this regard. Multiple cropping also needs to address both grain and fodder. Intercropping cowpea, for instance, has been shown to have no effect on corn yield. Cowpea fodder supplements the feed value of the corn stover in terms of additional protein. Other legumes like siratro may also be intercropped with cowpea, with corn-cowpea, and so on, allowing the slow-start siratro to persist through the dry season after harvesting the main grain crop.
Author's summary

IV CROPPING SYSTEMS

585 90 - 4/64

Cropping systems
Africa, Nigeria, Savanna zone, ultisol, intercropping, cassava, maize, groundnuts, productivity, field trials, split plot design, LER, varieties

IKEORGU, J.E.G. and ODURUKWE, S.O.

Increasing the productivity of cassava/maize intercrops with groundnuts (*Arachis hypogaea* L.).

Trop. Agric. (Trinidad), 67, 2, 1990, pp. 164-168

Cassava/maize intercropping is the most popular and productive bi-specific mixture grown in tropical Africa, Asia and Latin America. This mixture has also been shown to be superior to other cassava-based mixture in terms of total calorie yields/unit area/unit time although gross returns and LER were highest where cassava/maize intercrops included other low-growing crops.
Despite their high productivity, cassava/maize intercrops are often combined in traditional agriculture with low-growing crops such as melon (*Citrullus lanatus*), okra (*Abelmoschus esculentus*), cowpea (*Vigna unguiculata*), amaranths (*Amaranthus spp.*), groundnuts (*Arachis hypogaea*) and several leafy vegetables. This is because cassava and maize are the dominant species of most multi-specific complex mixtures with up to seven crops. There is a concensus from these reports that total yields are higher although the yield of the low-canopy crop is often reduced. Since cassava is often planted in low fertility soils, companion crops like legumes usually improve the nitrogen economy of the soil.
Groundnuts used to be a major cash/export crop in Nigeria; it was produced mainly by small-scale farmers who constitute more than 70% of the farming population in Nigeria. About 95% of groundnuts planted in Nigeria and 56% in Uganda are grown in mixture with other crops. General crops are by far the most common component crops grown with groundnuts and the general observation is that groundnut yield is readily reduced by competition from the cereal crop. In the cassava growing areas of Nigeria, both maize and cassava are intercropped with groundnuts in two or three crop mixtures.
This study was initiated to investigate the effects of inclusion of groundnuts into a cassava/maize system on yields of component species, and total land productivity of a cassava/maize/groundnuts mixture in a low fertility soil.
Cassava tuber yield was decreased by 12% in cassava/maize/-groundnuts intercrops where groundnut population was 100 X 10^3 plants ha^{-1} or more. Cassava yields were not reduced in cassava/maize and cassava/groundnuts bi-specific mixtures. Grain yield of maize at 50% of sole crop optimum population tended to be higher in mixtures than under sole cropping at equivalent

populations. Percentage yield reduction of groundnuts in groundnut/cassava/maize where groundnut populations were 50, 100 and 200 X 10^3 plants ha^{-1} were 39, 14 and 78, respectively. This study indicated that cassava/maize/ groundnuts is more productive than cassava/maize or cassava/groundnuts. Highest intercropping advantage, based on LER, was achieved where the cassava/maize system (mean LER = 2.08) included groundnuts at 100 X 10^3 plants ha^{-1} (mean LER = 2.88).
Higher groundnut population densities in mixture may cause reduced yield of component crops, especially of groundnuts. Cassava + maize + groundnuts at 100 X 10^3 plants ha^{-1} was most productive. This mixture was superior to the cassava/maize system. However, the cassava/maize system was better than cassava/groundnuts system. There is need to monitor the contributions of cassava/maize/groundnuts to the soil nitrogen economy as well as the ability of this mixture to check excessive weed infestation.

586 90 - 4/65

Cropping systems
Asia, India, arid zone, monsoon climate, field trials, pearl millet, rainfed cultivation, energy inputs

JOSHI, N.L.

Efficient use of energy inputs in rainfed pearl millet.

Agriculture, Ecosystem and Environment, 25, 1989, pp. 91-102

The commercial energy input to crop production has immensely increased with the adoption of Euro-U.S. models of crop production technology.
This trend is highly alarming since the crop production continues to depend largely on fast-depleting non-renewable sources of energy.
Pearl millet, *Pennisetum americanun* (L.) Leeke, is the staple food crop in arid tropics. Despite modest energy use in rainfed agriculture, pearl millet productivity has also become highly dependent on commercial energy inputs. Therefore, this paper attempts to illustrate the agronomic practices such as weed management, nitrogenous fertilizer use, intercropping and planting patterns for efficient use of energy inputs. These practices can increase pearl millet productivity in low rainfall areas and possibly conserve energy.
Studies were conducted at Central Arid Zone Research Institute, Jodhpur, India. The soil of the experimental site was coarse loamy, mixed hyperthermic Camborthids, low in organic matter (0.4%), and with moderate amounts of available P (17 kg ha^{-1}) and available K (190 kg ha^{-1}).
The region is characterised by a monsoon climate. About 90% of the average annual precipitation of 360 mm is received from the end of June to September. The sowings for the experiment were done with the monsoon rains. Four experiments, each for two consecutive years, were conducted.
Application of 40 kg N ha^{-1} with one manual weeding involving 8034 MJ ha^{-1} total energy input resulted in 72% increase in grain production, and a total energy output of 39.817 MJ ha^{-1} compared to 27.226 MJ ha^{-1} output without nitrogen. The nitrogen accounted for 12.591 MJ and the weeding for 21.886 MJ ha^{-1} energy output. Combined application of these resulted in complementarity of 15.5% over effect of individual input. The least specific energy of 1.76 MJ kg^{-1} biomass with the highest energy output per unit (7.45) was recorded by the application of 40 kg N ha^{-1} together with herbicide application. Energy output per unit of energy input varied with the cultivars, BJ 104 being the most efficient. Intercropping grain legumes with pearl millet increased the total crop productivity as well as the energy output. The intercrops clusterbean, dewgram and greengram, with only 91 MJ ha^{-1} extra energy input resulted in 7938, 3810 and 2215 MJ ha^{-1} additional energy output, respectively.

The pearl millet yields and energy output depended much on the quantity and distribution of rainfall during the growing season. The paired-row planting with 10^5 plants ha^{-1} proved to be a better planting pattern for pearl millet as it gave significantly higher yields and energy output over uniform row planting in the sub normal rainfall year and similar yields and energy output in the normal rainfall year.

587

90 - 4/66

Cropping systems
Africa, Nigeria, humid tropics, bimodal rainfall, lowland, intercropping, sole cropping, cocoyam, maize, leaf harvest

OLASANTAN, F.O.

The response of cocoyam, *Xanthosoma sagittifolium* (L.) Schott, to row arrangement, maize, intercrop, and frequency of young leaf harvest.

Beitr. trop. Landwirtsch. Vet. med., 28, 1, 1990, pp. 49-58

Cocoyam (*Xanthosoma sagittifolium* and *Colocasia esculenta* (L.) Schott) are staple food crops popular in the lowland humid tropics for their leaves and rhizomes.
The growing of cocoyams as intercrops is a common practice among farmers in the tropics. In the southern parts of Nigeria, the crops are frequently intercropped with young tree crops like rubber, banana, and cocoa, and then harvested before the perennial crops close canopy. Also, cocoyams are often found in mixtures with other subsistence staples like melon, maize and cowpeas, which are normally harvested at about the time when the cocoyam canopy closes and the late-maturing cocoyams are left to complete their growth. In traditional agriculture, cocoyams are usually one of the last crops harvested before the land is allowed to return to bush fallow. Intercropping between high and low canopy crops is a common practice in tropical agriculture. In order to improve light interception and hence yields of the shorter crops, they must be planted between sufficiently wide rows of the taller crops.
The present study was therefore conducted to determine the effects on cocoyam of row arrangement, maize intercrop, and the frequency of young leaf harvests.
Four experiments on *Xanthosoma sagittifolium* were carried out over a 3-year period.
The experimental site, which had previously carried maize and cowpeas, was prepared by ploughing and harrowing. Primary cultivation was performed to a depth of 150 mm with a disc plough.
The results show that intercropping of maize with cocoyam is more productive than sole cropping. This is due to differences in the habitus of the two species and the fact that maize was harvested before the rapid bulking of the cocoyam tubers. The yield and the number of the tubers per plant in cocoyam were not reduced by intercropping. The highest total yield per land unit was obtained by cultivating cocoyam and maize in alternate pairs of rows 45 cm apart. Removing young cocoyam leaves at 3-weekly intervals did not have any negative effect. Removing the leaves at 2-weekly intervals reduced the tuber yield by 48%. Harvesting young leaves at 3-weekly intervals reduced the tuber yield by 48%. Harvesting young leaves at 3-weekly intervals is therefore recommended if cocoyam is grown for both leaves and tubers.

The study shows that cocoyams are able to tolerate considerable insect damage of young leaves or overhead shading in crop mixtures so that loss of leaves or a slight reduction in the number and size of leaves due to intercropping during crop growth need not be damaging to the crops. It might be practical to deleaf cocoyams to produce more shoots and leaves for use in soups and/or to delay tuber yields to avoid a glut on the market and to ensure an extended and continuous supply of corms and cormels. Leaf removal in cocoyam production also ensures better light and rain penetration into the soil surface.
The land equivalent ratios (LER's) show that greater yields of intercropped maize and cocoyam are obtained in a 2:2 row arrangement than in a 1:2 or in alternate rows. This pattern is therefore recommended for farmers wanting to grow the 2 crops in mixtures to minimize weed and erosion problems, maximize growth resources, and obtain increased total crop yields. In countries where both the leaves and petiols of cocoyam are used as human food or animal feed, reasonable tuber yields can be achieved by adopting an optimum frequency or number of leaf harvests either as a sole crop or intercrop.

588 90 - 4/67

Cropping systems
Review, developing countries, humid zones, semi-arid areas, farming systems, agroforestry, multiple cropping, socio-economy, irrigation, ILEIA

BEETS, W.C.

Sustainable continuous crop production in a tropical environment.

ILEIA, 5, 2, 1989, pp. 24-26

This paper examines agro-environmental factors and cropping systems that make continuous cultivation possible. Socio-economic aspects are very important but are only briefly mentioned.
In the humid tropics the problems include infertile soils due to nutrient leaching and soil erosion, high incidence of weeds, pests and diseases, cloudiness and waterlogging. In the semi-arid tropics, constraints are shortness of the hydrologic growing season, moisture stress, soil erosion and excessive oxidation of soil organic matter. Agricultural practices to overcome these problems include continuous protection of the soil by covering it, timely planting, erosion control and irrigation works, the application of modest quantities of chemical fertilizers, and practices that reduce the risks of pests and diseases.
The possibilities for increasing agricultural productivity in the tropics are often debated and many strategies have been proposed. Crop production can be increased by one or more of the following methods:
- by expanding the area for planting crops;
- by raising the yield per unit area of individual crops; and
- by growing more crops per year (in time and/or in space).

In the past, agricultural production mainly increased by the cultivation of more land, but now there is limited scope for that. Nowadays, cultivated land should be cropped more intensively and, if possible, continuously.
Continuous cultivation can only be achieved with improved (multiple) cropping patterns. Such patterns should be based on prevailing natural resources, in particular agro-climate.
When natural resources are carefully manipulated and fully exploited, most of the tropical areas can technically be continuously cropped, especially with the help of irrigation. Population pressures in shifting cultivation type systems have often made sustainable cropping impossible as a result of environmental deterioration due to overcultivation.
It is possible to sustain cropping over long periods, but only if use of natural resources is optimised and if no environmental degradation occurs. The latter requires that sufficient attention is given to soil conservation and ecological stability.
In some areas, e.g. Zimbabwe, continuous cultivation has proven to be possible, but only after detailed analysis of the soil and climate and other natural conditions. This analysis forms the basis for establishing a more sound cropping pattern for

continuous cultivation in a rational way. Finally, the cropping pattern and the symbiotic relationships among crop types should form the basis for continuous cultivation.

