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Recent developments in cowpea cropping systems research

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Abstract

The importance of cowpea (*Vigna unguiculata* [L.] Walp.) is underscored by its use as a component in many cropping system combinations in Africa, Asia, and tropical America. Cropping systems research over the past decade has served as a multidisciplinary approach to examine the biological superiority of specific innovations, as well as the degree to which such innovations fit existing practices and meet the needs of resource-poor farmers. The scope of cropping systems research includes physiology (the nature of intercropping competition for light, water, and nutrients; useful intercrop cowpea characteristics), agronomy (cropping combinations, patterns, and timing of operations), and plant breeding (yield stability, breeding methodology, and identification of superior lines for specific cropping systems). The overriding assumption is that complex cropping systems are more stable than sole crop arrangements, but with lower total yields. Owing to increases in population and land pressure, it is crucial that improved systems of production provide a range of alternatives to increase yield, while maintaining the natural resource base. Cowpea research in the past 10 years has improved the focus on aspects of agronomy, plant breeding, and physiology. This paper highlights our understanding of improved yields and nutrition for resource-poor farmers.

Introduction

A cropping system has been defined as the sequence of crops grown in one field, and the way in which they are managed (Davis and Woolley 1993). This simple definition hides the incredible complexity that makes up the multiple cropping systems that are prevalent in the tropics. Cropping systems research is concerned with understanding how the large numbers of components which make up the cropping system interact. Scientists have noticed that, in many cases, the typical model of research does not yield useful results. This method usually involves the testing of one or two new variables on a research farm, and then recommending the highest yielding combination to local farmers. A typical farmer has a wide range of factors to deal with, which includes a specific piece of land with physical and fertility constraints, subject to the climatic conditions within the region. This

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climate consists of certain expectations with regard to rainfall, temperature, and radiation. Farmers have to decide how and when they will till their land in anticipation of planting crops. Although these are usually low-input systems, farmers may have to decide how to use limited quantities of organic fertilizer. Planting itself presents the farmer with a range of decisions that need to be made. What combination of species should be planted, and which varieties selected from within those species? What planting arrangements should be followed, and how many plants of each component crop should be sown? Farmers also understand that staggering the planting dates of certain crops could be advantageous for some crop species.

Crops grown in a specific area are determined by a number of factors. Even with adequate precipitation and sunlight, optimum temperatures, and fertile soil, it is quite possible that other factors will influence which crops are cultivated. There may be economic concerns (commodity prices, transport costs, etc.), social factors (consumer taste preferences, religious motivation, tradition) or even political reasons (marketing boards, price controls, price stability) that determine the crop choices that a farmer makes (Steiner 1984).

Cowpea is an important grain legume in West Africa. It provides an inexpensive source of protein for the urban and rural poor of the region (Alghali 1991). Nigeria accounts for 70% of the world's cowpea production. The grain is valued for its flavor and short cooking time, and the plant is especially favored by farmers because of its ability to maintain soil fertility through its ability to fix nitrogen. Farmers are also interested in the cowpea haulms that are used to maintain livestock during the dry season. Although the sole-crop potential grain yield of the crop is high (1.5–3.0 t/ha) when insecticide is applied to the crop, the actual farm yields that are obtained in the West African region are much lower (0.025–0.100 t/ha) due to severe attack from an extensive pest complex (Rachie 1985). Another reason for yields which do not equal research station results is that 98% of the cowpea in West Africa is intercropped (Arnon 1972). This is in comparison to routine yields of 0.3–0.5 t/ha at the IITA Kano research station for intercropped cowpea with no insectide protection.

Intercropping is usually defined as growing two or more crops simultaneously on the same field (Andrews and Kassam 1976). Subsistence farmers who practice low-input farming are particularly dependent upon this form of crop production (Ntare 1990). Hildebrand (1976) noted that intercropping is common where farmers lack land and/or capital, but labor is plentiful. Although agricultural research originally focused on sole cropping, and ignored the potential of intercropping (Willey and Osiru 1972), there has been a gradual recognition of the value of this type of cropping system (Blade 1992). Intercropping reduced damage caused by pests and diseases, and also ensured greater yield stability by producing some yield, even though some of the component crops failed (Andrews 1974). Although there are some contradictory reports, intercropping has been shown to produce higher and more stable yields in a wide range of component combinations (Ofori and Stern 1987).

