure-stand finger millet was replaced by an increasing number of sorghum rows. Calculation of Land Equivalent Ratios (LER) revealed that the differences among the various row arrangements in terms of yield advantage were not significant, although the 1:2 sorghum + millet row arrangement gave an exceptionally higher overall yield advantage at all planting densities tested.
Concluding, the present experiment has shown that total yield of each species was highest when grown in pure stand, and this decreased when a proportion of it was replaced by the other species.
On the basis of the results, it is advisable for a farmer interested in maximum yield, irrespective of which species, to grow pure stand sorghum. This is usually the case for farmers who grow sorghum primarily for making a kind of local beer from bananas; the sorghum flour is used as a starter in brewing the beer. However, farmers interested in some yield from both species should grow them in a 1:2 sorghum:millet row arrangement. This is suitable for farmers who use a mixture of sorghum and millet in preparing 'atapa' (thick porridge), a kind of food. In making atapa a little sorghum is mixed with a larger quantity of finger millet flour, in a proportion of about 1:4 (sorghum:millet), depending on how much millet flour is available. On this basis, even the 1:4 sorghum:millet row arrangement may be worthwhile since it yields more millet (than the 1:2 arrangement) and a still substantial amount of sorghum.

1113 92 - 4/156

Cropping systems
Asia, India, field trial, rice, wheat, sugarcane, mustard, greengram, economics, employment

YADAV, D.S. et al.

YIELD, ECONOMICS AND NUTRIENT BALANCE IN CROPPING SYSTEMS BASED ON RICE (*ORIZA SATIVA*).

Indian J. of Agricult. Sciences, 61, (12),1991, pp. 872-876

An experiment was conducted to find out the production potential, economical feasibility and nutrient removal of different rice-based cropping systems, including sugarcane as the component crop. The six cropping systems tested were viz.-wheat-fallow; S_2, rice-maize (*Zea mays* L.)-maize + cowpea [*Vigna unguiculata* (L.) Walp.] fodder (1:1); S_3, rice-toria [*Brassica rapa* (L.) Thell. emend. Metzger var *napus* L.; syn *B. napus* L. var *napus* L. sensu stricto; *B. campestris* L. var *toria* Duth. & Full.]-wheat-*dhaincha* [*Sesbania cannabina* (Retz.) Pers.] green-manure; S_4 rice-potato + Indian mustard [*Brassica juncea*(L.) Czernj. & Cosson] 3:1 - blackgram (*Phaseolus mungo* L.); S_5, rice-wheat + Indian mustard (9:1)-greengram; S_6, rice-wheat + sugarcane 4:1-ratoon-wheat (3-year rotation). Randomized block design was followed with 4 replications.
Rice (*Oryza sativa* L.) - potato (Solanum tuberosum L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.)-greengram (*Phaseolus radiatus* L.) system is the most remunerative among the tested sequences in eastern Uttar Pradesh. Sugarcane (*Saccharum officinarum* L.) is taken as a popular cash crop owing to its economical and ecological security.
Rice-wheat (*Triticum aestivum* L. emend. Fiori & Paol.) + Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]-greengram (*Phaseolus radiatus* L.) proved the most remunerative system with a net profit of Rs 12 178/ha/year and 1.07 cost : benefit ratio, whereas rice-wheat-fallow sequence showed the highest cost: benefit ratio. The highest cost of cultivation (Rs 17 337/ha/year) was incurred in rice-potato (*Solanum tuberosum* L.) + Indian mustard-blackgram (*Phaseolus mungo* L.) cropping system. This system also gave the highest employment opportunity and the highest rice-grain equivalent. The maximum removal of N, P and K was found in rice-maize (*Zea mays* L.)-maize + cowpea fodder [*Vigna unguiculata* (L.) Walp.] sequence. Positive apparent balance of N and P, and negative apparent balance of K was noticed in all the cropping systems except rice-maize-maize + cowpea (fodder), in which negative balance of N was found.
It was concluded that rice-wheat + Indian mustard-greengram cropping system gave high production and net returns, without much loss of fertility. An other alternative system, more productive and remunerative than the traditional rice-wheat system, is rice-potato + Indian mustard-blackgram. The sequence involving maize and rice both should be avoided in less-fertile soils.

1114 92 - 4/157

Cropping systems
USA, field trials, intercropping, sunflower, mustard, yield performance, nitrogen, land equivalent ratio, water use

PUTNAM, O.H. and D.L. ALLAN

MECHANISMS FOR OVERYIELDING IN A SUNFLOWER/MUSTARD INTERCROP.