589 90 - 4/68

Cropping systems
Africa, Ethiopia, Vertisol, ILCA, highlands, field trial, wheat, chickpea, sequential cropping, irrigation technique

ASTATKE, A. et al.

Sequential cropping of vertisols in the Ethiopian highlands using a broadbed-and furrow system.

ILCA Bulletin, 34, 1989, 15-20

Vertisols are agriculturally important soils in the Ethiopian highlands but because of waterlogging in the main rainy season, their potential for cropping is not fully realised. These soils are found mostly on land with less than 8% slope and have clay contents of 35 to 80%. Traditionally, many Vertisol crops are planted towards the end of the main rainy season and grow on residual moisture.
The productivity of Vertisols can be increased by surface drainage. Broadbeds and furrows made with low-cost, animal-drawn implements help drain excess water, thus enabling farmers to plant crops early in the main rainy season. Run-off rainwater can be conserved in ponds or reservoirs and used to irrigate the land for a second crop. Production of both human food and animal feed can thereby be increased.
The effects of improved surface drainage on the productivity of Vertisols were investigated in a wheat-and chickpea cropping trial conducted in 1987 at ILCA's Debre Zeit research site in the Ethiopian highlands.
Chickpea plots were subjected to four irrigation treatments (no irrigation; irrigation at planting; irrigation at planting and 35 days after planting; and irrigation at planting, 35 days and 70 days after planting). Water was supplied through furrows until the top 10 cm of the broadbeds were saturated. Soil-water tension at 10 and 30 cm depth was measured to determine its effect on plant height, 1000-seed weight, and grain and straw yields of chickpea. At 10 cm depth, soil-water tension differed significantly ($P<0.05$) between treatments. During the first 13 days of the trial, the 10-cm soil-water tension on control plots (without irrigation) was high enough to prevent seed germination. At 30 cm depth, the tension on control plots was significantly higher than on plots irrigated at planting, but after the second irrigation, soil-water tension was significantly higher on irrigated plots than on control plots.
Chickpea plants on plots with one irrigation were shorter and bushier than those on plots irrigated two or three times. Grain yield and 1000-seed weight from plots with one irrigation were higher than those from plots irrigated three times, but there were no differences in straw yield between treatments.
The trial showed that with a more intensive irrigation to aid the germination of a second crop, sequential cropping of two crops in the same growing season is feasible in the Debre Zeit area.

Thus in the Debre Zeit area, where chickpea is traditionally produced and where off-season water is available, sequential cropping of cereals and legumes is not only technically viable, but also economically promising and ecologically desirable.

590 90 - 4/69

Cropping systems
Europe, FRG, experiments, glasshouse, *VA mycorrhiza*, *Azospirillum*, fodder plants, growth, nutrient content

HENZE, H.

Wechselwirkungen zwischen *Azospirillum* und *VA-Mykorrhiza* auf Wachstum und Nährstoffaufnahme von tropischen Futtergräsern. (Interactions between *Azospirillum* and *VA mycorrhiza* on growth and nutrient content of tropical fodder plants.)

Göttinger Beiträge zur Land- u. Forstwirtschaft in den Tropen und Subtropen, Göttingen, 25, 1987, 210 p.

The objective of this study was to examine whether a combined inoculation of plants with nitrogen-fixing bacteria and a VA mycorrhizal fungus results in better growing and higher nutrient contents than an inoculation with only one of these microorganisms. A further point was to answer the question in which way environmental factors, especially soil factors, affect the efficiency of inoculation.
Three series of experiments were carried out unter glasshouse conditions with the grasses *Paspalum notatum* Flügge and *Panicum virgatum* L. For inoculation Azospirillum brasilense, strain Cd, was used, and a Göttingen strain of a VA mycorrhizal fungus.
The following soil factors were varied; kind of P fertilizer, soil-pH level, soil temperature and fertilization with molybdenum. Finally the bacterial inoculation and the VA mycorrhizal fungus was substituted by increasing amounts of N and P fertilizers to compare their efficiency to the combined inoculation.
In the first series of experiments the effects of the three kinds of inoculation were tested by using monocalciumphosphate (MCP), hydroxylapatite (HA), and rock phosphate (RP) as P fertilizers and at soil-pH levels of 4.5; 5.5; 6.5; and 7.5.
The combined inoculation as compared to the single inoculation was more efficient only at medium availability of phosphorus as it exists at pH 6.5 and HA fertilization. The mycorrhizal infection, particularly the development of vesicles and mycelium, rose by Azospirillum inoculation. Inoculation only with Azospirillum caused better plant growth at high P availability, especially at pH 6.5 and with MCP fertilization, and also at pH 5.5 and HA fertilization. The use of low-stuble phosphate promoted the efficiency of VA mycorrhiza by increasing the P uptake of plants, especially at pH 7.5 and use of HA or rock phosphate.
In the second series of experiments the influence of soil temperature on the efficiency of inoculation was examined. The temperature was arranged in four steps (22.5°C, 27.5°C, 32.5°C, 37.5°C) at pH 5.5, and in three steps (23°C, 30°C, 37°C) at pH 6.5.

Combined inoculation surpassed the other treatments at pH 6.5 at all temperatures, particularly at 23°C and 37°C. At 23°C and at 22.5°C Azospirillum strongly advanced mycorrhizal infection.
Inoculation with Azospirillum alone was efficient only at pH 5.5, particularly so at temperatures above 30°C. The efficiency of VA mycorrhiza was less at pH 5.5 than at pH 6.5 and was also reduced by high (37°C) or low (23°C) temperature.
In the experiments of the third series Azospirillum was substituted by increasing N fertilization, and VA mycorrhiza by increasing P fertilization. The efficiency of the mineral fertilization was compared with the effect of combined inoculation. Furthermore, the influence of molybdenum at two levels of fertilization (2 and 4 kg/ha) was tested.
VA mycorrhiza substituted 105 kg P/ha in the case of *Paspalum notatum*, and 150 kg P/ha in the case of *Panicum virgatum*. MO fertilization at 2 kg/ha increased the efficiency of Azospirillum in single or combined inoculation. A supply of 4 kg/ha showed no further effect.
Due to the high Mn content of the soil no definite conclusions with respect to the influence of Mo can be drawn.
Author's summary, amended

591 90 - 4/70

Cropping systems
Africa, Mali, Sahelo-Sudanian Zone, ICRISAT, pearl millet, maize, cowpea, traditional systems, intercropping

SHETTY, S.V.R. et al.

Amélioration des systèmes de culture axés sur le mil dans la zone sahélo-soudanaise au Mali. (Improving millet-based cropping systems in the Sahelo-Sudanian Zone of Mali).

Proc. of the Int. Pearl Millet Workshop, ICRISAT, Patancheru, India, ISBN 92-9066-134-8, 1987, pp. 306

Agronomic experiments on pearl millet-based production systems conducted jointly by Institut d'économie rurale (IER) and ICRISAT are briefly reviewed. Cropping systems research approaches are described which consider both improvements to existing pearl millet-based systems, and also the design and evaluation of more productive alternative systems. The two major production systems studied are two intercrops, maize/millet in the Sudanian Zone and millet/cowpea in the Sahelian Zone. The traditional maize/millet and millet/cowpea systems as practiced by the subsistence farmers in Mali are briefly described. The effects of such key agronomic factors as crop variety, density, and geometry, dates of planting and harvest, and added fertility on the total productivity of these systems are synthesized to develop improved technology packages. The suggested technologies for millet/cowpea system include planting millet after the onset of rains at about 30 000 plants ha^{-1} with about 25 000 plants ha^{-1} of cowpea planted later when millet is in the 3-4 leaf stage in a 2-row millet/cowpea system. The need to introduce management-responsive millet cultivars to develop more productive millet-based systems is emphasized.
Alternative production systems presently being studied are indicated with particular reference to millet/groundnut systems. It is suggested that the future target systems should include cash crops that provide income to farmers and as a result stimulate the use of agricultural production inputs on the millet component of the intercrop.

Cropping systems
Africa, Nigeria, humid tropics, highlands, intercropping, LER, potato, maize, yield, net income

IFENKWE, O.P. et al.

Effects of maize and potato populations on tuber and grain yields, net income and land equivalent ratios in potato/maize intercropping.

Trop. Agric. (Trinidad), 66, 4, 1989, pp. 329-333

The potato, *Solanum tuberosum* L., though a temperate/subtropical crop, is one of the major root crops in Nigeria.
Annual production in Nigeria is estimated at 200 000 t, valued at about N 80 million (equivalent to US $ 102 million).
Potato is both intercropped and monocropped in the Jos Plateau of northern Nigeria, depending on the season. In the fairly long dry season it is grown as a sole crop, but in the short rainy season it is intercropped at very low densities with a variety of cereals and legumes such as pearl and finger millets (*Panicum miliaceum* L. and *Eleusine coracana* (L.) Gaertn.), sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* (L.) Walp.).
As a reaction to the vagaries of the weather or by profiting from the scarcity of maize for food and feed, farmers around Jos are increasingly intercropping potato and maize. The lack of information on potato/maize intercropping has necessitated this study.
The field experiment was conducted in 1984 and 1985 at the National Root Crops Research Institute, Kuru (09°44'N, 08°47'E, elevation 1351 m and mean annual rainfall 1400 mm) as a 3 x 4 complete factorial in four randomized complete blocks.
The effects of three Solanum potato population densities (33, 24.75 and 16.50 x 10^3 stands ha^{-1}) and four maize population densities (33, 24.75, 16.50 and 8.25 x 10^3 stands ha^{-1}) on yields of potato tuber and maize grain, net income and total productivity were studied. Total potato tuber yield at each planting density declined with increasing plant density of maize. Sole potato gave significantly higher tuber yield than any potato/maize combination. Maize yield was not affected by potato population density. Sole potato gave the highest net return (N 3407 ha^{-1}) which was significantl higher than N 742 from sole maize. Net return from sole potato was not significantly higher than that from other potato/maize combinations. LER was increased with intercropping. A LER of 1.61 was obtained at a combination of the highest population densities of both crops. For all variables the interactions of the population densitiy of maize and potato were not significant. Mean maize yields were significantly higher in 1984 (2.69 t ha^{-1}) than in 1985 (1.75 t ha^{-1}); mean potato yields in 1985 (12.1 t ha^{-1}) were 82% higher than the mean yields in 1984.

Cropping systems
USA, Maryland, field trials, split block design, legumes, maize, cover crops, no-tillage, soil conservation

HOLDERBAUM, J.F. et al.

Fall-seeded legume cover crops for no-tillage corn in the humid east.