This paper reviews cropping systems research conducted with cowpea as one of the component crops. The biological advantages and farmer relevance of these systems will be assessed, and an overview of recent physiological, agronomic, and breeding research presented.

Biological advantages of cowpea intercropping

The partitioning of limited resources among crop plants occurs whenever plants are grown in association. This competition was originally defined as beginning when the immediate supply of a single necessary factor fell below the combined demand of the plants (Clements et al. 1929). Other terms such as hardship and interference were coined to indicate the effects that plants grown together had on one another (Harper 1961). Although many intercropping studies attempt to identify specific limiting factors, de Wit (1960) did not regard this as important, but instead defined the entire plant milieu as "space", and noted that growing plants competed for this entity. The concept of space provided a method for understanding how intercropping could produce yield advantages under certain circumstances. If sole crops consist of identical plants which have the same type and timing of resource demands, then intercrops with different plant types which possess variable requirements could use more "space" when grown in association. Huxley and Maingu (1978) referred to cereal-legume associations, calling the cereal the dominant crop and labeling the legume as the dominated species.

A common index of intercropping productivity is the land equivalent ratio (LER), which is defined as the ratio of the area needed under sole cropping to one of intercropping at the same management level to produce an equal amount of yield. LER is the sum of fractions of the yields relative to their sole crop yields (Francis 1986). An LER >1 indicates that the intercrop is more productive than the comparative monocrops. Such a situation indicates the potential for overyielding (Willey 1979). Heibsch (1980) proposed an area-time equivalency ratio, which was capable of evaluating crops on a yield per day basis. Hiebsch and McColloum (1987) suggested that the advantages of intercropping were overstated when LER was used.

The potential for overyielding indicates that resources are maximized in an intercropping system. Research has indicated that growing two or more species at the same time can have advantages in light interception, water use, and nutrient uptake.

Tsay (1985) has reported that the amount of light intercepted by crops is dependent upon the geometry and plant architecture of the component crops. The usual cowpea intercrop combines a tall cereal crop with a lower storey cowpea crop. Research on light has indicated that there is a benefit where resources are maximized when intercropping is done. Willey (1979) has suggested that the advantage may have to do not only with the amount of light intercepted at a particular time, but also with how light is intercepted during the entire growing season. The rapid establishment of a prostrate cowpea will enable more light to be used than if only a dominant crop, such as millet, is grown. Of course, this holds true when cowpea is planted with a slow-developing tuber, such as cassava. Clark and Francis (1985) have observed that if a tall crop, especially a C_4 plant, is combined with a shorter C_3 crop, there can be an enhanced use of total light. They also observed that maize-bean systems established total ground cover 1 week prior to sole crop beans and 3 weeks prior to sole crop maize. Srinivasan et al. (1990) observed that shade-tolerant cowpea performed well under *Casuarina equisetifolia.* As could be expected, Kang et al. (1985) reported that pruning leucaena increased the yield of maize and cowpea in an alley crop. Fawusi et al. (1982) reported that a maize-cowpea system intercepted 52.3% of incoming light, which is less than the 76.4% interception in a maize-cowpea system reported by Blade (1992). This difference was probably due to measurements being taken 6–8 weeks after planting in the Fawusi study, so that the total canopy was not developed. An additional explanation is that Blade used an early-maturity cowpea line, which rapidly established ground cover.

Water utilization can be increased when cowpea is grown with other crops. Lal and Maurya (1982) reported large differences in root stratification between cowpea (upper soil levels) and maize (lower soil levels) during development. The total rooting mass of the maize/cowpea intercrop was larger than either of the monocultures, but was smaller than the combined monocrop total. Shackel and Hall (1984) noted that neither sorghum or cowpea had an advantage in soil water uptake, since osmotic potential in either crop was not substantially affected by intercropping. In a humid forest experiment, it was observed that water-use efficiency was higher in a maize/cowpea intercrop than in either sole crop when water was not limiting, but in drought conditions the water-use efficiency of sole maize was greater than that of the intercrop (Hulugalle and Lal 1986). Ofori and Stern (1987) suggested that cereal and legume intercrops use water equally, and that competition for soil water may not be a determining factor for efficiency in intercrop systems. Villegas and Morris (1990) reported that monocropped cowpea and a cowpea/sorghum intercrop were equally effective at halting the drainage of residual water through the soil profile. In northern Nigeria, when water is limiting, an early-maturity cowpea can develop rapidly and expend limited soil moisture. Rees (1986) noted that cowpea was a strong competitor for water due to its deep rooting capability. Water was diverted from sorghum to cowpea in a sorghum/cowpea intercrop under the semiarid conditions of Botswana.

