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ECHO Development Notes

Farmer Field School Trials of 2:4:2 Maize/Legume Intercropping

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(/resources/bd00f7a1-7c21-4e07-86a7-f6d8189e2c13)Farmers often struggle to maintain the productive capacity of their soils, especially where they lack enough land for a fallow (rest) period between crops. Leguminous green manure/cover crops (GMCCs) can help; in association with rhizobial bacteria, legumes convert nitrogen from the air into a form that plants can use. Many tropical legumes have deep, extensive root systems that can take up nutrients which leach past the root zones of other crops. Thus, even on poor soil, they can produce an abundance of nutrient-rich, plant-based mulch. When left on the field, this mulch builds soil organic matter and fertility. Legumes also help suppress weeds and, depending on the species, produce beans and foliage for human and/or animal consumption. While these benefits are well-recognized, the benefit of GMCCs to small-scale farmers depends on how well they are integrated into smallholder cropping systems (see BPN 7 (http://edn.link/caefgc) for information on legume selection and planting strategies).

In *EDN* 133 (https://www.echocommunity.org/resources/91b29d3d-2236-43ec-b0c2-15ccbc63dcb8) we described a cereal/legume intercropping strategy in which two rows of a cereal crop are alternated with four rows of a legume. This "2:4:2" planting sequence is an outcome of research done by the International Institute of Tropical Agriculture (IITA) and national partners, with cowpea as the legume and maize or sorghum as the cereal crop (Ajeigbe *et al.* 2010). The planting configuration minimizes competition for light. It is best suited to areas where the return from the legume justifies devoting less land area to a cereal crop. Research at ECHO in Florida showed that the system has potential for integrating other legumes besides cowpea into maize, including those with taller canopies than cowpea, such as jack bean (*Canavalia ensiformis*).

After reading about the 2:4:2 strategy in *EDN* 133, and visiting the Florida research plots, Plant With Purpose (plantwithpurpose.org (https://plantwithpurpose.org/)) expressed interest in working with ECHO on a protocol that farmers in Democratic Republic of Congo (DRC) could use to test the 2:4:2 system. Tim Motis and Stacy Reader corresponded with Plant With Purpose partners in the DRC, together developing a way for farmers to compare the 2:4:2 approach to traditionally-grown maize using a Farmer Field School (FFS) model. Their experience is shared here, both to provide an update on the performance of 2:4:2 outside Florida, and to present one way in which farmers conduct their own research.

About the Farmer Field School Approach

Technologies such as the 2:4:2 planting sequence have been shown to have multiple benefits for farmers. One challenge of community development is to effectively share information about a new practice, and then create a forum where farmers can develop a deep understanding of the practice and adapt it to their local context.

FFS is a participatory approach where everyone involved is simultaneously both a learner and a teacher. Traditional agricultural training models involve experts sharing knowledge with farmers, so that information flows in one direction only. By contrast, FFS seeks to put farmers and instructors on an equal footing, so that everyone can share knowledge and information flows in many directions. FFS also introduces the ideas of simple field trials, formal field observations, and practical innovation. FFS emphasizes local testing on real farms, rather than in a specialized centre with specialized equipment and conditions. This kind of research is relatively low cost, and can be managed by community leaders and facilitators with some basic training.

A typical FFS involves a group of 20 to 30 farmers who meet regularly. Group members decide how often they will meet; usually they meet weekly or monthly depending on the nature of the trial. One farmer volunteers a small plot of land on his or her farm as the trial area. All farmers in the group work together to plan, establish, maintain, and harvest the trial, typically with the guidance and training of a facilitator or technician. The plot is typically divided in two, with one section for the treatment being tested (for example, a green manure crop) and the other section serving as the control. The control should be familiar to all participants, and gives a frame of reference to which results of the new treatment can be compared. A semi-structured observation process, also known as the agroecosystem analysis (AESA) can help guide farmers' regular observations.

Methodology

The Kakumba watershed is located in South Kivu, eastern Congo, in Uvira territory (Figure 1). It is part of the larger Congo River watershed and empties into Lake Tanganyika. Approximately 20,000 people live in the area, most of them depending on agriculture as their principle source of income.