Agron. J., 82, 1990, pp. 82-117

Substitution of fertilizer (FN) for biologically fixed N has increased with more extensive use of monocultures and simple rotations. Monocultures, especially row crops such as corn, can increase soil erosion. No-tillage and other conservation tillage practices along with fall-seeded legume covers can reduce runoff and soil erosion losses.
Published data have clearly shown that winter legume covers can replace significant amounts of FN for subsequent crops like corn.
Cover crop N availability to succeeding crops may be reduced more with no tillage than with conventional tillage. Increased soil organic matter and 1 lower mineralization rate of organic N with no-tillage have been reported.
Legume N contribution to succeeding nonlegume crops is quite variable and is dependent on many factors, including the N status of the soil, plus dry matter yield and N concentration of specific legume covers.
There is a need to identify legume cover crop species that provide satisfactory winter erosion control while supplying N to succeeding nonlegume crops. The objectives were to (i) evaluate a wide range of legume species for winter cover under different soil and environmental conditions in terms of winter survival and resulting soil cover for erosion control and (ii) to measure "apparent" N contribution to a succeeding no-tillage corn crop.
The suitability of 14 fall-seeded legumes, three small grains and four legume/grass mixtures was evaluated for winter covers from 1982 through 1985 on Matapeake silt loam (fine-loamy, mixed, mesic, Typic Hapludult) and Mattapex silt (fine-silty, mixed mesic, Aqualfic Normudult) Coastal Plain soils as well as Delanco silt loam and Chester silt loam (fine-loamy, mixed, mesic, Aquic Hapludult) Piedmont soils. Hairy vetch (*Vicia villosa* Roth), crimson clover (*Trifolium incarnatum* L.) and Austrian winter peas *Pisum sativum* (L.) Poir. were the most promising cover crops. Fall growth and early soil coverage was highest with crimson and lowest with vetch which had higher winter survival and spring growth. Peas and, to a lesser extent, crimson clover stands were damaged in some years by *Sclerotinia trifoliorum* Eriks. In some years top growth of vetch contained up to 350 kg N/ha. While N concentration varied among species, total N production was determined more by dry matter yield. Legume cover crops had a greater influence on corn grain yields on the heavier textured soils and longer growing season of the Coastal Plain. In 1985, N contribution to the

subsequent corn crop was reduced when small grains were seeded with annual legumes.
This study shows that fall-seeded legume covers can be successfully established in the Coastal Plain and Piedmont regions of Maryland to control erosion and serve as N sources for no-till corn. The best ground cover was provided by cereal grain/legume mixtures. While hairy vetch, crimson clover and peas performed well, hairy vetch appeared to be most reliable, especially in the Piedmont. Cereal grains alone provided effective ground cover in both regions but were poor N sources for succeeding corn crops. The adapted legume cover crops increased total corn N uptake by 65 to 130 kg N/ha over the corresponding control treatments on N deficient soils. Thus, legume cover crops can make significant contributions to the N nutrition of corn and should be considered when making corn FN recommendations.

594 90 - 4/73

Cropping systems
Asia, India, ICRISAT, semi-arid zone, Alfisol, rainfed condition, groundnut, pigeonpea, intercropping, spatial arrangement, randomized block design

REDDY, S.N. et al.

Row arrangement in groundnut/pigeonpea intercropping.

Trop. Agric. (Trinidad), 66, 4, 1989, pp. 309-312

A groundnut/pigeonpea intercropping combination is important because it involves two crops of different growth patterns for extended use of resources; it is prevalent in the red soil areas of the southern States of India and is quite predominant in the semi-arid tracts of Andhra Pradesh. Traditionally, in this combination pigeonpea rows are wide-spaced, up to 5 m apart, with 14-16 groundnut rows between. This practice gives high yields of the groundnut cash crop but the overall advantage of intercropping may not be substantial because the pigeonpea is too sparsely distributed to make efficient use of resources during the later part of the season and to produce an economic yield.
Recent studies at ICRISAT revealed that groundnut/pigeonpea at 3:1 or 5:1 ratios were more advantageous than either of the sole crops.
This paper describes studies carried out to suggest the most productive and profitable row pattern in a groundnut/pigeonpea combination under rainfed conditions in Hyderabad.
The treatments included two sole crops at their respective optimum population densities (333 000 plants ha^{-1} for sole groundnut and 60 000 plants ha^{-1} for sole pigeonpea) and five intercrop treatments involving groundnut/pigeonpea in 3:1, 4:1, 5:1, 6:1 and 8:1 ratios. The rows were sown 60 cm apart in sole pigeonpea and 30 cm in sole groundnut and all intercrop treatments. The intra-row spacing of both component crops in intercrop treatments was adjusted to maintain the population density equivalent to that of the sole crop optimum. Both 5:1 and 6:1 row arrangements were more productive in terms of yield advantage (LER of 1.49 for 5:1 and 1.48 for 6:1) and were also more profitable (5% monetary advantage for 5:1 and 3% monetary advantage for 6:1) than the 8:1 row arrangement (LER 1.41). Similar results were obtained in both years but the 6:1 row arrangement was more promising than the 5:1 row arrangement when the growing season was wet.

595 90 - 4/74

Cropping systems
Africa, Kenya, drylands, growth chamber, experiments, crop water requirements, drought resistance

HORNETZ, B.

Vergleichende Streßphysiologie von Tepary-Bohnen (*Phaseolus acutifolius* A. Gray) als "Minor Crop" und Mwezi Moja-Bohnen (*Phaseolus vulgaris*, GLP 1004) als Hochleistungsleguminose im tropischen Landbau. (Comparative stress physiology of tepary beans (*Phaseolus acutifolius*) as "minor crop" and mwezi moja beans (*Phaseolus vulgaris*) as high-yielding variety in tropical agriculture).

J. Agron. & Crop Sc., 164, 1990, pp. 1-15

The study deals with the ecophysiological demands of the "minor pulse" tepary beans (*Phaseolus acutifolius*) - possessing a high nutritional value - as well as of the high-yielding kenyan bean variety mwezi moja (*Phaseolus vulgaris*, GLP 1004).
Special reference is made to drought resistance of the crops in order to make recommendations for potential cultivation in the semi-arid and arid drylands of South and Southeast Kenya. Newly constructed growth containers gave possibilities to simulate different durations and intensities of water stress under controlled environmental conditions in climatic chamber experiments.
It was observed and recorded that teparies possess different mechanisms of morphological and physiological adaption to high temperature and water stress, apparently including the ability of osmotic adjustment. The patterns of adaption to water stress are combined with defined hydrature periods closely connected with the reduction of soil moisture.
There was no evidence of morphological adaption of mwezi moja leaves to water stress. It was observed and recorded that there is a partial drought resistance within the upper leaf unit, apparently caused by osmotic adjustment.
The crop seems to be less adapted than tepary beans to marginal cropping areas (e.g. in agroecological zone, AEZ, L6 or LM6) of the drylands due to high crop water requirements (about 30% more than the "minor pulse"), low drought resistance and a high relative yield decrease under water stress - in spite of a short vegetation cycle (about 60-65 days).
Author's Abstract

596 90 - 4/75

Cropping systems
Europe, Portugal, GTZ, semi-humid zone, crops, crop rotation, irrigation project, traditional farming, economic effect

SPEETZEN, H. and R. BARTSCH

Die Einführung neuer Kulturen und Fruchtfolgen im Bewässerungsprojekt des Unteren Mondegotales in Portugal. (Introducing new crops and crop rotations in the Lower Mondego Valley irrigation project, Portugal).

Der Tropenlandwirt, 89, 1988, pp. 33-43

The Lower Rio Mondego Scheme is the largest of the national irrigation rehabilitation projects. The rehabilitation includes modernisation of irrigation and drainage networks and the introduction of intensive and mechanised farming. In this task the Portuguese Ministry of Agriculture is assisted by a German Technical Cooperation project (GTZ). The above mentioned measures are backed-up by appropriate credit facilities, a functioning extension service and an efficient marketing system.
The change from present land use to higher productivity and production levels requires testing of new crops and crop rotations in experimental fields and their introduction at the farm level.
This paper deals with planning and implementation of the transition from traditional cropping to new crops and crop rotations in the Lower Mondego Valley of Portugal.
First the prevailing conditions of the valley are described, i.e. climate, soils and the traditional cropping pattern, in which rice and a maize-bean mixture predominate.
Then the organisation of experimentation, planning and execution of trials and testing the experimental results on a large scale are outlined. The measures to improve the agricultural extension service in the region are described. Finally some economic effects of the transition are briefly analysed.
Traditional land-use patterns:
Rice, with 54% of the total area, is at present the most important crop in the Mondego Valley.
Traditionally a maize-bean mixture has been grown mainly by family farmers on about 8.000 ha of Mondego Valley. However, since about 1979 its area has been decreasing to around 3.600 ha and rice is grown there instead.
The mixture is generally sown in April after the soil has been prepared in the traditional way, which is by plough and disc harrow. It is sown in rows either manually or by seeders which are drawn by animals or men. Maize (seed rate 50 kg/ha) and beans (30 kg seeds/ha) are grown together in the same row and the distance between rows is about 60 to 70 cm.
In August or September maize yields about 2.500 kg/ha and beans about 250 kg/ha. Harvesting is done manually. The irrigation system used is furrow irrigation with 2 to 3 applications of water depending on the requirements.

During the winter a limited amount of forage is cultivated i.e. *Lolium multiflorum* or an oats-vetch mixture. Soil preparation is the same as for the summer crop and all other work is done manually. Seed density is about 35 kg/ha for Lolium and 150 and 40 kg/ha for oats and vetch. The vegetation period is from October/November to March/April.
Farmers only harvest the daily feed for their animals. On average two cuts are harvested but exact information on yields is not available due to the more or less permanent harvesting and re-growth.
As regards potatoes the crop is produced by almost all farmers. On average 30% of production is for home consumption and 70% for sale.
In other even smaller fields peas, beans, tomatoes and onions are grown for local markets.
Although fruit trees and olive trees exist all over the valley, they only cover about 55 ha each.
At present about 180 ha of poplars are grown in the valley for the production of matches. Every 9 years the trees are cut, involving about 20 ha per year. The average yield is 16 t/ha.
The total number of cattle in the project area is about 21.000, which can be broken down into 4.000 milk cattle, 8.000 meat cattle and 9.000 working cattle.
For centuries working cattle have been kept in the project area for soil preparation for all crops and for transport. Even today a considerable proportion of the work is carried out by working cattle, although this proportion is decreasing.
The cattle fattened in the Mondego area are crossbreeds of Charolais and only very rarely pure-bred. Sheep are normally kept in herds of about 70 to 100 heads, with one shepherd for 100 sheep. Some herds consists of up to 170 heads. Many small farmers have 1 to 2 sheep which eat fodder left by the cattle.
The farm-survey carried out in the Mondego Valley in 1980/81 showed the number of farms in the Valley to be about 7.600 and the number of land owners to be 13.000. The average farm size is about 3.5 ha with an average area of 1.7 ha in the valley. The average number of plots per farm is 3.6.

Planning and implementation of the change

The planned increase in agricultural production is intended to be achieved by intensification of cropping and forage production. This requires improving technologies for existing crops such as rice and maize, the introduction of new crops and the adaption of intensified crop rotations.
The farmers of the Mondego valley are not accustomed to permanent exploitation of natural resources with all the resultant consequences. Although in adjoining higher lying areas, the so-called "montes", permanent but extensive agriculture is common, it is beyond the present capabilities of most farmers to use the "montes" and the valley more intensively.

Economic effects on farm level of the new cropping patterns

The new farming pattern is basically a shift from only one crop per year to two crops. This shift includes the introduction of innovations such as:

- Improving the traditional maize/bean mixture grown in summer.

- Replacement of rice on 2/3 of the scheme area by another cash crop.
- Introducing forage or a cash crop to replace the current winter fallow.
- Intensification of the production through adequate fertiliser application, plant protection and improved varieties.
- Mechanisation of land preparation.

According to calculations made, the new cropping pattern can be expected to more than double the income from farming. These increases are expected to be enough to motivate farmers to accept the technical risk of the proposed change in farming.

597 90 - 4/76

Cropping systems
Africa, Nigeria, IITA, rain forest zone, Alfisol, experiments, lowland, cowpea, fodder, grain, leaf, dual purpose varieties, breeding

AKUNDABWENI, L.S. et al.