The roots of intercropped species compete for finite nutrient resources. In a maize/cowpea study, Wahua (1983) reported that cowpea was severely affected by maize competing for nitrogen. Nitrogen uptake by intercrop cowpea was 64 kg/ha, but sole crop cowpea took up 88 kg/ha. Wahua also observed that maize was much more competitive for potassium in comparison to cowpea, especially at high nitrogen levels. Stoop (1986) noted that high soil phosphorus levels favored cowpea growth in cereal-cowpea associations. Both Chang and Shibles (1985) and Ofori and Stern (1986) observed that when no nitrogen was applied, there was strong competition for soil nitrogen. This was especially true between 49 and 63 days, when both crops were in their reproductive stages. Intercropping of cereals and legumes can result in a "nitrogen-sparing" effect, which results when soil nitrogen remains available to the cereal crop due to nitrogen fixation supplying some of the legume crop's nitrogen requirements. There is also the possibility that nitrogen is transferred from legumes to associated grasses during the growing season. Eaglesham et al. (1981) reported nitrogen transfer from cowpea to maize, but Ofori et al. (1987) found that ^{15}N concentrations did not differ between sole and intercropped maize grown in association with cowpea. Blade (1992) reported significant ^{15}N dilutions in intercropped maize from a field experiment, where maize was harvested one month after the cowpea had been harvested. Since ^{15}N applications were done at the late podding stage of cowpea, it appears that most of the transfer was due to decomposition of cowpea leaves, roots, and nodules. Burton et al. (1983) observed that nitrogen leaching from leaves, and the decomposition of legume leaves may also result in nitrogen transfer to the associated cereal.

What are the optimum physiological traits for cowpea? Terao et al. (1997) indicated that the ideotype for cowpea grown in the cereal-based cropping systems of the West

African savanna is a variety with a prostrate growth habit and a well-developed root system. The cowpea must also have high transpiration efficiency. This is similar to the findings of Ntare and Williams (1992). Although Ntare (1990) observed that early-maturing erect cowpea lines were useful in these systems, their appropriateness was judged by how little they affected millet yield. Terao et al. (1997) also reported that the amount of light reaching cowpea in cereal-based cropping systems varies (30–75% of ambient light). They noted that if the cereal canopy intercepts large amounts of light, cowpea growth is so limited that almost no foliage can intercept what light does pass through the cereal canopy. The local cowpea varieties are successful due to their flexibility in response to competition. Light in the early stages of development will influence the branching patterns, which will in turn determine the source and sink of the plant.

Agronomic advances in cowpea intercropping

The immense variety of permutations associated with the management of a piece of land have led to research which provides location-specific information that is often difficult to generalize for the efficiency of intercropping. Species selection, relative time of sowing, and both arrangement and spacing of constituent crops present infinite combinations that the researcher must deal with.

Cowpea is generally grown as the understorey crop in a system based on cereals or tuber crops. Cowpea is useful because it establishes rapidly, and this results in less soil erosion, a reduction in soil temperature, and lower weed pressure (Zuofa et al. 1992). Cowpea is often relay-planted into the cereal crops of the West African savanna. Farmers want to ensure that all fields have their cereals planted as early as possible, to take advantage of early rains, as well as the nitrogen flush which occurs when the onset of the rains moistens the dry soil, whose microbial activity releases plant-available nitrogen. Later planting of cowpea can reduce the competition with cereals to ensure that the high-priority cereal yields are not reduced. Following harvest of the millet, the cowpea is able to take advantage of late-season residual moisture and additional light, which influences both grain and biomass production. Such a system is indicative of a cardinal rule in intercropping: try to select crops, or use management techniques, to maximize the gap between reproductive periods. This will reduce the simultaneous demand for resources.