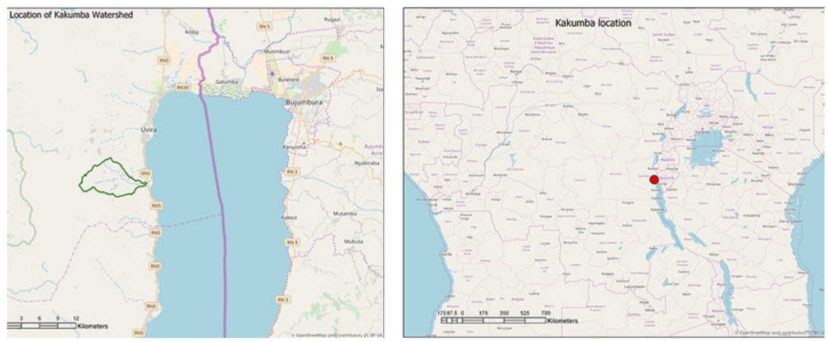

Figure 1. Maps showing the location of the Kakumba watershed in DRC. *Source: Open Street (Creative Commons Licence)*

2:4:2 maize/legume intercropping was new to the community, so prior to meeting with farmers, Plant With Purpose and ECHO developed a step-by-step process that FFS facilitators could easily communicate to farmers, and that farmers could then replicate. To minimize communication barriers, the research plan contained hand-drawn illustrations (Figure 2) with instructions translated into Swahili. The protocol called for locally-available seeds (of the cereal and GMCC crops) and fertility inputs, to minimize cost to farmers. A known, appropriately-sized (had to be small considering the small plot size) volume-based unit of measurement called the kigoz (Figure 3) was identified, to be used for quantifying grain production. One kigoz of maize or cowpea grain weighs approximately 0.67 kg. This meant that participating farmers did not need to purchase and calibrate scales or transport their harvest to a central location to be weighed. A questionnaire was developed to guide and record farmers' observations. We minimized labor requirements by limiting data collection to farmer observations and grain yield.

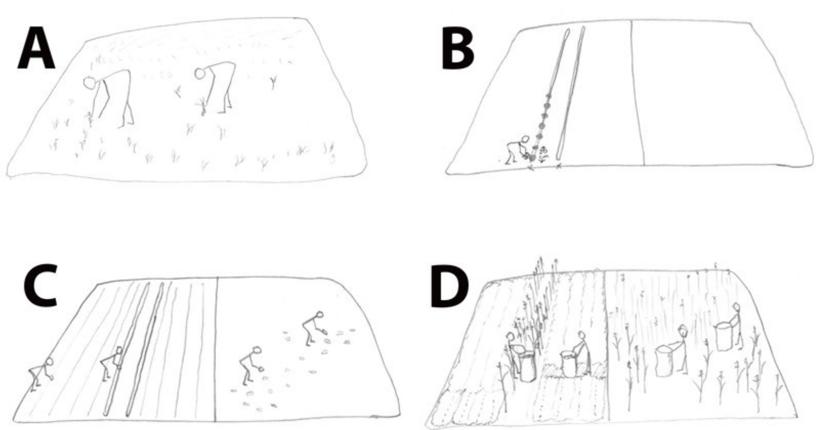

Figure 2. Hand-drawn illustrations of ground preparation (weeding [A] and compost application [B]), seeding (C), and harvesting (D). *Source: Robert Morikawa*

In FFS trials, farmers normally meet with a Plant With Purpose facilitator or technician, together discussing various options and deciding what they want to test. Farmers groups in Kakumba are regularly running FFS on a variety of topics such as soil conservation, improved crop varieties, and soil fertility practices. Because the 2:4:2 trial design was already well-defined, discussion this time focused more on which groups were interested, who would volunteer a plot of land, and what the control planting of maize would look like. The farmers decided that the legume would be cowpea, commonly known as ngore in the Uvira region. They chose cowpea even though it appears to be subject to some pest damage, is not widely planted, and seed is currently expensive. However, since the experimental plots were small, seeds for the trial did not cost a lot. In the future, farmers could multiply their own seed if they want to try the system themselves; also, if cowpea becomes more popular and is planted more widely, the cost of seed will decrease. Farmer groups, facilitators and technicians worked together to set up the trials.