Evaluation of elite lines of cowpea (*Vigna unguiculata* (L.) Walp.) for leaf/fodder plus grain (i.e. dual purpose)

Trop. Agric. (Trinidad), 67, 2, 1990, pp. 133-136

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important grain legume of the lowland humid tropics and the semi-arid areas. In Africa, it is widely distributed in cultivated and wild forms. In the West African savannas and the Sahel, cowpea is grown as a grain for human consumption and haulms for animals.
Cowpea exhibits large variation of morphologic types including both determinate and indeterminate types. These range from climbing and spreading to dwarf and/or erect forms. Significant progress has been made in breeding determinate erect varieties with high grain yield and early maturity. Such types do not produce many leaves over an extended period. A concern has been raised that with such a thrust, the tendency may be toward the creation of grain types unsuitable for dual purpose utilization. This is because sole grain types may not provide the needed high fodder or vegetable leaf yields and ground cover.
A systematic programme was initiated at the International Institute of Tropical Agriculture (IITA) to identify potential dual purpose varieties, and parents for use in a hybridization programme devoted to the development of dual purpose germplasm.
Experiments were conducted at IITA, Ibadan, Nigeria, in 1985 and 1986.
The experiments were conducted on a tropical Alfisol. 32 advanced breeding lines, pedigree selected for over seven generations, were evaluated.
This study was planted in a split-plot design replicated three times. A plot consisted of four rows each with 20 hills hand-planted 20 cm apart within the row and 60 cm between rows.
Generally, lower total fresh leaf yields were associated with early-to-medium flowering and with high total pod and total grain yields. Total fresh leaf yields were high in late flowering/maturing lines but they fluctuated with the season. One such line, Tvx 1948-01F, gave the best combination of a high grain plus high green leaf/fodder yield. Other lines were good in one respect but not in the other. IT83S-755-1, VITA-3, IT83S-951, for instance, were the highest green leaf/fodder yielders but were the poorest grain yielders. Results appeared to suggest that an initial strategy in a crossing programme should at least include the following steps: (1) an attempt to understand and as far as possible minimize the magnitude of a genotype-environment interaction in late flowering/maturing genotypes before they are

identified as parents; (2) an attempt to transfer the yielding attributes from the high grain but low leaf/fodder yielders into the high leaf/fodder but low grain yielders and; (3) effectively cull poor combinations and/or segregations in early-generation crosses made on the basis of step (2) using suitable dual purpose potential multi-trait selection indices.

598 90 - 4/77

Cropping systems
Asia, India, low external input, pulse production

MASOOD, ALI

Role of non-monetary and low-cost inputs in pulse production.

Indian Farming, Jan. 1987, 23-27

Pulses are mostly grown on marginal lands under poor level of management by farmers who lack the resources to buy fertilisers, pesticides, etc. Keeping in view, therefore, the importance and potential of non-monetary inputs in pulse production, field trials were conducted under the All-India Coordinated Pulse Improvement Project to pinpoint the ideal cultivation practices suited to different locations and situations.
Pulses are known to trap atmospheric nitrogen in their root nodules through symbiotic process with a group of soil bacteria called Rhizobium.
Since the native population of rhizobia is often low, the seed inoculation with specific culture considerably helps in root nodulation and consequently increases production. Results of demonstrations revealed that seed inoculation enhanced the productivity of gram (Gengalgram), lentil, cowpea, urdbean and arhar by 12.3 per cent, 9.1 per cent, 11.5 per cent, 12 per cent and 11 per cent respectively. The cost of bacterial culture is just nominal, that is Rs 4.00 per packet of culture (250 g) which is sufficient to inoculate 10 to 15 kg seeds.
Planting time has profound effect on growth and yield of pulse crops. Late-planting not only restricts growth and yield of crop but also invites large number of insect pests and diseases.
Delay in planting by two weeks registered a yield loss of 30-40 kg/ha/day in the north of India, mainly due to restricted growth period. Early-planting has also proved disadvantageous. Most of the studies have shown that early-seeded gram does not bear adequate number of pods as most of the early-formed flowers are shed due to low temperature at flowering time and the crop attains profuse vegetative growth.
One of the major constraints for low yield of most of the pulses has been found to be the low plant population per unit area. Several studies have shown that the crop yield increases with corresponding increase in plant density up to a certain level. The desired plant population in early arhar can be obtained by maintaining row-to-row spacing of 45 to 50 cm and plant to plant spacing of 10 to 15 cm. In case of late arhar 60 cm x 20 cm spacing is ideal. For realizing good yields from gram, kharif urdbean and mungbean and rabi arhar and rajmash, 30 cm x 10 cm spacing should be adopted. In case of lentil 25 cm x 5 cm spacing is optimal whereas for fieldpea 45 cm x 10 cm spacing is recommended.
Under late-sown conditions, plant growth is restricted and therefore, a higher population is desired for compensating yield

loss per plant. In general, 25 per cent higher plant population is required under late planting situations. For summer mungbean/urdbean 25 cm x 5 cm spacing (80 plants/m) has been found to be optimal.
It is generally observed that under intercropping system, the plant population of the legume component is often low as major attention is paid to cereal component. Studies have shown that by maintaining optimal row plant population of the component crops and adopting additive population, the yield of both the component crops should be considerably increased.

599 90 - 4/78

Cropping systems
Review, auditorial unit, study guide, intercropping, principles, beans, socioeconomic factors, competition, agronomic management, evaluation, intercropping effects, pest and diseases

CIAT

Principles of intercropping beans.

CIAT, Cali, Colombia, 1986, 40 p., Series 04 EB-12.05

The tradition of intercropping is as long as agricultural history itself, because man has always copied wild plant communities, which are comprised of several species and mixtures of genotypes. In small farms of the developing world, food production is based on intercrop systems.
Sole cropping is neither practical nor acceptable to many small farmers, and recent research indicates that multiple cropping systems can actually give more efficient total resource exploitation and greater overall production than sole crops, even at high levels of input use.
Yield benefits from sole cropping are often at the expense of system stability. Intercropping may lessen the yield of each component crop but it optimizes overall stability, showing less variability in total biomass and yield than does sole cropping. This greater stability in intercropping is achieved by compensatory effects among crops; reduced incidences of pests and diseases as a result of greater vegetative diversity; and more complete and earlier soil cover due to varying stages of growth of the component crops, which reduces the incidence of weeds.
The majority of small farmers in the developing world use intercropping systems to grow food to feed their families and to sell to their neighbors. Research into these existing intercropping systems and the development of subsequent improvements thus represents not only new dimensions for agricultural research and training, but also offers opportunities for increasing food production in the areas of the world where it is most needed.
The objective of this unit is to introduce the importance of intercropping systems in world food production. Discussions of

genetic, agronomic and socioeconomic factors involved in intercropping are facilitated by the development and use of a common scientitic language.
The objectives of the paper is to:
- explain the importance of including intercropping in research programs;
- describe common cropping systems involving beans;
- discuss possible advantages of intercropping for the farmer; and
- list the major genetic, agronomic and socioeconomic factors that affect intercropping and describe how they interact.

This paper concentrates on the intercropping aspects of traditional farming systems. It points out that intercropping can benefit the small farmer by providing: greater stability of production; a diversity of diet; an income spread by a range of crop maturities; erosion control; weed suppression; soil improvement; and reduced pest and disease incidence.

600 90 - 4/79

Cropping systems
USA, experiments, intercropping, sorghum, millet, competition, LER

STÜTZEL H. and R.L. VANDERLIP

Grain yield of intercropped sorghum and pearl millet as influenced by sorghum genotype and cropping pattern.

J. Agron. and Crop Sc., 160, 1988, 191-197

Intercropping sorghum, *Sorghum bicolor* (L.) Moench and pearl millet, *Pennisetum americanum* (L.) Leeke, is a traditional and widely used practice in third-world countries to ensure and increase yields. This traditional cropping system takes advantage of great differences in development between the crops.
The sorghum/millet intercropping literature shows experiments with great temporal differences between crops.
Yield increases because of intercropping can be explained by reduced competition between plants, since maximum demands by the two crops for growth factors occur at different times. However, large temporal differences in development allow only limited mechanization. When working with higher levels of mechanization, only small differences in maturity can be used, since both crops have to be planted and harvested at the same times.
Since both sorghum and millet are excellent feedgrains and could be harvested together, the purposes of this study were to find out:
- if relatively small differences in development of sorghum and pearl
  millet would result in yield increases, and
- how different moisture supplies and different planting patterns would influence competition and, as a result, grain yield.

Three sorghum hybrids with expected growth cycles from 90 to 110 days were planted in sole stands and in alternate rows and mixed within the rows with a pearl millet hybrid having a growth cycle similar to that of the early sorghum. Sole stands of millet also were included. The plots were planted at three locations in Kansas, two dryland and one including dryland and irrigated. Results show that yields were consistently highest in sole stands of sorghum, owing to the higher yield level of sorghum. No yield increase could be found on a land equivalent ratio basis, indicating no intercropping advantages. However, under good moisture conditions, a tendency toward yield increase was observed with the later maturing sorghums, which had 1-2 weeks of grain filling after the millet was mature. When moisture supply was insufficient, millet showed higher competitiveness for water than sorghum, and sorghum was adversely affected more than pearl millet was favored. It was concluded that moisture conditions have to be good and that temporal differences between sorghum and millet have to be greater than those used in this experiment to achieve intercropping yield advantages.

601 90 - 4/80

Cropping systems
Africa, Nigeria, experiments, cropping systems, intercropping, spatial arrangements, cassava, maize, cowpea, yields

OLASANTAN, F.O.

Intercropping of cassava (*Manihot esculenta*) with maize or cowpea under different row arrangements.

Field Crops Res., 19, 1988, 41-50

In the humid tropics, cassava (*Manihot esculenta* Crantz) is an important root crop often found in mixtures with other subsistence staples. There are many people in Africa who rely on the crop as the major source of energy. In the southern parts of Nigeria, intercropping of cassava and cereals or grain legumes is widely practised by smallholders. When cassava is intercropped with maize (*Zea mays* L.) or cowpeas (*Vigna unguiculata* L. Walp) it is usually regarded as the main crop for yield; the farmer's principal objective would be to obtain a good tuber yield and to add an extra yield of the maize or cowpeas. Cassava may be planted early with maize and cowpeas at the beginning of the rainy season, but often it may be planted later so as to minimize competition with the other crops which are more sensitive to soil fertility and moisture. The earlier-maturing maize and cowpeas are harvested at about the time when the cassava canopy closes and the later-maturing cassava is then left to complete its growth. Hence, the later-maturing species may not suffer too much by competition with the early species. The competitive relations in the mixture may be manipulated by the choice of variety of either species and by the time of planting. In traditional agriculture, cassava is usually one of the last crops harvested before the land is allowed to return to bush-fallow.
The diverse mixed-cropping systems in the tropics vary in the duration of mixing and the spatial arrangement of components of the mixture according to particular environmental factors, especially water supply and light penetration into the canopies of shorter components. Intercropping between high and low-canopy crops is a common practice in tropical agriculture, and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wide rows of the taller ones.
This study was designed to evaluate the effect of row arrangements on intercropping of cassava and maize or cowpeas, and the possibility of improving the yields of intercropped maize and cowpeas, without markedly reducing the cassava yield.
Sole cropped cassava produced the largest yield; this was significantly reduced by about 40% when intercropped with maize or cowpeas but only when using a 1.2 (cassava:intercrop) row arrangement, mainly because of a reduction in its population

density. Cassava yield differences among different row arrangements were more marked when grown with maize than with cowpeas. Maize and cowpea grain yields were reduced by intercropping, but somewhat less so when grown with cassava in widely spaced rows. Cassava row spacing did not affect maize yield, but cowpea yield was affected significantly. Land Equivalent Ratios were always greater than 1, irrespective of the crop combinations and row arrangements. However, increased yields of intercropped cassava:maize were obtained at 1:1 or 2:2 row arrangements and of cassava:cowpea at 2:2 rows, without much reduction in cassava tuber yield.

Cropping systems
Africa, Nigeria, humid tropics, cropping systems, intercropping, maize, cassava

IITA

Maize plant "architecture" as an important factor in intercropping with cassava.

