Final Report for 2008-2012 – Univ. of Florida UFL157

Title: Systems Approach to Enhance Peanut Production under Resource Limitation.

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I. Final Summary:

a. Statement of Overall Goal: To conduct field research on resource limitation to peanut production in Ghana and Burkina Faso and to test new technologies (fungicides, herbicides, improved cultivars, irrigation practices, fertilization, crop management, and harvesting technologies to improve peanut production, with the aim of being appropriate, low cost, cost-effective technology to improve producer income and maintain good market position.

b. **Significant Technical Achievements:** Scientists in Ghana (J. B. Naab with UFL-157 project, and Abudulai Mumuni with NC131-project) and Burkina Faso (Philippe Sankara and Z. Bertin with UFL-157 and TAMU-137 projects), collaborated to conduct multiple seasons of trials to evaluate fungicides, herbicides, and screening of 20 cultivars at two sites in Ghana and at two sites in Burkina Faso. Yield, disease score, and weed ratings were made.

Objective: To evaluate peanut cultivars for yield potential and leafspot resistance in on-station trials, with the goal of identifying several cultivars to test in on-farm trials.

Multi-location screening of 20 cultivars was conducted over three seasons at Wa (J. B. Naab) and Nyankpala (A. Mumuni) in Ghana and at Farakoba and Gampela, Burkina Faso by P. Sankara and Z. Bertin. Graduate student, Stephen Narh (Ghanian) funded by GTZ-ICRISAT and University of Florida, collected in-season data on growth analyses traits and disease scores of 20 cultivars at Wa and Nyankpala in 2010 and 2011, to determine relationships of yield to physiological traits and disease resistance. Short season farmer check cultivars included Chinese, T32-1, and Doumbala. PC79-79 was entered as a disease resistant check. Six lines were ICRISAT lines previously screened at the Nyankpala location, three were SARI releases (F-Mix, Nkatesari, and Gusie Balin), two were SARI crosses from ICRISAT materials, and six were crosses made by Mark Burow, Texas A & M University. No fungicide was applied to allow screening for cultivar differences in disease resistance. Yield and ICRISAT disease score were obtained.

Pod yield results, averaged over 4 sites and over 2 years (Table 1), showed the top two cultivars ICGV-96814 and Nkatesari yielded 1755 and 1722 kg/ha, significantly more (85% more) than the three short-season farmer cultivars, Chinese, Doumbala, and TS-32-1 which yielded between 889 to 979 kg/ha. In fact, ICRISAT lines or crosses derived from ICRISAT lines accounted for 7 of the top 8 cultivars, with an unknown line (NC-7, not the USA line), among the 8. The Texas-derived crosses did not perform well.

Table 1. Pod yield of 19 peanut cultivars averaged over 2010 and 2011 in multi-location trials at Wa-Ghana, Nyankpala-Ghana, Farakoba-Burkina Faso, and Gampela-Burkina Faso (Naab, Mumuni, Sankara, Bertin).

Cultivar	Pod Yield (kg/ha)	Duncan's MR Test
ICGV-IS 96814	1755	A
NKATESARI	1722	A
ICGV-IS 92093	1581	B
F-MIX × SINK 24	1524	B
NC 7	1496	B
ICGV-IS 92101	1359	C
GUSIE BALIN (92099)	1323	C
ICGV (FDRS)-20 × F-MIX-39	1309	C
PC 79-79	1078	D
ICGV-IS 96895	1048	DE
CHINESE	979	DEF
DOUMBALA	960	DEF
G204TX95	947	DEFG
B106TX95	935	DEFG
GM 57	898	EFG
TS 32-1	889	FG
GM 123	881	FG
G122TX95	853	FG
GM 515	804	G

Leafspot disease and defoliation were more prevalent on Chinese, Doumbala, and TS-32-1 (short-season check cultivars). Many of the other cultivars were more leafspot resistant than the short-season Spanish types, although a few of the Texas lines were quite susceptible to leafspot. Leafspot resistance of PC79-79, the local disease tolerant check, was similar to, but not better than resistance of ICRISAT-derived lines. Some of the more vigorous, green, and leafspot-resistant lines appeared to be Nkatesari, Gusie-Balin, F Mix x Sink 24, FDRS-20 by F-Mix 39, ICGV-96814, ICGV-92101, ICGV 92093, F-Mix, NC-7, G122Tx95, and G204Tx95. Unfortunately, some of the same cultivars had poor stands in 2011 (Gusie-Balin, G122Tx95, ICGV-96814, F-Mix and NC-7). The three short-season farmer checks had consistently the highest stands (seed germination), thus highlighting a possible reason for their success in farmer fields, and a need for peanut breeders to pay attention to seed germinability. Some cultivars appeared to tolerate the water-logged fields of Farakoba and Nyankpala better than other cultivars.