Six separate FFS groups each established a trial (Figure 4). Each trial site measured 12.6 m x 7.5 m, with each site divided into two 6.3 X 7.5 m plots. One plot was randomly assigned to the control treatment and the other to the 2:4:2 treatment. The control treatment consisted of traditionally grown maize, with seeds sown at an approximate spacing of 50 cm X 80 cm, and with no fertility input applied; only in recent years have farmers in the Kakumba watershed begun to use compost to grow maize. The 2:4:2 plot contained a mixture of maize and cowpea--four rows of cowpea alternated with two rows of maize, with rows spaced 70 cm apart. In-row spacing was 40 cm for cowpea and 30 cm for maize. Maize seeds were sown into shallow furrows (dug with hoes), to a depth of about 15 cm. Prior to seeding the maize, a handful of compost was placed every 20 cm within furrows and lightly covered.*

Figure 3. A typical kigoz measuring can. *Source: Biriori Dieudonne*

Figure 4. Measuring (left) and hoeing (right) activities to establish a 2:4:2 trial. *Source: Biriori Dieudonne*

***NOTE: The 2:4:2 approach, as outlined by IITA, makes use of fertility inputs, especially for the maize. DRC farmers did not have NPK fertilizers, so they used compost instead; a high rate was used to compensate for no NPK fertilizer being used, but farmers could certainly experiment with lower rates. The purpose of the trial was to simply compare two cropping systems; a more rigorous design could have included treatments to determine the contribution of manure and cowpea to the maize.**

Cowpea rows received no fertility inputs. Seeding was done at the beginning of the rainy season, during the months of November-December 2017. Crops were rainfed; no irrigation was used.

Figure 5. Farmers observing maize and cowpea plants at a 2:4:2 trial site. *Source: Biriori Dieudonne*

Farmers in the FFS groups met twice a week to record planting and harvesting dates, as well as observations related to pests, disease, soil, crop growth, grain yield, and the overall performance of each treatment (Figure 5). At the end of the season, each group recorded the volume (number of kigozes) of maize and cowpea grain that were harvested. The number of kigozes per plot were converted to kilograms (kg), and final yields were expressed as kg per hectare (ha) of a 2:4:2 or traditional growing system. At the end of the trial, farmers held focus group discussions (summarized below), to share their reactions to the 2:4:2 system.

Grain Yields

Cowpea grain yield

Grain yields for each FFS group are summarized in Table 1. Cowpea grain production ranged from 213 to 638 kg/ha. Yields at one Kalonge site (managed by the Umoja Wetu group) and at one Gomba site (managed by the Uamusho group) exceeded the 100 to 500 kg/ha average for tropical parts of Africa (Madamba *et al.* 2006); the average for all six sites, 406 kg/ha, was on the high side of that range. A 2:4:2 cowpea crop is capable of producing 800 or more kg/ha of grain (Ajeigbe *et al.* 2010) when fertilized and protected from insects, so these trial results seem promising considering that there was no additional fertility or pest-control management.

Table 1. Grain yield produced by maize alone or maize and cowpea in a 2:4:2 (two rows of maize alternating with 4 rows of cowpea) planting sequence.

Farmer Field School		Cowpea and maize grain with the 2:4:2 system			
Group name	**Site**	**Cowpea (kg/ha)**	**Maize (kg/ha)**	**Cowpea + Maize (kg/ha)**	**Sole Maize (kg/ha)**
Muungano	Gomba	319	851*	1170	425
Umoja Wetu	Kalonge	638	851*	1489	709
Ushirika	Kalonge	425	851*	1276	425
Maarifa	Katongo	319	425	744	709
Mupango wa Mungu	Kigongo	213	425	638	709
Uamusho	Gomba	532	1276	1808	709
	Average	408	780	1188	614

*Similarity of these numbers is due to the same number of kigoz (local unit of volume) reported for each site; farmers were not asked to report fractions of a kigoz.

In many parts of Africa, cowpea is grown under cereal or cassava crops. With the 2:4:2 approach, farmers can still grow these crops at the same time, but without competition for light. Within a 2:4:2 system, 67% of the crop rows are occupied by legume plants. With their low nutrient requirements, farmers are able to use most (if not all) of their fertility inputs to benefit the maize crop. That said, if a field is low in nutrients and organic matter to begin with, legume growth may be optimized with modest amounts of organic or inorganic fertilizer. Legumes do need some phosphorus in order for biological nitrogen fixation to occur (Ssali and Keya 1983; Zahran 1999). They also need sufficient levels of other plant-essential nutrients. Fortunately, as mentioned earlier, many tropical legumes have deep root systems able to take up nutrients from soil layers that may not be accessible to roots of the cereal crop. Leaving legume biomass on the soil returns those nutrients to the soil surface, thus helping to maintain crop-accessible nutrient levels.