Farming Syst. Progr. Res. Highlight 1981-84, IITA, Ibadan, Nigeria, 1985, ISBN 978-131-007-3

More than 70% of the food crops consumed in the humid tropics, especially in tropical Africa, comes from intercropping. Therefore, it is important that plant breeders develop appropriate crop types with the best plant "architecture" for mixed cropping, particularly in relation to efficiency in the uses of environmental resources such as light, water, and nutrients required for crop growth. A popular combination with high yield potential in humid/subhumid Africa is a cassava/maize intercrop.
In an experiment conducted over a four-year period, IITA scientists intercropped five improved maize genotypes of varying growth habits with cassava variety TMS 30572 at two maize populations of 30.000 and 60.000/ha. They found that plant height and leaf display were important in selecting maize for intercropping with cassava because cassava root yields were significantly lower when intercropped with tall, spreading, late maturing maize types such as TZSR-W-1 compared with the shorter genotypes such as Pool 16. Major reason for the lower cassava yields was a reduction in the amount of light reaching cassava through the maize.
Because the shorter maize types now available usually yield less than tall, highly vegetative types, one of the challenges faced by plant breeders is to produce short, high yielding maize types with erect upper leaves for intercropping with cassava. Evidence that such varieties can be grown at higher intercrop populations is given. Grain yield of Pool 16 increased up to 60.000/ha population.
The long maturity gap between maize and cassava (three to four months for maize and more than 12 months for cassava) could have enabled cassava to overcome any depression in growth due to maize, but this is not the case because of a drastic reduction in yield of etiolated, lodged cassava stands.
Because cassava contributed such a large proportion of cash returns from the cassava/maize mixture, maize genotypes which result in reduced cassava root yield may not be attractive to farmers.

Cropping systems
Asia, India, greenhouse experiments, field trials, intercropping, cereals, legumes, nitrogen transfer, rhizobium inoculation

PATRA, D.D. et al.

N studies on the transfer of legume-fixed nitrogen to associated cereals in intercropping systems.

Biol Fertil Soils, 2, 1986, 165-171

There are a number of possible ways by which the N can enter the cereal and legume components. The cereal in the intercropping system obtains its N from three possible sources, viz. (a) fertilizer N applied, (b) native soil N and (c) underground transfer from legume of atmospheric N fixed, whether by direct excretion and/or by root or nodule decay.
In a cereal-legume mixture, N uptake by cereal can be influenced by two opposing factors. The legume may increase the supply of available N in the root medium but it may also compete with the cereal for N. In most experiments the transfer and competition are not estimated separately, but the net result is obtained. The legumes in intercropping increase N supply in soil and the associated non-legumes also benefit.
In the present study an attempt has been made to obtain a quantitative estimate of the N fixed by legume and transferred to an associated cereal in an intercropping system using ^{15}N as a tracer under both greenhouse and field conditions.
An attempt has been made to estimate quantitatively the amount of N fixed by legume and transferred to the associated cereal in intercropping systems of wheat (*Triticum aestivum* L.) - gram (*Cicer arietinum* L.) and maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) by labelling soil and fertilizer nitrogen with N. The intercropped legumes have been found to fix significantly higher amounts of N as compared with legumes in sole cropping and the intercropped cereal-legume received the same dose of fertilizer N as the sole cereal crop. But when half of the dose of the fertilizer N applied to sole cereal crop was received by intercropped plants, the amount of N fixed by legumes in association with cereals was significantly less than that fixed by sole legumes. Under field conditions 28% of the total N uptake by maize (21.2 kg N ha^{-1}) was of atmospheric origin and was obtained by transfer of fixed N by cowpea grown in association with maize. Under greenhouse conditions gram and summer and monsoon season cowpea have been found to contribute 14%-20%, 16% and 32% of the total N uptake by associated wheat and summer and monsoon maize crops, respectively. Inoculation of cowpea seeds with *Rhizobium* increased both the amount of N fixed by cowpea and transferred to maize in intercropping system.

Cropping systems
Asia, India, field trials, Java citronella, intercropping, legumes, crop rotation, yield

PRAKASA RAO, E.V.S. et al.

Intercropping studies in Java citronella.

Field Crops Res., 18, 1988, 279-286

Java citronella (*Cymbopogon winterianus* Jowitt) is a perennial, aromatic grass cultivated in various parts of the world. The essential oil obtained by steam distillation is widely used in perfumery, flavouring beverages and the manufacture of deodorants and mosquito-repellent creams. In the Bangalore area in India, Java citronella is one of the most important aromatic crops cultivated, its oil widely used in the perfumery industry.
Java citronella is very slow-growing initially, leaving most of the land uncovered. The present study explored the possibility of intercropping some food crops in the initial lag phase.
An experiment conducted during 1982-1984 showed that the legumes cowpea (*Vigna unguiculata* (L.) Walp), blackgram (*Vigna mungo* (L.) Hepper) or greengram (*Vigna radiata* (L.) Wilez) could be intercropped in the initial stages of Java citronella, to give extra yields over and above that of Java citronella, which remained unaffected by the presence of the intercrops. Another experiment (1984-1985) showed that a two-crop rotation system could be intercropped in Java citronella without affecting the yields of the main crop. The crop rotation systems tested were cowpea, blackgram, or greengram, followed by fodder sorghum (*Sorghum bicolor* (L.) Moench), fingermillet (*Eleusine coracana* (L.) Gaertn.) or groundnut (*Arachis hypogea* L.).

Cropping systems
Asia, India, field trial, cropping systems, monoculture, intercropping, turmeric, coconut, oil contents

SATHEESAN, K.V. and A. RAMADASAN

Curcumin and essential oil contents of three turmeric (*Curcuma domestica* Val.) cultivars grown in monoculture and as intercrop in coconut garden.

J. of Plantation Crops, 15, (1), 1987, 31-37

Turmeric is valued principally for the pigment curcumin. Apart from curcumin, turmeric possesses a specific aroma also owing to the presence of a significant quantity of essential oil. Pigment and essential oil content of turmeric rhizomes can differ considerably among cultivars. Even though turmeric is presently cultivated in different cropping systems, little information is available on the curcumin and essential oil contents of different cultivars as influenced by various environmental conditions. In the present study, the concentration and accumulation of curcumin and essential oil in the rhizomes of three turmeric cultivars grown in monoculture and in association with coconut were investigated at different stages of crop growth.
The maximum concentration of both curcumin and essential oil was attained prior to the maturity of the rhizome. The cultivars showed differential response towards the cropping systems in their curcumin and essential oil contents in the rhizome. The change in the accumulation as well as concentration of essential oil was different from those of curcumin as influenced by the cropping systems.
Author's summary

606 90 - 4/85

Cropping systems
USA, review, cover cropping, mulching, orchard, vineyard, crop management, tillage systems, living mulches, legumes, rotations, intercropping, vegetable

ALTIERI, M.A.

Cover cropping and mulching.

In: Agroecology: the scientific basis of alternative agriculture, 1987, 127-137, Westview Press Inc., 5500 Central Avenue, Boulder, Colorado 80301, ISBN 0-8133-7284-4

Cover cropping is the practice of growing pure or mixed stands of annual or perennial herbaceous plants to cover the soil of croplands for part or all of the year. The plants are incorporated into the soil by tillage, as in seasonal cover cropping, or they are retained for one or several seasons. When plants are incorporated into the soil by tillage, the organic matter added to the soil is called green manure.
The possible benefits of cover cropping in orchards and vineyards are discussed.
The drawbacks of cover crop systems can be reduced or eliminated with careful management and agronomic practices. Limitations are small compared with the alternatives.
For a cover crop to be beneficial, it must decay in the orchard or vineyard. To promote decomposition, the material must be incorporated with damp soil. Therefore, it might be advisable to turn under a cover crop deeper than that provided by the shallow summer cultivation. Care should be exercised, however, to make sure that plowing and disking is not so deep as to cut many tree roots. All orchard disks should be equipped with rollers to prevent excessive penetration. It may sometimes be desirable to break down a large cover crop with a drag or disk before working the crop into the soil. This procedure makes plowing or final disking easier, and lessens the loss of water by transpiration - a result to be desired if the soil is drying out faster than the cover crop can be turned under.
Legume species commonly used as living mulches include short white clover, hairy vetch and red clover. Growth characteristics of representative legumes usually used as living mulches are presented. Except for alfalfa, most legume species are annuals or biennials. Adaptations range from semi-temperate for hairy vetch and crimson clover to temperate for alfalfa, winter pea and sweet clover.
Cropping systems with legume cover crops:
Legume cover crops can be corporated into year-round cropping systems by overseeding (also termed interseeding), legume sod-based rotations, sod strip intercropping or vegetable living mulch systems.

- Legume overseeding:

Overseeding legume cover crops into small grains in the spring has beena standard farming practice for several decades. It is a low-cost, efficient way to establish the sod rotation. Midwest farmers overseed legume cover crops when planting corn, soybean or vegetable crops or before harvesting to maintain soil fertility.
Legume species that appear to have real promise are red and white clover, Austrian winter pea and hairy vetch.

- Legume sod-based rotations:
Legumes in rotation or as green manure are useful in controlling soil erosion and maintaining soil organic matter. A typical three- to six-year crop rotation common among organic farmers in the Midwest and Northeast states involves alfalfa or clover, corn, soybeans and small grains, with the number of years of alfalfa or clover increasing with increasing slope.
- Sod strip intercropping:
In strip intercropping, crops are grown simultaneously in different strips wide enough to permit independent cultivation, but narrow enough for two or more different crops to interact agronomically. The components can be a combination of row crops or a mixture of row crops and legume or grass sod. Using a legume sod is more advantageous from the standpoint of soil nitrogen. Sod strip intercropping may be limited to row crop production in sloping or hillside farms. These systems break the flow of water down the slope, reducing erosion substantially.
- Vegetable/living mulch system:
A living mulch system may be an economical way for vegetable growers to reduce soil erosion, increase organic matter and keep yields consistent with conventional systems.

Trial results of growing vegetables in existing grass and clover sod are further discussed in this paper.

607 90 - 4/86

Cropping systems
Latin America, Brazil, field trial, intercropping, maize, beans, fertilizer, spacing, planting, yield

LIMA, G.R. et al.

Sistema consorciado de produçao feijao x milho. (Maize/beans in association).

In: Empresa Pernambucana de Pesquisa Agropecuária. Projeto Feijao. Recife-PE, Brasil., 1980, pp. 47-57

Different parameters of bean/maize intercropping were studied in Pernambuco, Brazil. In an experiment on population density and spatial arrangement of plants in soils with different levels of fertility (without fertilization and with 40 and 60 kg N and P/ha), the highest bean yields were obtained with 150.000 and 25.000 bean and maize plants/ha, with 3 rows of beans between 2 of maize (653 and 826 kg/ha for nonfertilized and fertilized beans, resp.) and with 225.000 and 12.500 bean and maize plants/ha with 3 rows of beans between 2 of maize (625 and 766 kg/ha for nonfertilized and fertilized beans, resp.). In another experiment in which bean density was maintained constant (200.000 plants/ha) and maize densities and planting densities varied, bean yield was affected by increasing maize populations: 717 kg beans/ha with 12.500 maize plants and 4 rows of beans between 2 of maize; 374 kg beans/ha with 50.000 maize plants and 2 rows of beans between 2 of maize. The greatest economic productivity was obtained with 33.300 maize plants planted at 1.5 x 0.4 m with 3 rows of beans between 2 of maize. In an experiment on density and arrangement of climbing bean (P. 589) plants, in which maize was used as support, the highest production of beans (644 kg/ha) was obtained with 33.300 and 200.000 maize and bean plants spaced at 0.7 x 0.3 x 2 m. In a preliminary trial to evaluate climbing and semiclimbing bean cv. in association with maize, it was found that this type of var. has a higher production potential compared with bush types due to a greater leaf area, larger no. of nodes/unit area, high atm. N fixation rate, and a greater ability for intercropping.

608 90 - 4/87

Cropping systems
Review, Africa, tropics, intercropping research, strategies, trial design, treatment combination, CIMMYT, sustainability

FRANCIS, C.A.

New innovations in intercropping research.