Stephen Narh's analysis (being written up for his dissertation) indicated causes for the 80% higher yields for the best cultivars. High yielding cultivars had longer life cycle (100 to 115 days rather than 90 days), better leafspot resistance, less defoliation, greater dry matter accumulation, and higher partitioning to pods (as measured by slope of pod harvest index and final pod harvest index). Stephen used the CROPGRO-Peanut model to solve for genetic traits from growth analysis data at two sites in Ghana, and with those solved traits was able to predict surprisingly well the cultivar performance at the two independent sites in Burkina Faso. This lends promise for using the model as a genetic improvement assistance tool to evaluate target environments for cultivars.

Objective: To evaluate improved technologies, especially improved equipment and practices of applying fungicides and herbicides to control disease and weeds, with the goal of increasing production and profit margin.

Herbicide by fungicide evaluation trials were conducted for two seasons (2009, 2010) by Naab and Mumuni on Chinese cultivar sown in Wa and Nyankpala, Ghana, while Sankara and Bertin conducted three seasons of the trials (2009, 2010, and 2011) on Chinese at Farakoba and Gampela, Burkina Faso. The herbicide was pendimethalin and the fungicides were chlorothanil and folicure, starting at 28 days, every 14 days, alternating fungicides. ICRISAT disease score and defoliation were recorded. The pendimethalin was variably effective across sites, in part because the weed species pressure varied. Grassy weed control was good at Wa, but not as good at Nyankpala because other dicot weeds were present. Weed control was partial at Gampela where weeds were vigorous vine-type, Pennisetum, and broadleaf types. Weed control was partial at Farakoba, where water-logging was a problem and sedges escaped control. Herbicide-alone increased yield over the weedy check, but was never sufficient by itself. The role of this herbicide at best is for partial control of grasses, linked to hand-weeding. The fungicide treatment was reasonably effective at all sites, but never complete. Averaged over sites, the fungicide treatment increased pod yield by 69% over the no-fungicide treatment (1719 versus 914 kg/ha at Wa in 2009; 1809 versus 1015 kg/ha at Farakoba in 2009; 2623 versus 2313 kg/ha at Gampela in 2009; 2616 versus 1270 kg/ha at Nyankpala in 2010, 2486 versus 1696 kg/ha at Gampela in 2010, 449 versus 248 kg/ha at Farakoba in 2010). Fungicide benefit to yield is similar to results from prior studies.

Herbicide evaluation trials were conducted in 2011 and 2012 by collaborators in Ghana (Naab and Mumuni) at Nyankpala and Wa (Burkina collaborators started this in 2012), testing the effects of four herbicides (Pendimethalin, Galant, Agil, and Basagran) alone, and in combination, and further in combination with hand-weeding, compared to weedy check and hand-weeded control. There was valuable weed control from the different herbicides, as well as differential herbicide effects, with certain species of weeds escaping control. Combinations involving any one or two of the three herbicides (pendimethalin, galant, and agil) controlled the grassy weeds, but allowed broadleaf escapes. Basagran gave no control of grasses, but controlled some broadleaf weeds. At both sites, there was excellent potential for control of early grass weeds with any of the three grass-controlling herbicides, particularly in combination with later hand-weeding.

Objective: To enhance production of high-value fresh market peanut crop in off-season in Ghana by irrigated production via determination of optimum sowing dates and irrigation practices.

Off-season winter irrigation was evaluated as a way to create an income-generating activity. Experiments were conducted by J. B. Naab (Ghana) during February to May 2008 and again in 2009 in farmer fields at the Sankana irrigation project near Wa, using low pressure drip irrigation. Treatments consisted of factorial combination of three sowing dates and three irrigation levels (50, 75, and 100% of potential evaporation). The Chinese cultivar was grown, no fertilizers or fungicides were applied, and weeds were controlled manually. For the 2008 season, the peanut pod yield averaged 874, 1186, and 687 kg ha^{-1} for sowing on 13 February, 13 March, and 13 April, respectively. Pod yield was increased as irrigation amount was increased from 50, to 75, to 100% of potential evapotranspiration, yielding 703, 990, and 1054 kg ha^{-1}, respectively. For the 2009 season, the pod yield averaged 2660, 1742, and 1043 kg ha^{-1} for sowing on 12 February, 13 March, and 12 April, respectively. There was excellent publicity and interest on the part of the farmers. Dr. Naab conducted a demonstration for farmers and the public. Newsmen were present who wrote up a story in the Ghanian Times describing how peanut could be produced in the winter season with double the pod yields attributed to less disease pressure, and also for a much higher market value in the winter season than in the rainy season. Winter irrigation of groundnut for fresh market has been continued since that time by those farmers.