Remison (1982) reported no advantage when either maize or cowpea were planted early, in comparison to simultaneous planting. Ofori and Stern (1987) also noted no advantage in a maize/cowpea intercrop, although they did report that the LER followed cowpea yield trends rather than those of maize. Nangju (1979) found that late planting of cowpea in established maize resulted in cowpea grain yield decreases of 58–78%. Blade (unpublished) found that in the Sudan savanna, delaying cowpea planting by 2 or 3 weeks resulted in a cowpea grain yield reduction of over 50% in comparison to simultaneous millet/cowpea planting (Table 1). Similar results were observed in an experiment where no insecticide was applied. The rationale for these experiments was that improved cowpea lines must have the flexibility to perform well in systems where cowpea planting time can vary greatly, due to environmental and farmer constraints. However, in 1993, simultaneous millet/cowpea planting reduced grain yield (715 kg/ha), in comparison to 940 kg/ha when cowpea was planted 3 weeks after millet. Agronomists must be careful not to suggest innovations that clash with farmer objectives.

Table 1. Cowpea grain and fodder yields (kg/ha) for a 2-year millet/cowpea intercrop experiment testing a local and an improved cowpea variety using four dates of planting in 1993 and 1994 (three insecticide sprays).

Time of cowpea planting	90K–59	Dan 'Ila	Mean
Cowpea grain yield (kg/ha)			
Simultaneous	394	244	319
1 week after millet	259	167	213
2 weeks after millet	176	156	166
3 weeks after millet	131	67	99
Mean	240	159	
LSD (5%) between cowpea lines averaged over plantings = 61			
LSD (5%) between planting treatments averaged over cowpea lines = 77			
Cowpea fodder yield (kg/ha)			
Simultaneous	494	819	657
1 week after millet	430	754	592
2 weeks after millet	394	647	520
3 weeks after millet	300	538	419
Mean	405	690	
LSD (5%) between cowpea lines averaged over plantings = 217			
LSD (5%) between planting treatments averaged over cowpea lines = 155			

Agboola and Fayemi (1971) did not observe any difference in yield when maize and cowpea were planted in the same or alternate rows. Fawusi et al. (1982) reported that LER values increased as maize and cowpea density increased, and that cowpea was less competitive, since cowpea yields decreased significantly at higher maize densities. Chang and Shibles (1985) noted that the level of the maize population usually limited intercrop cowpea yield, but cowpea density had no influence on maize productivity. Ofori and Stern (1986) pointed out that even though the cereal usually produces a larger proportion of the intercrop yield, any LER advantage for a particular system is usually influenced by the legume's productivity.

The planting of strips of component crops has also been attempted. Strips of cowpea within strips of cereal rows increase the ease of weeding and the spraying of insecticide, reduce the influence of competition in comparison to alternate row planting (Cenpukdee and Fukai 1992), and take advantage of the "border effect". Baldev and Ramanujam (1980) described the "border effect" as the compensatory yield of the outer rows of the dominant crop, which can over-compensate for the reduced yields in the dominated crop. It is possible that differential competition at the interface could result in no yield loss for the understorey crop (Lai and Wen 1990). Blade (unpublished) reported that when varying the number of cowpea rows (1–4) between single millet rows, the best mean grain yield resulted with three rows of cowpea (Table 2). The traditional practice of alternating single rows of millet and cowpea resulted in the lowest cowpea yield. Dan 'Ila fodder production

Table 2. Cowpea grain and fodder yield (kg/ha) for five cowpea lines and four row arrangements in a millet/cowpea experiment (three years) at Kano (three applications of insecticide).

Cowpea line	Cowpea rows between millet rows				Mean
	1	2	3	4	
Cowpea grain yield (kg/ha)					
89KD-391	535	548	560	450	523
84S-2246-4	242	341	392	392	341
89KD-374-57	378	463	572	498	478
Dan 'Ila	225	268	319	288	275
89KD-288	0	0	0	0	0
Mean	283	332	372	330	
LSD (5%) between cowpea lines averaged over treatments = 76					
LSD (5%) between row arrangements averaged over cowpea lines = 57					
Cowpea fodder yield (kg/ha)					
84S-2246-4	432	545	653	874	626
89KD-374-57	619	902	1006	1272	950
89KD-391	1180	2388	1932	2150	1913
Dan 'Ila	890	1177	1326	4457	1962
89KD-288	2714	3126	3485	3715	3260
Mean	1167	1628	1680	2494	
LSD (5%) between cowpea lines averaged over treatments = 993					
LSD (5%) between row arrangements averaged over cowpea lines = 874					

was much larger in the four-row treatment; this indicated that the local check had the ability to take advantage of the extra light so that a large amount of fodder was produced.

Cropping systems are also influenced by the application of mineral fertilizers. The addition of nitrogen to a cereal/cowpea system is generally thought to favor the cereal at the expense of cowpea (Midmore 1993). Fukai et al (1990) have reported that when soil nitrogen levels are low, the legume is less affected than the cereal, but the addition of nitrogen has the effect of both decreasing the legume's nitrogen fixation and increasing the cereal's development. Such growth increases the cereal's ability to intercept light. Ofori and Stern (1987) found that LERs did not increase when nitrogen was added to the maize/cowpea system. Chang and Shibles (1985) also reported that increased nitrogen and high maize density resulted in decreased cowpea yield due to shading. Such data indicate that intercropping is most beneficial when soil fertility is low (Rachie and Rockwood 1973). One promising report was that there was cowpea cultivar variation in how cowpea cultivars respond to nitrogen when intercropped with maize (Ezumah et al. 1987). Researchers at Nyankpala Agricultural Experiment Station in Ghana have done extensive work on nitrogen balance in maize/cowpea intercropping systems, indicating the benefit of the legume crop during the growing season and for subsequent crops. Singh (1993) estimated that cowpea contributed 46–54 kg/ha of nitrogen to the following season's wheat crop.

In a 2-year experiment in the Sudan savanna, Blade (unpublished) used four fertility treatments on an alternate-row millet/cowpea intercrop: (1) broadcast NPK at recommended rate; (2) broadcast P at recommended rate; (3) 50% of recommended P rate applied only on cowpea rows; and (4) the nonfertilized check. The NPK treatment significantly increased millet yield in comparison to the nonfertilized check, but cowpea was unaffected. Millet was not affected by the other treatments. If the recommended P rate was broadcast on the plot, cowpea grain yield increased (480 kg/ha) in comparison to the check (397 kg/ha). If 50% of the recommended P rate was applied only to the cowpea rows, the cowpea grain yield increased to 607 kg/ha. Such results indicate that simple management techniques can greatly improve overall yield. The technology was not new to farmers, since they now drop handfuls of NPK near the hills of millet along the cereal row, to maximize the impact of costly and sometimes limited stocks of inorganic fertilizer.

Intercropping research has also sought methods of management that limit the impact of weeds, pests, and insects. Matteson et al. (1984) reported that maize/cowpea systems had 42% less flower thrips (*Megalurothrips sjostedti*) than sole cowpea. However, cropping pattern had no effect on *Maruca* pod borer or pod-sucking bugs. It was also reported that early infestations of *Maruca* were equal in sole and intercropped cowpea, but 12 weeks after planting the populations were significantly higher in the sole crop plots. Alghali (1993) noted that intercropping cowpea with sorghum reduced flower thrip and pod-sucking bug populations. Tests indicated that only two sprays of insecticide in the intercrop equaled the protection provided by three applications in the sole cowpea crop. Ezueh (1991) noted that mixed cropping can protect cowpea from insect attack. Jackai et al. (1985) also indicated the appropriateness of intercropping as one component of integrated pest management.

Cowpea improvement for cropping systems

Plant breeding initially focused on the selection of genotypes that perform well in sole cropping. It was thought that superior sole crop lines could be planted in intercrops with the same results. Selection was usually done under research station conditions, which tended to eliminate many of the problems (low fertility, lack of labor, weeds) which existed on the fields of traditional farmers. This led to many cowpea improvements that could not be taken advantage of by the small-scale farmer.

Plant breeders were subsequently influenced by the objectives farmers set for their intercropping systems. Yield stability, maximum profitability, increased biological yield, or provision of a nutritionally balanced harvest may be some of the goals which the breeder must take into consideration. The primary focus breeders have had in the past 20 years when looking for genotypes that do well in intercropping systems is the existence of genotype × cropping system interactions. When studying cereal/legume combinations, several studies have indicated that significant interaction between cereal genotypes and cropping patterns does not occur (Davis and Garcia 1983; Francis et al. 1983), although Odo (1991) reported differences in the response of short and tall sorghum varieties when intercropped with cowpea.