Farming Systems Bulletin No. 3, CIMMYT, ISSN 0187-828X, 1989, pp. 1-9

Following the 'Western' or the 'Asian' model of development, earlier strategies to increase potential productivity focused on developing infrastructure and making inputs such as irrigation water and fossil-fuel based fertilizers and pesticides available. It is increasingly clear that for a number of complex reasons this model has met with limited success in the African context. What is emerging appears to be a development strategy uniquely designed by Africans for their own climatic, social, and political realities but based on agricultural and economic experiences from Africa and elsewhere. Intercropping is an important component of this new strategy.
Intercropping research to date has followed established patterns within national and international public institutions. Choice of treatments and experimental units; use of traditional research designs, and data collection and analysis have employed the methods developed primarily for monoculture systems. The innovative part of this research has been a focus on entire cropping and even total farm systems rather than specific crops and practices. Research and extension specialists implementing the farming systems methodology have sought more participatory approaches in the field in the design of trials, and in collection and interpretation of results, compared to specialists conducting traditional research with monocultures. Women's roles have been identified explicitly in some programmes and taken into account in the design of new technology.
Over the past two decades, there has been an accelerated interest in the entire range of component technology for intercropping: breeding new hybrids or varieties, determining fertility needs, assessing weed and other pest management strategies, and designing alternative systems. Most treatments have been evaluated using traditional measures of productivity, such as grain yield per hectare and net income per hectare.
However, it is likely that these are not the only or perhaps even the primary criteria that farmers with limited resources use to evaluate their own success. Criteria such as the return to labour, risk of adopting new technology, stability and sustainability of production, and nutritional and other food quality factors may in fact be more important to the farm family. Complex questions in farming systems may be more easily studied across a wide range of climatic conditions through simulation research. This would require credible baseline data, relevant measures of system

productivity in terms or units which are meaningful to farmers, and careful consideration of the appropriate levels of inputs and resources. Interdisciplinary team approaches are essential to understanding the complexity of intercropping and how systems can be manipulated to increase productivity and sustainability.
Opinions differ on how to approach the critical research questions on components versus systems, on-farm versus on-station research, high-technology versus low-technology solutions, internal versus external resources, cash crops versus subsistence food crops. These questions are frequently confounded with decisions in research on intercropping systems. This is to be expected, since so many factors outside the biological world impinge on the success of complex systems used by low-resource farmers.
It is important to think about setting research priorities, to seek efficient designs for field research, to consider extension and application of results before the actual field work is initiated, and to think creatively about approaches to improving intercropping systems.
Agroecology and agroforestry are new areas receiving increased attention in research and extension. Biological interactions among crops, livestock, pest populations, and microorganisms are becoming better understood. These interactions are especially complex in an intercropping system, and biological principles can be used to better design new and more productive systems. More creative approaches to measuring system productivity are needed-ways to evaluate yield the same way that farmers evaluate success. This activity is not a simple one, and research on intercropping is likely to be one of the most challenging among the priority topics on the agenda for the next several decades.

609 90 - 4/88

Cropping systems
Review, Africa, Asia, Latin America, intercropping, biological sustainability, economic sustainability, sustainable intercropping system, cropping systems research, nutrient cycling, weed control, pest management, CIMMYT

FRANCIS, A.

Sustainability issues with intercrops.

Farming Systems Bulletin, No. 4, CIMMYT, 1989, pp. 1-5

Intercrop yields and income sustainability are key issues faced by farmers and decision makers in research.
Defining sustainability has become difficult because of the lack of consensus on the time frame, the projected availability and cost of resources, and how technology will be used and by whom in agriculture. More simply put, it is to agree on 'sustainability of agricultural production' under many conditions: costs of fossil fuels, acceptable limits on environmental disturbance, health and safety issues for humans and other species, and for how long?
In a practical, research-based extension program an operational definition of sustainable agriculture as a management strategy has been used which helps the producer to choose hybrids and varieties, a soil fertility package, a pest management approach, a tillage system, and a crop rotation to reduce costs of purchased inputs, minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming.
Intercropping systems have been developed for a number of complex biological, economic, nutritional, and social reasons. We know that these systems represent a perceived optimum strategy to produce food and income under some of the most difficult farming situations where resources are limited. The importance of the many factors which influence management decisions in intercropping systems has not been studied in detail, nor have the multiple interactions of those factors been quantified successfully by researchers or extensionists. Conventional wisdom suggests that multiple species in the field each year - whether intercropped, relay cropped, or sequentially cropped - make more efficient total use of resources, provide a more varied food supply and income source, and present less risk of failure to the farmer than monoculture systems in the same region under the same conditions. Limited experimental evidence appears to support the hypotheses of efficient resource use and of reduced risk with intercrops. There is greater production stability of crops together in the field, just as diverse natural ecosystems persist over a range of different climatic conditions from year to year.
Some of the specific areas in sustainable agricultural systems where more research is needed have been listed. Since many of these research priorities are relevant to intercropping, the list has been edited for presentation here:

- Alternative nutrient sources and nutrient cycling
  . Information base on legumes and organic wastes
  . Nutrient cycling processes and efficiencies
  . Role of rhizosphere and associated organisms
- Cropping systems research
  . Information base on rotations and practices
  . Tests of cover crops, tillage, chemical impacts
  . Intercropping alternatives
- Alternative weed control strategies
  . Cultural factor effect on competition and populations
  . Weed ecology and biology
  . Biological control of weeds
- Alternative disease and nematode management strategies
  . Effects of cultural practices on microorganism balance
  . Methods to favour indigenous antagonists and biocontrol
  . Improved genetic resistance/tolerance to pathogens
- Alternative insect management strategies
  . Ecology of cropping systems as they influence insects
  . Methods for cultural and biological control of insects
  . Improved genetic resistance/tolerance to insects
  . Understanding regional insect pest dynamics

Future research strategies for intercropping need to take into account information that is already available, both from the research stations and from farmers. There is a large body of knowledge on biological principles of crop growth and productivity, interaction with environmental factors, and stability of yield. Even though much of this knowledge has been developed in monoculture systems, most information has a direct application to intercropping systems. The challenge is to find out which information is relevant and how it can be applied efficiently. There is an even greater need to continue the emphasis on interdisciplinary research and on the research-extension-farmer interaction to develop methods and systems that will help improve the productivity of intercropping systems. These are among the most important current issues relating intercropping to sustainability of food production systems.

610 90 - 4/89

Cropping systems
Asia, India, field trial, intercropping, land-equivalent ratio, net returns, cutting management, potato, *Brassica napus*, onion, wheat, berseem

NARWALL, S.S. and H.W. KADIAN

Influence of intercropping and cutting management of gobhi sarson (*Brassica napus*) on yield, land-equivalanet ratio and net returns of potato (*Solanum tuberosum*) and relay crops.

Ind. J. of Agric. Sc., <u>60</u>, (1), 1990, pp. 29-35

India is facing a recurring shortage of vegetable oils, and the price of potato (*Solanum tuberosum* L.) frequently decreases to an uneconomic level. To overcome these problems, it has been suggested to intercrop slow-growing, frost-escaping and late-maturing gobhi sarson (*Brassica napus* L.) with fast-growing and early-maturing 'Kufri Chandramukhi' potato. Gobhi sarson matures in 75-80 days after potato harvest and the land vacated by potato receives adequate sunlight for crop growth, owing to the presence of leaves at stem base. This space and residual fertility of potato could be utilized for growing short-statured crops like Egyptian clover or berseem (*Trifolium alexandrinum* L.) onion (*Allium cepa* L.) and wheat (*Triticum aestivum* L. emend Fiori and Paol.) (transplanted). These crops could be sown in standing gobhi sarson crop because seed-bed becomes ready after potato digging, gobhi sarson plants are only 49 cm tall at potato harvest and these crops could be sown manually.

The present investigation was undertaken to study the feasibility of relay intercropping after harvest of intercropped potato, to select suitable relay crops and to determine the influence of gobhi sarson cutting for fodder on its own grain yield.

Intercropping of gobhi sarson cut for fodder (60 days after sowing) and 'Kufri Chandramukhi' potato and relay intercrops [sown in land vacated after potato harvest, viz 'Muscavi' Egyptian clover or berseem (*Trifolium alexandrinum* L.), 'Pusa Red' onion (*Allium cepa* L.) and 'WH 147' wheat (*Triticum aestivum* L. emend. Fiori and Paol.)] was studied. All these crops were also grown as sole crops. Intercropping of gobhi sarson with potato decreased the yields of potato (9.12%) and relay crops; however total production was greater than of sole crops. Gobhi sarson intercropping did not reduce the seed yield of berseem, slightly reduced the potato yield (9.12%), but greatly reduced those of onion (67.53%) and wheat (80.79%) compared with their sole crops. In intercropping, cutting of ghobhi sarson for fodder increased the yields of potato (9.76%), onion (5,45%) wheat (2.86% and berseem seed (2.70% and fodder (55.2%) compared with uncut gobhi sarson.

Intercropping and relay intercropping increased the productivity or land-equivalent ratio compared with sole cropping. Gobhi sarson

+ potato-berseem (seed) gave maximum land-equivalent ratio, 2.71 with gobhi sarson cutting and 2.58 without its cutting.
Relay intercropping of gobhi sarson (cut) + potato-berseem (seed) gave maximum net return compared with sole potato and sole gobhi sarson, because (i) intercropped gobhi sarson, potato and berseem gave respectively only 25.9 and 1% lower yield than their sole crops; (ii) gobhi sarson and berseem provided additional green fodder (12.4 tons/ha), and (iii) the sale price of berseem seed was maximum (Rs 25.000/ton) and its cost of cultivation was minimum compared with other intercrops.
It was concluded that small farmers of subtropical areas having assured irrigation may grow gobhi sarson (cut for fodder at 60 days after sowing) + potato-berseem (seed) for getting maximum productivity of the crops and obtaining the maximum net return.

611 90 - 4/90

Cropping systems
Africa, Niger, Sahel, semi-arid zone, moisture stress, sand reddish coloured soil, cowpea, cultivars, pearl millet, intercropping, IITA, ICRISAT

NTARE, B.R.

Evaluation of cowpea cultivars for intercropping with pearl millet in the Sahelian zone of West Africa.

Field Crops Res., 20, 1989, pp. 31-40

Cowpea (*Vigna unguiculata* L. Walp.) is commonly grown intercropped with pearl millet (*Pennisetum glaucum* (L.) R.Br.) and sorghum (*Sorghum bicolor* L. Moench) in the Sahelian zone of West Africa.
In traditional farms, a 90-110-day-cycle millet is the first of the two crops to be sown. The cowpea, generally of 120-150-day-cycle, is sown between millet rows from 2 weeks to 1 month after the millet, depending on the onset of the rainy season; in this situation, the millet becomes the dominant crop. Millet is often harvested before the cowpea, the latter maturing on residual moisture after the end of the rains. In most years, particularly in the northerly regions of the Sahel, the late-maturing cowpea may produce little grain and be useful only for fodder production.
Varietal selection for improved intercrop performance is dependent on the objectives of the system. In the Sahel, farmers intercrop to stabilize productivity, reduce risk of crop failure due to irregularities in climate, and spread labour peaks. They apparently seek to have a full millet grain yield with some additional cowpea grain and fodder. Research is increasingly being directed towards endeavouring to maintain the inherent stability of traditional cropping systems while increasing productivity.
Field trials were conducted at ICRISAT Sahelian Centre, Niger, to examine the performance of contrasting cowpea cultivars intercropped with pearl millet. Significant effects ($P \leq 0.05$) of cropping system and cultivars were observed for cowpea grain yield. Cultivar x cropping system interaction was significant only for fodder yield. Intercropping reduced cowpea yields significantly but the degree of reduction varied among cultivars. Early-maturing erect cultivars exhibited greater yield reduction than the indeterminate spreading types and had the least effect on millet yields. Indeterminate spreading cultivars produced greater grain and fodder yield than erect types and caused the greatest millet yield reduction.
The relationship between the yield of cowpea cultivars and millet when intercropped was negative. Linear correlations between yield of cowpea in sole and intercrop were positive and significant ($P \leq 0.01$) with r-values ranging from 0.45 to 0.91. However, a small proportion of the greatest and least-yielding cowpea cultivars in intercropping would have been selected and rejected, respectively, on the basis of sole-crop grain-yield. It was concluded that selection of cowpea cultivars for intercropping

with millet based on their grain yield in sole crop may have limited success. Selection based on fodder yield favoured late-maturing cultivars. Selection of cowpea cultivars for intercropping should be based on their intercropped performance, paying special attention to other agronomic factors. An appropriate cowpea cultivar for intercropping with millet would be the one that is less competitive with millet and yields both grain and fodder.