Using seed of improved varieties is another way to optimize legume productivity. Depending on your location, seeds may be available through research centers like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT (http://www.icrisat.org/from-grass-to-great-tropical-legumes-project-transforms-agricultural-extension-in-northern-nigeria/)). Depending on the length of the rainy season, use of early-maturing varieties may allow for two cowpea crops in a single growing season (Ajeigbe *et al.* 2010).

Maize yield

Maize production at four of the six sites was higher with 2:4:2 than when maize alone was planted. Ajeigbe *et al.* (2010) also reported higher first-year grain yield in Nigeria with 2:4:2 maize (978 to 2533 kg/ha) than with traditionally-grown cereals (489 to 1611 kg/ha in multi-crop systems such as maize + sorghum, with or without cowpea). That study used more inputs than ours did (for details, a link to their online report is available here (http://www.academicjournals.org/article/article1381143218_Ajeigbe%20et%20al.pdf) and in the references section).

The Nigeria and DRC trials show that it is possible to produce as much or more maize with the 2:4:2 system as with traditional practices. This is important in light of how much less land there is for maize in a 2:4:2 system than in a traditional cropping system. With spacings used in the DRC trial, a farmer would plant 11,111 maize plants per ha of 2:4:2, compared with 25,000 plants per ha of traditionally cropped maize. Maize in the 2:4:2 plots received more fertility inputs than maize in traditional plots; traditionally grown maize production would likely have been higher if those maize plants had received the same level of inputs as the 2:4:2 plants. However, in low-resource settings, farmers are unlikely to generate enough manure or compost, or to afford enough NPK fertilizer, to treat an entire field.

Total grain yield

Total 2:4:2 grain yield (maize + cowpea) exceeded that of traditionally-grown maize in five of the six sites (Table 1). Averaged over all six sites, the 2:4:2 system produced nearly twice as much grain as the traditional method, clearly showing the benefit of cowpea as a second source of grain in the 2:4:2 system. However, the quantity of grain produced by a legume is only one piece of the picture; the suitability of a 2:4:2 system in any given area also depends on the economic value of the grain. In the Kakumba Watershed, a kigoz of cowpea was more valuable (1500 FC) than maize (1000 FC), making 2:4:2 with cowpea an attractive option. Economic returns from cowpea grain would probably decline if a large number of farmers start growing cowpea at the same time, which could be a reason for future FFS trials to evaluate other legumes such as pigeon pea.

Farmers’ Reaction

Farmers’ reactions to the FFS trials were positive. When the 165 participating farmers were asked about the 2:4:2 system, 88% said they were interested in trying it on their own farms. Farmers were primarily interested in the 2:4:2 system for increased yields, and for improved soil quality. One disadvantage noted by farmers was the extra labor required to prepare fields at pre-planned spacing. Farmers also observed some pest damage to leaves during their early development. Despite these challenges, all 6 FFS groups are starting a second season of the 2:4:2 trials on the same plots of land, and 4 new groups are starting first season trials.

The farmers’ discussion, analysis, and action demonstrate the way FFS allows farmers to research and learn within the local context. In fact, 40% percent of farmers involved in the FFS groups would like to experiment with other legumes besides cowpea, indicating that the FFS model is helping to stimulate farmer-led research within the community.

Conclusion

Research that benefits small-scale farmers can be done in a variety of ways. Rigorous studies with multiple replicated/randomized treatments can best be done at project sites or research stations; these are also good locations for pilot studies. In this case, an initial ECHO trial in Florida helped us craft a 2:4:2 protocol that could then be tested by farmers. Research that benefits farmers is much more likely to occur when farmers are able to participate in the process. Plant With Purpose staff shared the following when asked about starting a FFS:

> In our experience, FFS has worked best where there is already a well organized and motivated group within the community. It works well when integrated into a teaching curriculum which offers ideas and technologies that are well suited to the local context, and that meet recognized needs of farmers. FFS and trial design principles should be clearly explained and principles kept as simple as possible. Catalyzing farmer-led research is challenging, and requires a process that creates as few barriers as possible for farmer participation. This includes using training materials and strategies that work with people who typically cannot read or write, or who have limited education. It is also important that trainers be able to use a participatory style of instruction rather than a top-down style. As much as possible, farmers should be encouraged to participate, and they should be viewed as experts as well as learners.

We hope this article inspires you to find ways to involve farmers in conducting research that improves their livelihoods.

References

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Zahran, H.H. 1999. Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC98982/#B303). *Microbiology and Molecular Biology Reviews* 63(4):968-989.