Agronomy J., 84, 1992, pp. 188-194

The objectives of this study were to verify the occurence of overyielding and to examine patterns of N and water use as possible mechanisms for over-yielding in sunflower/mustard intercrops. Secondary objectives were to examine the effect of N fertilizers and intercrop structure (planting pattern) on intercrop resource use and yield advantage. It is hypothesized that the lack of competition between species for a significant resource (the competitive production principle) was a cause of previously observed advantages in this intercrop system.
Two intercrop patterns and sole crops of mustard (*Brassica hirta* Moench) and sunflower (*Helianthus annuus* L.) were planted in 1988 and 1989 on a silt loam soil to examine mechanisms for overyielding in this intercrop system.
A strip intercrop pattern where 2.28-m strips of sunflower (76-cm rows) alternated with 2.28-m strips of mustard (15-cm rows) was compared with a more intimate row intercrop pattern of 76-cm sunflower rows interplanted with four 15-cm rows of mustard. Nitrogen was applied at planting at 0 or 112 kg N ha^{-1} to whole plots, with planting patterns allocated to subplots in a split-plot design. Soil water content, nitrate N, and total N were measured at different locations and depths in the intercrop and sole crop patterns during the growing season. Mustard rows adjacent to sunflower in the strip intercrop yielded an average of 61% more than sole crop rows. Sunflower rows adjacent to mustard in the strip intercrop yielded an average of 40% more than sole crop rows. Yields of both sunflower and mustard were lower in the row intercrop compared with respective sole crops. Land equivalent ratios ranged from 0.96 to 1.43 in the strip intercrop and were generally below 1.0 in the row intercrop. Application of N did not consistently affect LER. Soil depletion patterns indicated that border rows of mustard obtained both soil water and N from the strips planted to sunflower at a time when demand for these reources by sunflower was low. Sunflower border rows obtained water and N from mustard strips later in the season.
Concluding, intercropping, although an inexpensive technology, is an intensification of management. In the sunflower-producing areas of the northern Midwest of USA, extensive management practices are more common. Although previous studies confirm that strip intercropping of the two species potentially could increase yield, few producers are currently using this technique. This may be due partly to the minor crop status of both crops in this region, but other Cruciferae, such as canola (*Brassica napus* L. or *Brassica*

campestris L.), are also candidates for this type of strip intercrop system with sunflower.
The strip intercrop used in this study was narrower than would be practical for equipment used currently in the sunflower-producing regions of the USA.
Other management practices, such as tillage, weed control, diseases, insects, harvesting, and timing of agronomic practices, must also be considered. Mustard is a crop that requires a fine seedbed, and sunflower, though less exacting, is compatible with mustard in this respect. Both crops are planted early, although sunflower could be planted later in a strip arrangement.
There is no evidence in the field trials that disease or insect infestation differed in the intercrops compared with the monocultures.
In summary, there are potential yield and land-use advantages for the practice of strip intercropping but not row intercropping of sunflower and mustard. Complementary use of water and N over time are implicated as causes of overyielding exhibited by both species in this pattern. The creation of border areas between species through strip intercropping resulted in areas of excess soil N and water (compared with sole crops) that could be used by border rows of the companion crop during critical times of development, producing a border row yield advantage. This overyielding could be applied to mechanized systems if cropping intensification is wanted.

1115 92 - 4/158

Cropping systems
Australia, field trial, intercropping, cassava, pigeonpea, agronomic practices, land equivalent ratio, crop productivity

CENPUKDEE, U. and S. FUKAI

AGRONOMIC MODIFICATION OF COMPETITION BETWEEN CASSAVA AND PIGEONPEA IN INTERCROPPING.