Cropping systems
Africa, Nigeria, humid tropical zone, IITA, Oxic Paleustalf soil, field trial, cassava, maize, okra, melon, intercropping, small-scale farmers, economic yield, land equivalent ratio

IKEORGU, J.E.G. et al.

Productivity of species in cassava/maize/okra/egusi melon complex mixtures in Nigeria.

Field Crops Res., 21, 1989, pp. 1-7

In Nigeria, cassava (*Manihot esculenta* Crantz) and maize /*Zea mays* L.) are dominant components of many traditional complex mixtures. The cassava/maize package developed and recommended to small-scale farmers was not readily adopted because of the non-inclusion of minor crops which, in traditional mixed-cropping systems, are as important as the base crops. Some of the minor crops frequently grown with cassava and maize are egusi melon (*Citronella lanatus* Thunb.), okra (*Abelmoschus esculentus* Moench) and fluted pumpkin (*Telfairia occidentalis* L.). It is not realised that small-scale farmers will not adopt any technology that excludes these essential minor crops. Apart from preliminary work on cassava/egusi melon and cassava/okra mixtures at IITA, little attempt has been made to determine the productivity of major root-crop-based complex mixtures. The study was carried out to determine whether, under technologically improved conditions, the inclusion of egusi melon and/or okra in cassava/maize intercrops actually improves total productivity. Information from this work will reveal the strenghts and weaknesses of the cassava/maize recommendation.
Tuber yield of cassava in cassava/maize/okra (15.8 t/ha), cassava/maize/egusi melon (15.1 t/ha) and cassava/maize/okra/egusi melon (14.5 t/ha) did not differ significantly from that in cassava/maize (16.4 t/ha). Maize grain yield was not depressed by intercropping with vegetables. The economic yields of intercropped okra and egusi melon were reduced by more than 50% of their respective sole crop yields.
The cassava/maize cropping system yielded highest calories per hectare per day ($18.6x10^4$ cal ha^{-1} day^{-1}) but land productivity, based on land equivalent ratio (LER) was higher where the cassava/maize system (LER = 1.58) included both okra and egusi melon (LER = 1.60).
The cassava/maize system is highly productive in terms of calorie yield per unit area per unit time. Inclusion of okra and egusi melon into the cassava/maize system did not further improve calorie yields. The four-crop mixture had slightly lower calorie yields but higher LER than cassava/maize intercrops. This means that although okra and egusi melon did not improve the calorie yields of cassava and maize-based complex mixture, they could improve total productivity per unit area of land. The

cassava/maize recommendation could have been based on the high-calorie productivity of the cassava/maize intercrops.
The data of this experiment seem to provide an explanation for the persistence of traditional practice. While dietary requirements are better satisfied, the farmer also saves more land by including vegetables in cassava/maize intercrops.

613 90 - 4/92

Cropping systems
Africa, Rwanda, Burundi, breeding, maize, beans, traits for intercropping, yield evaluation, farmer participation, CIAT

DAVIS, J.

Breeding for intercrops, with special attention to beans for intercropping with maize.

Farming Systems Bulletin, No. 5, CIMMYT, ISSN 0187-828x, 1990, pp. 17-21

Beans in eastern and southern Africa are grown mostly by small farmers who commonly use multiple cropping systems. In some areas, such as Rwanda and Burundi, land is increasingly scarce, so that improving its productivity is more important than increased labour productivity. In addition, the many stresses to which crops are subjected cause farmers to diversify, planting more than one crop species together and using variety mixtures to reduce the risk of failure.
For a crop such as beans, it is essential to consider the social and physical environment in which new varieties will be used, because their acceptance or rejection will depend on how well they fit into both. Since breeding takes time, it is necessary to predict how the social environment will change. As farmers move from subsistence agriculture to marketing their produce, they tend to move away from intercropping toward the use of more uniform varieties. This trend can already be seen in some areas with access to urban markets, for example northern Kivu in Zaire. However, the increased land productivity and reduced risk inherent in intercropping are not to be given up lightly, and new varieties bred for existing cropping systems could help achieve sustainable improvements in productivity.
A problem here is that cropping systems as well as cropping environments are rather varied.
Beans are rarely a promising subject for large scale seed production, and an alternative in their case would be seed production in cooperatives of small farmers at the local level to obviate the need for widely adapted varieties. Farmers could become involved at an earlier stage in selecting among the large genetic diversity in the breeding programme, and varieties more specifically adapted to local conditions and cropping systems could be selected.
In this paper some methodologies, with examples, for developing bean varieties specifically adapted to intercropping with maize are introduced.

614 90 - 4/93

Cropping systems
Study, tropics, mycorrhizae, crop nutrition, crop development, marginal lands, CIMMYT

DIEDERICHS, C. and MANSKE, G.G.B.

A importancia dos fungos micorrizicos na nutriçao de cultivos das regiões de clima quente (The role of mycorrhizae in crop nutrition in warmer regions).

In: Proc. Ist Int. Conf. on Wheat for the non-traditional warm areas, CIMMYT, Ignaza Falls, Brazil, 1990, pp. 1-19

The beneficial effect of vesicular-arbuscular (VA) mycorrhizal fungi on crop development is becoming more and more recognized by agricultural scientists. The main advantage of mycorrhizal fungi is their ability to promote phosphorus uptake by crops in particular under marginal soil conditions with environmental extremes and low nutrient status.
Many factors can decisively influence the development of VA mycorrhiza. In the present report the crucial role of the mycorrhizal symbiosis in crop nutrition under various environmental conditions, agronomic practices and plant breeding aspects is presented and discussed.
Although the number of mycorrhizologists has increased tremendously offering a wide spectrum of publications from various research fields, the application of effective VAM fungi in crop production systems under field conditions is restricted to small-scale field trials because of the ponderous inoculum production. Currently commercial use of VAM inoculum (produced in the "pot culture" method) is restricted to citrus and avocado nurseries and ornamentals. Under these conditions where seedlings are raised in sterilized soil the addition of effective mycorrhizal fungi is indispensable to obtain maximum growth. The situation, however, of limited application of VAM fungi in agricultural production systems should not discourage scientists to carry out further research.
Breeding of low-input cultivars with little need of fertilizer, especially for marginal soils with P fixation in the tropics and subtropics should include the VA mycorrhiza. Under P deficiency an intense, but also well infected VA mycorrhizal root system can promote P uptake of wheat. Genotypes with intense root systems, but with semidwarf haulm length to avoid lodging, and with high VA mycorrhizal colonization and efficiency can be selected.
If one wishes to utilize the mycorrhizal symbiosis effectively in agricultural production programs mycorrhizal management deserves special attention and many agricultural aspects must be taken into account:
- Fertilization level
- Pesticide application
- Soil type
- Plant involved in crop rotation

- Soil/host combination to which efficient VAM fungi are best suited
- Interaction with other soil-borne microorganisms
- Competition between exotic and locally adapted VAM strains
Because VAM fungi occur in all ecosystems, regardless of the crop or cropping system, any disturbance due to inappropriate agricultural practices may decisively change the potential of native VAM fungi resulting in a decline of productivity and sustainability of the ecosystem. Even the introduction of effective exotic VAM fungi which had previously been isolated from one soil may, 1) not favour plant growth in another soil, or 2) modify the native population of mycorrhizal fungi due to interendophyte compatibility.
Considering the potential that VA mycorrhizal fungi offer, the scale of mycorrhiza research in tropical regions should substantially be expanded with the objective of selecting effective mycorrhizal strains which have favourable associations with a wide array of crops.

615

90 - 4/94

Cropping systems
Africa, Senegal, Zimbabwe, ICRISAT, pearl millet, constraints to cultivation

THIAM, A. and S.C. GUPTA

La culture du mil - face aux contraintes de l'agriculture intensive (Constraints to intensive cultivation of pearl millet).

In: Proc. of the Int. Pearl Millet Workshop, ICRISAT Center, Patancheru, A.P. 502 324, India, ISBN 92-9066-134-8, 1987, pp. 319

Intensive cultivation of pearl millet crops is faced with certain constraints such as nonavailability of high-yielding varieties, lack of mechanization for cropping operations and postharvest soil cultivation, lack of mineral and organic fertilizers, and lack of protection against insect pests, weeds, and diseases.
Initial efforts at pearl millet crop intensification in Senegal indicated the need to reduce the straw production of local cultivars as has been done with excellent results in India in dwarf hybrids having relatively long and broad heads. However, this modification in African millets did not produce the desired effect.
Results of the studies on pearl millet from 1975 to 1983 in Senegal have highlighted the following points:

- Due to their more efficient use of water, cultivars that mature in 80-90 d are more productive than shorter-duration material. But they can only be grown in regions where climatic conditions are not erratic.
- Straw plays a significant role in yield development. Head and 100-grain mass are the only yield components with any stable effect on grain yield. The influence of other yield components varies with location. Therefore varietal diversity for these phenotypically plastic characteristics facilitates adaptation to different environments.
- Improvement of the grain/straw ratio is not clearly understood; this characteristic is apparently controlled by 1000-grain mass and by the number of heads and tillers per plant.
- A better understanding of the population dynamics of spike worms has enabled the recommendation of medium-duration varieties that can avoid pest infestation.
- Tillage operations, in spite of their beneficial effect on yield, cannot be carried out by farmers who lack equipment and time, and under sociological constraints. Crop intensification requires improved techniques that can delay soil dessication, thus allowing more time and effort for tillage operations.
- Plowing in the crop residue increases nitrogen productivity in sandy soils and improves fertilizer use by the plant. However, the incorporation of crop residue combined with

NPK fertilizer cannot adequately maintain the nitrogen fertility of the soil.
Attempts to apply the research results show that mechanization can only be envisaged in case of commercial cropping.

616 90 - 4/95

Cropping systems
Africa, Nigeria, field trials, humid rainforest zone, cassava, cowpea, maize, okra, land equivalent ratio, monetary equivalent ratio, multi-storey intercropping, competition indices, row intercropping, strip intercropping, substitutive model

ADETILOYE, P.O. and A.A. ADEKUNLE

Concept of monetary equivalent ratio and its usefulness in the evaluation of intercropping advantages.

Trop. Agric. (Trinidad), 66, 4, 1989, pp. 337-341

Various methods have been developed for assessing the yield advantage of intercropping over sole cropping. Among the concepts of relative crowding coefficient, competition index, aggressivity index, relative yield total, it has been observed that the land equivalent ratio, (LER), was the preferable index for any intercropping situation. The concept of land equivalent coefficient, (LEC), assesses the agronomic advantage of intercropping over sole cropping. The superiority of the LEC over the LER index was attributed to the ability of the LEC to indicate the minimum level of reasonable contribution by the least productive intercrop component when a yield advantage is indicated. All the above indices measure the agronomic advantage of intercropping by comparing the yields in association with that of the individual sole crops.
In this paper the concept of monetary equivalent ratio (MER) is presented and discussed. The MER concept can be used in the choice of intercrop plant population proportions and in the choice of the distribution of crops in time and space in such a way that the agronomic as well as the economic advantage of intercropping will both be maximized.
The monetary equivalent ratio (MER) is defined as the sum of the ratios of intercrop monetary returns to the highest sole crop monetary return from the entire land area occupied by all intercrops unit $time^{-1}$.
The MER measures the economic superiority, or otherwise, of intercropping over the most economic sole crop.
The yield advantage of an association of cassava-cowpea-maize was assessed. The economic advantage of intercropping was only 6-14% (MER = 1.06-1.14) even though the agronomic advantage ranged 12-63% when assessed with the land equivalent ratio (LER = 1.12-1.63). In a cassava-okra-maize,cowpea association, the agronomic advantage ranged 2-25% (LER = 1.02-1.25). The MER indicated no economic advantage and the efficiency of the system was only 50-62% of the most economic sole crop, which was cassava.
The disparity between the LER and the MER values indicates that a substantial agronomic advantage does not guarantee an economic advantage in intercropping. The allocation of intercrops to strips facilitates field operations, enhances light energy utilization and increases crop yields in intercropping over sole cropping.