Further Reading

Ajeigbe, H.A., B.B. Singh, A. Musa, J.O. Adeosun, R.S. Adamu, and D. Chikoye. 2010. Improved Cowpea–cereal Cropping Systems: Cereal–double Cowpea System for the Northern Guinea Savanna Zone. International Institute of Tropical Agriculture (IITA).

> This document explains with pictures how to establish a 2:4:2 planting. It can be found in the IITA Bibliography (http://biblio.iita.org/index.php?page=publication&kind=list&type=year) website; type “improved cowpea cereal cropping systems” into the search bar, click the “search” button, and click on the PDF button to the right of the publication title that comes up.

Davis, K., E. Nkonya, E. Kato, D.A. Mekonnen, M. Odendo, R. Miiro, and J. Nkuba. 2012. Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Development*. 40(2):402-413.

> A review of the literature on FFS. Studies reviewed show that FFS participants have higher crop value per hectare, greater livestock gains per capita and greater agricultural income per capita. More vulnerable households tend to benefit more from FFS participation. A full-text 2010 IFPRI (International Food and Policy Research Institute) version is available here (https://pdfs.semanticscholar.org/d0c7/9ae04439217101c80170383c2375976ee1f1.pdf).

ECHO/MEAS Summaries (https://www.echocommunity.org/resources/59dbf4a4-a609-4681-93a9-0c1a56ebd9ae)

> A series of ECHO Summaries publications, written to distill MEAS (Modernizing Extension and Advisory Services) resources for the benefit of our network, contains information on farmer extension and training.

Khatam, A.M., S.H. Muhammad, K.M. Chaudhry, and M.U. Khan. 2014. Impact of farmer field schools on skill development of farming community in Khyber Pakhtunkhwa Province, Pakistan (http://www.aup.edu.pk/sj_pdf/20-%20107-2012%20%20formatted%20FRESH%20AFTER%20FOREIGN%20REFREE%20COMMENTS.pdf). *Sarhad Journal of Agriculture* 1:30(2).

> This study identified improved learning, decision-making capacity, and community organization as benefits of FFS; FFS groups also showed increased knowledge of pest identification and pest control methods.

Ortega, D.L., K.B. Waldman, R.B. Richardson, D.C. Clay, and S. Snapp. 2016. Sustainable intensification and farmer preferences for crop system attributes: Evidence from Malawi's central and southern regions (https://www.sciencedirect.com/science/article/pii/S0305750X15302497). *World Development* 87:139-51.

This article describes a study in Malawi, which showed that farmers had varying preferences for maize only, maize plus legumes or legumes only. Preferences depended on local conditions and availability of labor.

Pretty, J., C. Toulmin, and S. Williams. 2011. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability* 9(1):5-24.

This review of 40 projects in 20 African countries examines the factors that contribute to successful adoption of technology by farmers. Key factors include: farmers and scientists collaborating on research; creation of social structures to generate trust between farmers and agencies; and sharing of information through use of farmer field schools.

Sileshi, G., F. Akinnifesi, O. Ajayi, and F. Place. 2008. Meta-analysis of maize yield response to woody and herbaceous legumes in sub-Saharan Africa (https://www.researchgate.net/publication/225198955_Meta-analysis_of_maize_yield_response_to_woody_and_herbaceous_legumes_in_sub-Saharan_Africa). *Plant and Soil* 307(1):1–19.

Sileshi G., F.K. Akinnifesi, O.C. Ajayi, and F. Place. 2009. Evidence for impact of green fertilizers on maize production in sub-Saharan Africa: a meta-analysis (http://www.evergreenagriculture.net/sites/default/files/Evidence%20for%20impact%20of%20green%20fertilizers%20on%20maize%20production%20in%20sub-Saharan%20Africa.pdf) ICRAF *Occasional Paper* No. 10. Nairobi: World Agroforestry Centre.

These extensive meta-analyses of 94 studies in sub-Saharan Africa demonstrates that herbaceous green manures increase maize yields by 0.8 t/ha on average compared to unfertilized plots.

Waddington, H., B. Snilstveit, J. Hombrados, M. Vojtkova, D. Phillips, P. Davies, and H. White. 2014. Farmer Field Schools for Improving Farming Practices and Farmer Outcomes: A Systematic Review. *Campbell Systematic Reviews* 2014: 6. Campbell Collaboration.

A systematic review of the FFS literature, covering both the benefits and constraints of FFS.