Field Crops Res., 30, 1992, pp. 131-146

The objective of the study was to gain better understanding of how competitiveness of component species in cassava intercropping is determined and modified by agronomic practice when a long-season crop (pigeonpea) is used in association. Two cassava cultivars of contrasting canopy size were used, in addition to the variation in time of sowing and plant density of pigeonpea, to vary further the competitive ability of cassava.
In all intercropping treatments, radiation interception by the combined canopy increased rapidly, and full ground was maintained up to pigeonpea harvest (ca. 100 days). When pigeonpea was planted simultaneously with cassava, it became taller than cassava and its canopy occupied most of the cassava interrow space. When it was sown 35 days later than cassava, then cassava cultivar MCol 1468, which was tall and had a large canopy, dominated pigeonpea almost completely, whereas the smaller cultivar M 19 occupied up to only about half the total interrow area. Pigeonpea at high plant density (based on four rows between cassava rows) had similar height to that at low density (based on two rows), but its canopy occupied more interrow space and enhanced its competitiveness. The canopy width during the time of the complete ground cover was directly related to total dry-matter production and partial land equivalent ratio (LER) for economic yield of each component crop. However, cassava LER was more sensitive to reduced cassava canopy width than was pigeonpea LER, and higher total LER was obtained when a large cassava canopy width was maintained.
The results suggest that when cassava is intercropped with a crop of high competitiveness, agronomic management should be adopted so that the cassava canopy is taller than or about the same height as the associated crop and it occupies most interrow space.
The results also suggest that for high total LER of economic yield, the cassava/pigeonpea intercrop should be managed so that a wide cassava canopy is maintained when the ground is fully covered. This is because cassava LER is more sensitive to reduction in its canopy width than is pigeonpea LER. It appears that when pigeonpea dominates and cassava canopy widths is reduced, tuber growth is reduced.
It is therefore concluded that a vigorous cassava cultivar and late sowing of pigeonpea at a low density can sustain the desirable canopy width and competitiveness for high productivity of cassava/pigeonpea intercropping.

1116 92 - 4/159

Cropping systems
Africa, Nigeria, savanna, study, white Guinea yam, minisetts, production systems, economic evaluation

KALU, B.A. and P.O. ERHABOR

PRODUCTION AND ECONOMIC EVALUATION OF WHITE GUINEA YAM (*DIOSCOREA ROTUNDATA*) MINISETTS UNDER RIDGE AND BED PRODUCTION SYSTEMS IN A TROPICAL GUINEA SAVANNA LOCATION, NIGERIA.

Trop. Agric. (Trinidad), 69, 1, 1992, pp. 78-82

The objective of this study was to assess quantitatively the production and economic efficiency of *D. rotundata* (cv. Dan Onitcha) minisetts under two production systems - planting on ridges and on raised (flattened top) beds - with the view to evolving an additional technological package that would enable yam growers to produce both marketable ware yams and seed yams simultaneously from minisetts in quantity.
Studies in Nigeria have shown a high potential and suitability of use as minisetts in rapid seed yam multiplication.
Though the minisett technique has been developed for the rapid production of seed yams, farmers preferred its use for the simultaneous production of seed and ware yams.
The productive and economic attributes of a local variety, Dan Onitcha, of white Guinea yam (*Dioscorea rotundata* Poir.) minisetts were assessed under two production systems - planting on ridges and on beds at the same plant population density of 40 000 stands ha^{-1} during the 1987 to 1989 production seasons. The bed system improved emergence percentage (E% by 11, stand establishment by 18% and gave 28% increase in total tuber production over the ridge system. An average of 67% of total harvested tubers were classified as ware yams (401-3000 g) under the bed system, and 77% as seed yams (less than 400 g) under the ridge system. Based on gross margin analysis, the economic returns from the bed system was 275% more than returns from the ridge system, due in part to the high proportion of the more valuable ware yams realized from the bed system.
The results from this study suggest on technical grounds that farmers could use the ridge system if the priority is to produce only seed yams and to use the bed system if the decision is to produce only ware yams. Overall, the bed system was superior to the ridge in producing both seed and ware yams.
Gross margin analysis of the two production systems indicate a high level of profitability of both. The analysis further showed clearly that the bed system was more economically efficient than the ridge system.
On both technical and economic grounds, the bed system was superior to the ridge system.

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Cropping systems
Latin America, Brazil, field trials, intercropping, cassava, maize, beans, evaluation, smallholder, farming systems, land equivalent ratio, fertilization

ZAFFARONI, E. et al.

EVALUATION OF INTERCROPPING CASSAVA/CORN/BEANS (*PHASEOLUS VULGARIS* L.) IN NORTHEAST BRAZIL.