However, the selection of intercrop proportions as well as the spatial arrangement of crop in time and space should reflect the economic value of the crops in association. There is therefore a need for caution in designing intercropping experiments with a view simply to guarantee a good agronomic advantage by using the replacement method or by strip intercropping with a disregard to the economic value of the system.
One major limitation in the use of the MER is that the MER value of a given system will vary both with time and place. Since, however, it is expected that the development of a productive cropping system will eventually be evaluated on the fields of farmers in the region where the system is to be adopted, the MER concept will be a useful guide to the researcher in that region.
The usefulness of the MER concept is its ability to weigh the economic returns of several intercrops against the most productive sole crop. Even if the yield and unit price of each crop vary with time, the relative economic value of crops as measured by the MER will still be less variable than both the crop yield and the crop price at a given location. The concept of MER presented in this study suggests the need for caution in the use of the substitutive model and of strip-intercropping in intercropping research. This is because both practices can produce substantial agronomic advantage in intercropping over sole cropping without necessarily giving an economic advantage.

617 90 - 4/96

Cropping systems
Latin America, Honduras, management system, bean, maize, small farms, evaluation

CATIE

Alternativa de manejo para el sistema maiz - frijol (La Esperanza, Honduras): descripcion y evaluacion en fincas pequenas (Alternative management systems for corn and beans (La Esperanza, Honduras): description and evaluation of small farms).

Informe Tecnico No. 46, CATIE, Costa Rica, 1984, 105 p.

As part of CATIE's project of developing site-specific cultivation systems for improving small farm productivity in Central America, the main characteristics of an alternative maize-bean cultivation system - designed to be incorporated into the traditional maize-bean-potato system of La Esperanza, Honduras - are herein described. The report focuses on results and evaluations of on-farm trials of the proposed system.
First, the traditional farm management and cultivation practices for maize and beans in the high plateau region and technical options for improving them, which center on shorter distances between plantings and use of Cytrolane for pest/disease control, are described. Next, the recommendation domain for the proposed system is outlined, including characteristics of the region (geographic and climatic aspects, geology and soils, vegetation, available extension services) and of the farmers most likely to benefit. A third chapter analyzes the technical and economic feasibility of the new technology by comparing its agronomic/economic indicators with those of the traditional system. Finally, the experimental research methodology and results are presented.
Abstract from FSR

618 90 - 4/97

Cropping systems
Study, tropics, developing countries, intercropping, land equivalent ratio, area time equivalency ratio

BALASUBRAMANIAN, V. and L. SEKAYANGE

Area harvest equivalency ratio for measuring efficiency in multiseason intercropping.

Agron. J., 82, 1990, 3 pp. 519-522

More than one growing season per year exists in tropical areas with bimodal rainfall distribution. Multiseason intercropping systems are those in which one or more of the component crops occupy the land for more than one season.
In these systems, the component crops occupy the land for various lengths of time depending on their growth cycle/duration.
Intercrop advantages can result from one or both of the following: (i) increased conversion (resource use) efficiency or net assimilation rate, and (ii) prolonged exploitation of resources at the same efficiency due to longer combined leaf area duration. The relative contribution of these two mechanisms to yield increases of intercrops can be separated by physiological measurements.
This study was undertaken to develop a practical concept or measure of resource-use efficiency for multiseason intercropping systems.
Both area and time factors have to be considered to quantify resource-use efficiency in multiseason intercropping. The land equivalent ratio (LER), commonly used as an indicator of efficiency, is not suitable because it considers only the area factor to estimate intercrop advantages. The area time equivalency ratio (ATER) unrealistically assumes continuous crop growth throughout the year, thus it underestimates the advantages of intercrops. To avoid these problems, some authors used the mean value of LER + ATER as an arbitrary compromise. This paper proposes a new concept called area harvests equivalency ratio (AHER).
The new concept of AHER combines the area and time factors in a practical sense for quantifying intercrop yield advantages, particularly in multiseason associations. In AHER, the time factor (n_i) is the number of possible harvests of each component species of an association that could be obtained during the full intercrop period, if each component was monocropped. The values of n_i will always be whole numbers, because fractional harvests of crops are inappropriate. In the definition of n_i, AHER assumes that sole crop yields of component species in successive seasons are similar, which may not always be true. In situations in which crop yields vary highly between seasons, it is better to measure the actual sole crop yields in successive seasons. Using four different cases of intercropping systems, it has been shown that AHER is a better and more practical measure of intercrop

productivity, particularly in multiseason associations, as compared with the earlier concepts of efficiency. The problem with any attempt to quantify resource-use efficiency is that there is no "true value" for yield advantages in intercrops. However, intuitively, AHER does seem to be nearer to the "true value" than others.

619 90 - 4/98

Cropping systems
Asia, India, intercropping systems, field trials, ICRISAT, productivity, risk evaluation, yields, land equivalent ratio, income

RAO, M.R. and M. SINGH

Productivity and risk evaluation in contrasting intercropping systems.

Field Crops Res., <u>23</u>, 1990, pp. 279-293

Four contrasting intercropping systems, sorghum (Sorghum bicolor (L.) Moench)/pigeonpea (Cajanus cajan (L.) Millsp.), groundnut (Arachis hypogaea L.)/pigeonpea, sorghum/pearl millet (Pennisetum americanum (L.) Leeke), and groundnut/pearl millet, were evaluated along with sole crops from 1979 to 1982, each year in nine different situations spread over different soil types and agronomic managements, with the objective of analysing the productivity and risk associated with these systems. Productivity of intercrops was closely related to the diversity of the crops involved. The two pigeonpea-based systems, with an interval of about 3 months between harvests of the crops, showed a large and consistent advantage over the respective sole crops. On the basis of land productivity, sorghum/pigeonpea averaged 49% and pigeonpea/groundnut 53% advantage over their respective sole-crop yields. In economic terms, these intercrops were also more profitable than the respective sole crops. The other two systems, with only 2-4 weeks' difference between harvests of the components, showed a much lower and less-consistent advantage. The groundnut/millet recorded 18% advantage and the sorghum millet 7% over their respective sole crops. Risk was measured by calculating the probability of success or failure of intercrops in satisfying specified quantities of yields or income in comparison with an optimal shared sole system having some of both sole crops. Pigeonpea-based intercropping systems were less risky than shared (or optimal) sole crops over a wide range of expected yields or income. There was no advantage for the sorghum/millet intercropping compared with the shared sole crops at lower expectation, and for higher expectations sole sorghum should be preferred to the intercrop. Risk from groundnut/millet was less than from the shared sole system only in limited situations. Reduced risk of pigeonpea-based intercrops was associated with higher productivity and lower variability of combined intercrop yields or income. The methods employed in this study can be extended for risk evaluation in other intercropping and mixed systems.
Author's Abstract

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Cropping systems
Africa, humid tropics, subhumid tropics, cropping systems, soil fertility

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Cropping systems and soil fertility management in the humid and subhumid tropics with special reference to West Africa.

In: Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan Africa, Eds. A.U. Mokwunye and P.L.G. Vlek, Martinus Nijhoff Publishers, The Netherlands, ISBN 90-247-3312-X, 1989, pp. 83-94

In the humid zone, traditional agriculture is dominated by tree components including plantain and bananas. These are the most stable production systems for the humid tropics.
Large areas of humid and subhumid tropical Africa are dominated by low-activity clay (LAC) soils consisting mainly of Alfisols and Ultisols. These soils have major constraints for intensive and continuous arable crop production. Traditional farmers rely on the fallow period for restoring the soil fertility which is exhausted during the short cropping cycle.
Reduced tillage systems combined with use of crop residue and in situ mulches from planted fallow play an important role in maintaining the level of soil organic matter and soil fertility. With judicious fertilizer use and liming, sustained crop yields can be attained on Alfisols and Ultisols. Integration of food and tree crop production as in alley cropping can be used as a low-input (nitrogen) soil fertility maintenance system for continuous food crop production in the tropics.
The traditional cropping system, which has been the mainstay of agricultural production in tropical Africa, is undergoing rapid changes in response to increasing population and land use pressures and changes in socioeconomic conditions. The system, which relies on restoration of soil fertility by means of a long fallow period, is not well suited to these rapid changes. Shortening the fallow period because of land scarcity and prolonging the cropping cycle with no inputs has thus resulted in a rapid decline in soil fertility and crop yields as already observed in many areas in tropical Africa dominated by highly weathered soils.
Despite the considerable efforts made by various research institutions during the last two decades to describe, improve, and develop alternative methods to the traditional production systems, progress attained is still limited. Similarly, only some progress has been made in developing soil fertility management practices for sustained and viable crop production on the LAC upland soils. Some of these developments are discussed in this paper:

- <u>Crop production systems:</u>
  - . Tree-based cropping systems
  - . Major food crop-based systems

  - . Cassava-based cropping systems
  - . Plantain-based cropping system
  - . Rice-based cropping systems
  - . Yam-based cropping systems
  - . Maize-based cropping system
  - . Sorghum-based cropping systems
  - . Millet-based cropping system
- <u>Fertility management for crop production:</u>
  - . Major soil constraints for crop production
  - . Soil fertility maintenance in the traditional system
  - . Fertilizer use and soil fertility management in multiple cropping systems
  - . Low-input fertility management involving trees and shrubs

The paper concludes that fertilizer use in improved farming systems will result in larger removal of nutrients in the crops, a correspondingly increased return of cations will be required to correct acidity and maintain high levels of production on these fragile soils. In many parts of the humid tropics where lime is not readily available, inclusion or integration of trees and shrubs in the crop production system as practiced in alley cropping can serve as an important solution to part of the acidity problem in LAC soils. The trees and shrubs with their deep rooting are able to gather cations leached from the surface and return them to the topsoil through leaf litter or prunings.

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Cropping systems
Review, multiple cropping systems, booklet, VITA

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Understanding multiple cropping.

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Multiple cropping in some form can help get the maximum crop production from fixed land holdings, particularly in subtropical and tropical areas of the world. Both low and high technology societies can profit by adopting one or more of the various multicropping techniques. Even small farmers who lack the capital to purchase inputs (e.g.,) equipment, fertilizers, herbicides) but generally have abundant hand labor, can find the practice of some form of multicropping to be to their benefit.
Multiple cropping places heavy demands on the soil and cannot be successful unless the crop is supplied with adequate fertilizer. Where the extra fertilizer is not available, a few crops with low fertilizer needs may be planted (such as cassava [*Manihot* sp.] and plaintain [*Plantago* sp.]). Many marginal farmers find the purchase of inorganic fertilizers beyond their means, even if obtainable, and should not consider intensive multicropping systems. More limited multicropping can be practiced where substantial amounts of animal manure and/or composted plant materials are available. Minerals provided by burning cleared land have only temporary value. On the other hand, many systems of multicropping originated under subsistence farming and can be made to work using available sources of fertilizer. Placing fertilizer in bands between plants or directly in the planting hole are two ways of making more efficient use of fertilizer at hand. Where possible, legumes should be planted for their ability to obtain nitrogen from the air and convert it into forms available to plant roots.
The advantages of multicropping include greater use of available solar energy in the dry season, improved pest control, greater insurance against crop failure, better nutritional balance for families because a wider variety of foods is produced, and a more stable farm income.
As in any departure from traditional methods, some cautions and hazards may be encountered in switching from mono- to multicropping. Farmers should consider their options carefully and seek help if necessary from local extension agencies or from technical assistance services such as VITA.
This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis.
VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations.