WARDA has a mandate for rice research in West Africa; the Natural Resources Institute (NRI) has many years experience in managing crop pests, including weeds. Weeds are the major pest of rice in West Africa; so what better combination to tackle the problem in West Africa than WARDA and NRI? This is exactly what the two institutes decided in the early 1990s. After preliminary discussions, a project proposal was designed for consideration by the UK Department for International Development (DFID, then the Overseas Development Administration or ODA)—the upshot was that an NRI Weed Scientist, David Johnson, was stationed at WARDA’s headquarters to coordinate the joint research efforts, and to conduct many of them.

From the beginning, weed research activities were integrated into WARDA’s multi-disciplinary teams, while at the same time WARDA agronomists, economists, entomologists, breeders and pathologists were drawn into the WARDA/NRI weed activities. The use of multi-disciplinary teams is essential for achieving a holistic view of a problem—intervention in one area so often has a knock-on effect to another area. Maximizing crop production, be it in terms of output or efficiency, depends largely on finding the right balance of crop and other resources management and interventions to get the best out of the crop and the resources used in growing it.

What the farmers think
By the early 1990s, WARDA and NRI realized that improvements in crop production were only likely to be of value when they are designed specifically to deal with farmers’ problems as farmers see them. So, along with early research into weed distribution and their impact on the crop, a survey was conducted among 178 rice farmers to see exactly how they perceived the role of various pests in their crop. Every single farmer identified weeds as a problem! This compares with 84% citing birds, and a mere 40% recognizing the importance of insects (see Table 2). It seems that visibility of the pest plays a role in farmer perception, but this does not detract from the importance of weeds.

Studies on the effects of weeds soon showed that the farmers’ perception of this pest is correct: in three of the main rice-growing ecologies of West Africa—rain-fed upland and hydromorphic, and direct-seeded
Since farming in West Africa is essentially limited by the availability of labor, rather than the availability of land, any reduction in the labor required for weeding would free farmers to expand their cultivation and therefore grow more rice. In this way, it is weeds that keep small farmers small.

To make matters worse, farmers in the survey indicated that intensification of rice cultivation (that is, growing rice on the same piece of land more often) was making the weed problem worse. Traditionally, farmers have practiced slash-and-burn agriculture, with land left fallow between farming cycles for eight or more years (especially in the forest). The increasing need to produce more food (partly as a result of population growth) from the same land has led to a serious reduction in fallow periods and a simultaneous increase in the number of years a piece of land is farmed before being abandoned to fallow.

To quantify this, trials were conducted on farmers’ fields in the forest, transition and savanna zones in which farmers’ intensive (short fallow) or extensive (traditional fallow) cropping were compared. This study showed that, across the agro-ecological zones from forest to savanna, intensification of rice farming led to

(as opposed to transplanted) irrigated systems—weeds are the main yield-limiting factor, reducing production by 25–30%, and sometimes up to 40%. In fact, if weeds were left uncontrolled, total crop failure could ensue. It is not surprising, therefore, that farmers invest more labor in weed control than in any other single farm activity for their rice crop. Tim Dalton, WARDA production economist, reports “between 27 and 37% of the total labor invested in rice is taken up by weeding.

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Table 2. Percentage of farmers citing various pests as problems in rice production, Côte d’Ivoire, 1992

<table>
<thead>
<tr>
<th>Pest</th>
<th>Agro-ecological zone</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humid forest</td>
<td>Forest-savanna</td>
<td>Savanna</td>
<td>Combined</td>
</tr>
<tr>
<td>Weeds</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Birds</td>
<td>98</td>
<td>98</td>
<td>53</td>
<td>84</td>
</tr>
<tr>
<td>Rodents</td>
<td>88</td>
<td>87</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>Insects</td>
<td>48</td>
<td>60</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Diseases</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

Sixty farmers were sampled in each of Gagnoa (humid forest) and Touba (forest-savanna), and 58 in Boundiali (savanna).
a 38% reduction in yield, and that 54% of this reduction was attributable to weeds. The weed growth itself was 75% greater on the short-fallow fields than on the long-fallow ones.

So, the stage was set for the development of techniques for reducing weed pressure on rice. Weeds had clearly been identified as a major constraint in rice cultivation, and as farming becomes more intensive, the problem is getting worse. At this point, we have to bear in mind that we are dealing with poor farmers—farmers who have little access to chemical pesticides or fertilizers. So, control with, or at least total reliance on, herbicides is not an option.

**Into battle**

Two avenues of research in particular have proved fruitful: first, the use of rice plant types that are inherently more able to suppress weeds than others, and second the use of legume crops during the ‘fallow’ part of a crop rotation.

Research at WARDA to identify rice varieties which can compete successfully with weeds began in 1992 with the screening of a range of varieties grown under low-input conditions. The varieties expressed clear differences in weed competitiveness. An early finding which has been borne out by later studies was that weed suppression can be a direct result of profuse early growth—in particular, some examples of the cultivated African rice (*Oryza glaberrima*) out-compete weeds very successfully. The advantages of *O. glaberrima* in weed-suppression are a result of the way the plants develop with vigorous early growth, and droopy leaves, which form a canopy under which weeds cannot thrive. *Oryza glaberrima*, however, has low yield potential, so was only really beneficial under high weed pressure, when the higher-yielding but weed-susceptible varieties were smothered. The major breakthrough, by Monty Jones at WARDA, of producing fertile offspring of crosses between *O. glaberrima* and high yield-potential Asian rice (*O. sativa*) opened the door to capitalizing on the weed-suppressing features of *O. glaberrima*. The story of ‘new rice for Africa’ should be well known to most readers of WARDA’s Annual Reports—plants have been produced combining the early weed-suppressing characteristics of the African parent with the high yield-potential of the Asian parent.
As a result of WARDA’s emphasis on weed competitiveness, screening methods are being developed whereby many lines can be assessed at one time for their likely productivity in competition with weeds. Results to date suggest that maize and IG10 (a competitive O. glaberrima rice) are effective competitors and, therefore, good experimental ‘weeds.’ Each line to be screened is grown in a single row bordered by ‘weed’ rows. Two indicators for weed competitiveness have been determined: ‘specific leaf area,’ that is leaf surface area per unit weight of leaf, and the early growth of tillers. Such methods will enable a large number of lines to be screened, and the promising ones to be put into full field screening, yield trials and later on-farm trials.

Working with Mathias Becker, the WARDA agronomist, the WARDA/NRI project investigated the use of legumes in place of traditional (weedy) fallows. The idea is that the legumes smother weeds, limit soil erosion, and increase the organic matter and nitrogen contents of the soil. Some 39 legume species were tested in comparison with weedy fallow. Rice was grown immediately after harvesting of the legume or clearing of the fallow. The theory was upheld, with some legumes substantially increasing soil nitrogen and decreasing weeds in the subsequent rice crop (see Figure 6), and consequently supporting greater rice yields. In terms of weed control, a suitable legume reduces the build-up of crop weeds during the fallow period, thus reducing the number of seeds waiting to germinate in the soil when the rice is grown. The work also investigated the performance of various legumes in the different ecosystems, leading to the identification of suitable legumes for each farming system.

Figure 6. Growing a legume such as Crotalaria nicans during the fallow period reduces the weed biomass in the subsequent rice crop.
The effect of ‘legume fallows’ on rice production is not a simple matter of weed suppression; in fact, the increase in soil nitrogen as a direct effect of growing the legumes is probably more significant in improving rice yield. This is an illustration of the different levels at which various interventions work—hence the collaboration between weed science and agronomy.

Thus, we have two major interventions applicable at farm level. Firstly the use of weed-competitive rice varieties, and secondly the introduction of legumes into the fallow part of the crop rotation. Both methods help reduce the weed problem in the rice crop, thereby reducing the amount of time that farmers have to devote to weeding. This in turn opens up the possibility of expansion of the rice area and small farmers may, in future, not be so small!

**Weeds as allies**

The rice field is a dynamic ecosystem and controlling weeds may affect other components of the pest complex. In particular, it was considered worthwhile to investigate the effects of weed management on insect pests (another cause of serious yield loss in rice) and their natural enemies (mainly predators). Research student Kofi Afun undertook three years of study on this aspect with the weed project, through which he not only gained his PhD, but also a national prize for research from his home country, Ghana. The main predators of insect pests in rice are spiders and predaceous insects (mainly beetles and dragonflies). Any amount of weeding significantly reduced the spider populations in the rice fields, but leaving the crop unweeded simply led to total crop loss through weed competition. Spider populations were higher in manually weeded fields than in herbicide-treated fields. Conversely, populations of rice insect pests were unaffected by weed control methods—that is, there were as many rice insect pests in herbicide-treated and hand-weeded plots as there were in unweeded plots.