J. Agronomy & Crop Science, 167, 1991, pp. 207-212

The objective of the study was to test different sole and intercropping systems with cassava, corn, and beans (*Phaseolus vulgaris*) at two technological levels: traditional and one considered improved with use of fertilizer (N, P, K).
The treatments were repeated four times in a randomized block design in a factorial arrangement, with and without application of fertilizer (at rates of 50 N, 20 P_2O_5 and 30 K_2O kg/ha at planting).
The soil was prepared by tractor in ridges 1 m apart.
Yield and yield components were taken in all crops.
All the data were analyzed statistically. The crops were adequately protected from insect pests, diseases and weed infestation.
The Northeast Region of Brazil grows 51% of the country's cassava, the greatest amount being produced in the region with an average annual rainfall of 650-1000 mm.
Intercropping is a major farming system in Northeast Brazil. Cassava is grown in two or three associations, probably to reduce the risk of harvest loss by a prolonged absence of rain and to improve the intensive use of a small area and family labor force. It is usually intercropped with beans and corn, and sometimes with cotton, rice, tobacco, coco palm, rubber trees, and *Opuntia* sp. (forage cactus). In the typical multiple cropping association in this area, advanced agricultural practices such as selected cultivars, pest and disease control, and the use of fertilizer, are not used.
Yields of beans were not affected by either intercropping systems or fertilization. Yields of corn and cassava were affected by intercropping systems, fertilizer, and cropping systems x fertilizer interaction. LER values were significantly different among cropping systems.
Growing three crops together was considered more attractive to the small farmers. Besides the greater advantage regarding the land use, this cropping system would have greater income and give different kind of nutrients to the farmers.
The use of fertilizer did not significantly enhance the advantage of intercropping when analyzed through LER. This indicates that the advantage of intercropping is not improved by the addition of nutrients.

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Cropping systems
Asia, Taiwan, study, field trial, sweet potato, legumes, varieties, planting dates

AVRDC

INTERCROPPING OF SWEET POTATO AND LEGUMES.

In: AVRDC Progress Report 1990, pp. 240-243; ISSN 0258-3089; AVRDC, P.O.B. 205, Taipei 10099

This study evaluated different leguminous crops and examined their planting time relative to that of sweet potato to increase the productivity of sweet potato-based intercropping systems.
Two soybean varieties (AGS 66 and AGS 129) one vegetable soybean (AGS 292), one mungbean (VC 3890 A) were intercropped with sweet potato (TN 67) on two relative planting dates.
This trial was carried out in late spring to compare with results from previous trials in different planting seasons and to determine the relationship between environment and agronomic management of these intercrops.
The climatic conditions during this trial was from a dry cool toward a hot-humid season.
Results of light interception clearly indicated that the mungbean canopy developed slowly compared to other crops. Thus, sweet potato growth, in terms of light interception after the legumes' harvest was less affected by mungbean than soybean. Vegetable soybean sown nine days after sweet potato reduced light interception of sweet potato less than that sown on the same days as grain soybean sown at either date.
The results show that there were significant effects of genotypes, and relative planting dates of legumes on sweet potato yield and the combined yield. Planting of legumes nine days after sweet potato transplanting substantially reduced the competition between legumes and sweet potato. Among legumes, mungbean was dominated by sweet potato because of its slow initial growth. Mungbean was more suited for intercropping with sweet potato than other legumes.
Results of the combined yield indicated that late planting in spring is not suitable for sweet potato-legume intercropping compared to that in other planting seasons in previous trials.
It can be concluded that sweet potato-legume intercrop performed better in cool dry than in hot wet season. If it is adopted across dry and wet seasons, planting should begin in wet season with maturity in the dry season. To maximize the yield advantage of intercrops, suitable genotypes and appropriate relative planting time should be identified.
Component crops when intercropped usually compete with each other for growth resources such as light, nutrients and water. To minimize this competition and increase production, appropriate cultural practices such as choice of genotypes, plant populations and spatial arrangements and relative planting time should be adopted.

1119 92 - 4/162

Cropping systems
Review, book, Africa, shifting cultivation, cassava, technology development, ecological system analysis, systems framework, socio-economic aspects

FRESCO, L.O.