However, Davis and Garcia (1983) and Woolley and Rodriguez (1987) both found highly significant bean genotype x cropping system interactions. In the most recent review of the literature, Smith and Zobel (1991) reported that significant genotype × cropping system interactions occur, especially in the dominated (cowpea in cereal-based systems) species. Blade et al. (1992) reported significant cowpea genotype × cropping system interactions in both forest and savanna ecologies. Variation among environments for cowpea grain yield was greater when no insecticide was applied. Singh (1993) noted that one strategy for improving cowpea for traditional cropping systems was defect elimination of selected local varieties, or development of completely new photosensitive, spreading-type varieties by standard methods, using relevant parents. He also proposed the screening of advanced breeding lines using cropping systems (and inputs) of the subsistence farmer. The lines selected from such screening are then evaluated under farmer-participatory trials.

Blade (1992) reported tremendous differences in the response of cowpea in four management systems: sole crop + insecticide, sole crop + no insecticide, intercrop + insecticide, and intercrop + no insecticide (traditional). Cowpea genotypes that performed well in intercrop + no insecticide systems across the West African savanna were identified (Table 3), and they have also performed well in farmers' fields in several West African countries, including Cameroon (Endondo 1994). Evaluation of improved cowpea in the other management systems provided useful information concerning how genotypes responded in "improved" management systems, as well as how traditional management limited the genotypic potential of the tested lines.

Yield stability is a complex product of genetic yield potential and tolerance to stress conditions (Smith and Francis 1986). Subsistence farmers require crop varieties which produce an acceptable yield under a wide range of environmental variability. Finlay and Wilkinson (1963) devised the method of using simple linear regression of genotype performance on an environmental index (usually the mean of all genotypes in each

Table 3. Cowpea grain yield (kg/ha) for ten cowpea lines intercropped at seven locations with no insecticide protection in 1993.

Cowpea line	Kano, Nigeria (642)†	Wudil, Nigeria (750)	M. Madori, Nigeria (426)	Maidugiri, Nigeria (239)	Maroua, Cameroon (947)
90K-59	648	189	391	39	238
89KD-319	379	42	77	7	175
89KD-374-57	392	68	244	38	249
89KD-261-3	279	61	161	28	124
89KD-355	330	56	221	28	177
89KD-391	470	41	116	0	186
89KD-277-2	341	162	186	10	530
89KD-867-11	349	72	289	16	122
89KD-245	188	0	9	32	38
Local check	195	14	158	17	188
LSD (5%)	158	86	135	ns	87

† Rainfall (mm).

environment). Gomez and Gomez (1983) used this method to rank the performance of soybean lines in several cropping systems. They observed that all varieties tended to have higher yields in environments with high environmental indices (as was expected), but that the varietal ranking differed from one environment to another. Blade et al. (1992) reported that yield stability of cowpea lines varied, depending on cropping system (sole or intercrop), as well as whether or not insecticide was applied. It is thus critical that plant breeding programs develop lines suited for specific cropping systems, such as the traditional (intercrop-no insecticide) management system; many promising lines may be rejected if selection is only done in high-input sole crop management systems. Singh (1993) suggested evaluation of new breeding lines under three systems: (1) pure crop with two sprays of insecticide, (2) pure crop with no insecticide, and (3) intercrop with no insecticide. This would enable the breeder to select suitable varieties for different systems, and also select varieties with low genotype × environment interaction for wide adaptation.

Cropping systems research and extension

During the 1970s, the problems associated with agricultural experimentation based at research stations evolved into a discussion on how agricultural scientists could better relate their work to farmers and their concerns. This led to the development of a framework that involved participatory research. Francis et al. (1989) documented that this transition was not always easy. It was perceived that farmers were interested in large plots where they could visually judge the effect of a new variety or fertilizer application. Farmers wanted innovations which did not cost a great deal of capital, or demand a great change in traditional farming methods, and the focus to be on changes that increased yield and profitability while reducing risk. If experimentation was done on the farm, a farmer wanted conditions to be representative of their own farm, so they could be confident that the new methods would work for them. On the other hand, scientists wanted replicated plots for statistical testing of their hypothesis with specific treatments, which could result in publishable data. Researchers wanted to generalize results of such on-farm experiments as what would happen on a larger regional basis.

Participatory research (Maguire 1987) was developed in order to provide a link between farmers and researchers. The steps in this process, along with recent cowpea research examples, can be summarized as follows:

1. *The problem must be identified.* Alghali (1991) went to farmers to understand what they saw as the major problem in cowpea production. The farmers said that insects were the biggest cause of yield losses. Low fertility, shading due to cereals, and low cowpea population were also identified as constraints.