Experiments on the management of weed residues (i.e. what is done with the uprooted weeds) showed that placing the uprooted weeds in piles within the rice field resulted in significantly larger populations of spiders than did scattering, laying in strips or removing the weed residues (see Figure 7). For timing of weeding activities,
mid-season weeding resulted in the most active spider populations. In fact, mid-season hand-weeding gave similar rice yields to herbicide-treatment, without depleting the spider population. Further studies are underway to determine the extent of interactions between weeds, insect pests and the latter’s natural enemies.

**Another problem altogether**

So far, we have talked about weeds as competitors for resources (soil, light, water), but there is another group of weeds which has also been the subject of research by the WARDA/NRI project—parasitic weeds. The parasitic weed *Striga* doesn’t so much compete with the rice crop for nutrients, as steal those nutrients from the rice plants themselves! What is more, parasitic weeds like *Striga* are among the most prolific seed producers in the plant kingdom. One plant can produce more than 100 thousand minute seeds—enough to infest surrounding fields over a large area! While *Striga* in Africa is principally a problem on maize, sorghum and millet, rice can be devasted where the soil is infested with *Striga*.

Research on *Striga* started with a series of experiments in the UK. A wide range of rice varieties was screened by another NRI weed scientist, Charlie Riches, for resistance to *Striga* in a greenhouse at Long Ashton Research Station (home of NRI’s weed research group). Seeds of two species of *Striga* known to parasitize rice—*S. aspera* and *S. hermonthica*—were collected from Côte d’Ivoire and elsewhere in Africa for use in the screening. The varieties which showed resistance in the UK were then tested in field trials in natural *Striga* ‘hot spots’ in northern Côte d’Ivoire (*Striga* is restricted to the savanna, and is not found in the forest zone). Varieties of *O. sativa* and *O. glaberrima* were resistant to *Striga* in the greenhouse (that is, they were attacked infrequently), but much of this resistance was not evident in the field in Côte d’Ivoire. Overall, however, *O. glaberrima* had fewer *Striga* plants growing on it and was more tolerant of the *Striga* than *O. sativa* was (that is, the rice plants did ‘well’ despite infestation by *Striga*). Such differences indicate that resistance and tolerance are available in rice for utilization in breeding programs. Crosses made on the basis of these field trials are now being tested in greenhouses in the UK.

**Widening the network of collaboration**

The latest avenue of the WARDA/NRI weed research program greatly broadens the research partnership to include the Centre for Arid Zone Studies of the University of Wales (UK), the International Rice Research Institute (IRRI, Los Baños, The Philippines) and the Agronomy Institute, Harare (Zimbabwe).

The work on weed-suppression showed the importance of rapid rice plant development to shade out weed seedlings. Thus, any means of speeding up the early development of the rice plant should give the crop an advantage over weeds. Such a method is ‘seed priming’—soaking seeds in water and then drying them before sowing. The method was developed by seed companies in temperate zones for the advantage it gives the seed at the time of sowing—the seed is ‘primed’ to germinate by the pre-soaking, so utilizes water available in the soil at sowing to germinate, whereas germination is delayed in un-primed seeds. The method has already
been applied successfully by the Centre for Arid Zone Studies in trials in India, where primed seed led to plants which not only germinated faster than un-primed ones, but also developed and matured faster—a goal in itself for the Indian farmer.

The advantages bestowed by seed priming of rice, especially in terms of weed suppression, are to be tested and are expected to be significant. The method is already adapted to the farm level through the work in India: farmers can soak their own seeds over night, then surface dry and sow them the following day. Once dried, the primed seeds should retain their advantage over un-primed seeds for several days; so a short delay in planting should not negate the value of priming.

Concurrent with on-station trials into the effects of seed priming on rice development, seed priming will be introduced into WARDA’s Participatory Varietal Selection program to evaluate farmers’ perception of the method. Meanwhile, the reaction of different varieties will be assessed in trials at Bangor and IRRI.

To further develop collaborative links, WARDA is a member of the project on Integrated Weed Management in Rice (part of the CGIAR System-wide Program on Integrated Pest Management). This project has the objective of fostering collaboration among research groups in Africa, Asia and Latin America, together with advanced institutions, so that greater progress and impact can be made in reducing the high costs and drudgery involved in weed control world-wide.

The collaboration between WARDA and NRI has yielded a lot of information on the dynamics of weeds in rice fields. It has also brought out several useful interventions that farmers can apply to manage weeds to improve their rice yields, while highlighting the negative effects of completely destroying and removing weeds from the field. That collaboration has now spread out to encompass three more research institutions, so the benefits of this collaboration are being shared for the benefit of rice farmers throughout Africa and Asia.