CASSAVA IN SHIFTING CULTIVATION. - A SYSTEM APPROACH TO AGRICULTURAL TECHNOLOGY DEVELOPMENT IN AFRICA.-

Publ. of Royal Tropical Institute, Amsterdam, Netherlands; ISBN 90-6832-013-0; 1986, 240 p; price 39.00 Dfl, Available: Publ. Departm., Royal Trop. Institute, Mauritskade 63, 1092 AD Amsterdam, Netherlands

Cassava is the most important staple food crop in Zaire, where both tubers and leaves are used, the former being the major source of energy and the latter a major source of protein, vitamins and minerals. Cassava plays an important role in the agricultural systems in Zaire.
Through a case study of cassava production in the Kwango-Kwilu region of central Zaire, this book provides a systems approach to agricultural technology development in Africa. In the region studied, cassava production has increased considerably over the last thirty years, keeping pace with or even surpassing population growth.
The author reviews the evolution of cassava production in the region, and its agronomic effects. Cassava, cultivated as a key component of a shifting cultivation system, allows great flexibility in cultural practices. The expansion of cassava onto marginal soils, the increased presence of cassava in crop rotations and associations, and the reliance on female labour explain much of the production growth. At the same time, however, cassava yields have declined and the shifting cultivation system is rapidly breaking down. Past and present research efforts on cassava are discussed with a view to determining strategies for agricultural technology development.
The relevance of this study lies in its detailed analysis of changes in shifting cultivation as well as in its method of analysis. It draws upon ecological system analysis and, to a lesser extent, on farming systems research, and presents a systems framework that allows the integration of technical and socio-economic aspects of crop production which has wide application.
There is certainly a need for greater research in areas such as postharvest handling and processing of cassava in order to find better ways of utilizing the crop at village and farm levels. This is an area that IITA will concentrate on in future as part of a strengthened commitment to cassava research in the humid tropics.

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Cropping systems
Africa, Nigeria, humid zone, field trials, intercropping, yam, maize, stake densities, production costs, economic returns

NDEGWE, N.A.

ECONOMIC RETURNS FROM YAM/MAIZE INTERCROPS WITH VARIOUS STAKE DENSITIES IN A HIGH-RAINFALL AREA.

Trop. Agric. (Trinidad), 69, 1992, pp. 171-175

The main objective of the study was to assess the effects of producing yam and maize under intercropping with a reduced stake population ha^{-1} without materially affecting their yields, and to determine the stake population ha^{-1} that gave the highest net economic return.
The profitability of producing yam (*Dioscorea rotundata* Poir.) with 0-5000 stakes ha^{-1} when intercropped with maize in a high-rainfall area in Nigeria was examined. Yam and maize populations used were 10,000 and 20,000 plants ha^{-1}, respectively.
The high cost of producing yam in the forest zone of West Africa discourages farmers from increasing areas cropped with yam. The high production cost arises mainly from the cost of planting material (seed yam), the cost of stakes and a high labour requirement.
In this study tuber yield and weight $tuber^{-1}$ decreased with lesser numbers of stakes ha^{-1}. No changes occurred in maize grain and stover yields or in height and girth $plant^{-1}$. Production cost was highest with 5000 stakes ha^{-1} and lowest in unstaked yams. Cost of staking decreased with fewer stakes ha^{-1}, being 27, 17, an 13% of total production cost with 5000, 2500 and 1666 stakes ha^{-1}, respectively. Trailing six stands $stake^{-1}$, gave the best net return (48%) in sole yam but two stands $stake^{-1}$ gave the best (22.4%) in intercropped yam, making the best net cash return in sole-cropped yam twice as profitable as a yam/maize mixture.
It is concluded that stake population density is an important factor affecting yield and net cash return in a yam/maize mixture, in addition to other factors.
If yam is to be cultivated with maize, as is practised by most farmers in this area, then not more than two stands should be tied to a stake. When yam is intercropped with maize, the expected best net return will be only about 50% of that of sole yam trailed six stands $stake^{-1}$, demonstrating that it is more profitable to grow yam as a sole crop in the environment than in mixture with maize.
Intercropping unstaked yam with maize did not affect the yield of yam. The yam vines were expected to climb the maize stems and eventually tap more light to give a higher yield than sole, unstaked yam. Most yam vines in unstaked yam plots with maize did not climb the maize stalks. This shows the need for the common practice of trailing yam vines to stakes to be adopted.
An appropriate stake population ha^{-1} or an intercropping system must therefore be used to produce yam tubers of desirable

commercial size. Medium-sized tubers are now generally preferred to big tubers by buyers because big tubers are often more prone to spoilage in storage from injuries sustained at harvest in this high-rainfall area and also because big tubers cost more than an average buyer can afford.
This study further demonstrates the high cost of producing yam, mainly from the high cost of planting material, stakes and labour. Stake population ha^{-1} can be reduced in sole or intercropped yam without adversely affecting yield; such reduction is therefore a good area for reducing production cost and hence increasing profitability in yam cultivation.