2. *Objectives must be set.* Seventy farmers surveyed by IITA Kano researchers (Singh 1993) indicated that fodder was a key element of the cowpea crop. In some cases, farmers planted specific cowpea varieties which were known to supply either grain or fodder, so that both requirements could be met. Both breeders and farmers came to an understanding that this must be part of the selection criteria for intercropped cowpea. These observations also underscored the potential for dual-purpose (combined grain and fodder) cowpea varieties.

3. *Selection of solutions and project design must be done.* Farmers who were looking for a new crop to grow in dry season fadama areas came to IITA; they wanted to grow different improved cowpea lines on their own plots to evaluate the usefulness of the IITA materials. These materials were much more successful than local cowpea lines (Table 4) because of aphid resistance. Good lines were multiplied, and many farmers benefited when they opted for the tested cowpea to plant in their own fadama plots.

4. *Project implementation.* Farmers tested improved IITA cowpea lines in their rainy season intercrops in the Kano region. Management of the crops was done by the farmer, but data collection and overall project management were handled by the researcher. However, it was critical that the farmers' observations concerning the new lines were noted, since this provided valuable information about what criteria farmers use to judge cowpea lines.

5. *Interpretation and sharing of results.* Farmers were brought together and discussions were held concerning how improved IITA cowpea lines performed on their own fields. Farmers showed great interest in lines that produced excellent yields for both grain and fodder. They were the ones to champion specific genotypes, which should be made available to the farming public.

It is clear that such applied research must be based on a strong research base, which is capable of generating new technologies that are attractive to farmers. Shetty (1993) reviewed the approach of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to cropping systems research. Site selection and description are the

Table 4. On-farm evaluation of dry season cowpea lines (sole crop-no insecticide application) at several locations in northern Nigeria (1994).

	Farmers (no.)	Mean yield Grain (kg/ha)	Mean yield Fodder (t/ha)
Cowpea line			
89KD-941-1	8	690.8	1.8
89KD-374-57	11	536.3	1.5
84S-2246-4	8	604.3	1.4
Local check	11	573.6	1.4
LSD (5%)		ns	ns
Date of planting			
1–10 Feb	13	943.3	2.2
11–20 Feb	15	477.7	1.5
21 Feb – 28 Mar	9	314.1	0.7
LSD (5%)		288.6	0.6

starting points to conduct useful and representative research. It is then necessary to identify specific systems which are important in the area, and exhibit sustainability and stability of production. Such an undertaking must also have a multidisciplinary approach, which would incorporate the observations and expertise of an entire team of agricultural scientists. Growth analysis, nutrient and moisture uptake, light interception, and nitrogen fixation could involve physiologists and soil scientists. Integrated pest management systems could be tailored by entomologists, virologists, and pathologists. Cropping system agronomists would focus on designing alternative systems on the basis of this work, with plant breeders identifying suitable genotypes which fit into the system. This research effort would involve all groups of researchers, including Consultative Group on International Agricultural Research (CGIAR) centers, national programs, universities, and research staff of local development authorities.

The future of cowpea cropping systems research

The importance of cowpea as an intercrop component has prompted a considerable volume of cropping systems research in the past decade. Researchers have made great progress since the pioneering work of the Institute for Agricultural Research, Samaru, when questions were first raised about the role of cowpea in the traditional cropping systems of the West African savanna (Andrews 1972; Norman 1974).

The farming systems now used have evolved by trial and error over a long period of time (Okigbo and Greenland 1976). These systems, to survive, must be well adapted to the environment in which they exist. However, there is a great deal of opportunity to improve these systems through changes to factors which are managed by the farmer. Owing to constant change in both the environment and the farmer's actions, cropping systems undergo a continuous cycle of changes from new crops, different pest complexes, access to inputs, or increased population density.

Cropping systems researchers, in collaboration with farmers, have increased the productivity of these complex systems, while maintaining their yield stability. The success of IITA in developing improved cowpea varieties can be measured by the interest of governments and farmers throughout West Africa in lines that perform well in all systems: both sole crop and intercrop, as well as niche opportunities, such as in dry season fadama or irrigated production. This has been accomplished by understanding the dynamics of these complex systems, and implementing innovative changes which address the socio-economic and biological constraints of farmers and their farms.

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