Objective: To use crop modeling as a tool to evaluate research results, to predict leafspot effects, to predict peanut growth and yield response to weather, soils, & disease.

Crop physiology and modeling research in Florida by J. Erickson, K. Boote, and M. Singh (Ph.D. graduate student, not funded on project) completed a 2-year experiment on leafspot effects on leaf and canopy photosynthesis, leaf area index, growth, and pod yield of a leafspot-tolerant cultivar (York) compared to a leafspot-susceptible cultivar (Carver). M. Singh completed his Ph.D. dissertation in May 2011 and wrote two papers for publication and a third is accepted pending revisions. In this work, code improvements were made in the leafspot disease subroutine of the CROPGRO-Peanut model to create direct linkage of leafspot necrosis on leaf-level photosynthesis. The leafspot defoliation and leafspot necrosis were directly entered into the model with the improved linkage. The resulting simulation of canopy photosynthesis and growth was shown to accurately reproduce yield reductions due to leafspot-induced defoliation and necrosis.

K. J. Boote collaborated with Piara Singh on an ICRISAT-linkage project to evaluate the potential for genetic improvement in peanut yield in response to climate change. He assisted P. Singh and post-doctorate at ICRISAT in review of peanut response to climate change factors for a paper published in Advances in Agronomy.

c. Significant Issues

There were difficulties in arranging the initial sources of seed, because of reluctance of a senior scientist at SARI, Nyankpala, to give up the existing peanut multiplication lines to

Nicholas Denwar to take over as peanut breeder. It took diplomacy to solve the problem but eventually selected lines from SARI were obtained and joined with cultivars from Burkina Faso, and the Nyankpala trial was assumed by A. Mumuni because of the delayed return of Denwar from his Ph.D. program in Texas. In addition, there were difficulties in getting fungicides and herbicides available for trials and for farmers to use. Dr. Naab intervened with government administration in Accra, to request permissions for import and use of fungicides and herbicides on peanut and arranged with local agrichemical dealers in Wa, to obtain these materials for farmer use.

d. Capacity Development

Weather stations were provided to scientists in Ghana and Burkina Faso, for weather data collection to improve the interpretation of weather effects on peanut production. Portable computers were provided to J. B. Naab (Ghana) and P. Sankara (Burkina Faso), to facilitate data analyses, crop modeling, and paper writing.

e. **Human Capacity Development:**

Graduate students trained. Recruited and funded independently from USAID system.							
Name	Gender	Country	Degree	Completion	Trained	Res. Site	Employment
Philip Alderman*	Male	USA	Ph.D.	Aug. 2013	Univ. Florida	Wa, Ghana	Hired by CIMMYT
Stephen Narh**	Male	Ghana	Ph.D.	Aug. 2013	Univ. Florida	Wa, Ghana	Position SARI -GH
Maninder Singh***	Male	India	Ph.D.	May 2011	Univ. Florida	Florida	Post-doc with UF
*USA student funded by University of Florida Alumni Fellowship, hosted by J. B. Naab. **Ghanian student funded on UF Fellowship and GTZ-ICRISAT grant, partially supported on Peanut CRSP, hosted by J. B. Naab, conducted peanut cultivar trial in 2010 and 2011 in Ghana, will return to position in Ghana in August 2013. ***USA student, funded by UF, advised by John Erickson, did research related to CRSP.							

f. Short-Term Training of Host Country Scientists: J. B. Naab and P. Sankara visited Florida to work with experimental data, do crop modeling, and write papers related to production constraints and improved practices.

Jesse Naab visited the University of Florida from April 7 to Dec. 20, 2008, on a sabbatical, funded by USAID Soil CRSP (5 months) and Peanut CRSP (4 months). Dr. Naab worked with experimental data, did crop modeling, and wrote papers for publication (see list of papers). He participated in the APRES peanut meetings held in July, the ASA meetings in October, and Peanut CRSP investigators meeting in Dec 3-4.

Jesse Naab visited the University of Florida during Feb 1 to March 31, 2010 to work with K. Boote and J. Jones on papers from Peanut CRSP experiments (see list of papers).

Jesse Naab visited the University of Florida during Feb 12 to May 28, 2011 to work with K. Boote and J. W. Jones on papers from Peanut CRSP experiments, to include modeling

peanut response to P fertilization and leafspot disease (paper just submitted). During that time, he participated in the Peanut CRSP investigators meeting on March 30-April 1, and the Biological Systems Simulation Conference held April 19-21.

Philippe Sankara visited the University of Florida during March 1 to 20, 2012, and Jesse Naab visited during March 7 to April 9, 2012, to work with K. Boote on data from the herbicide by fungicide trial (time was short and paper is still being worked on.).

g. Publications

Naab, J. B., K. J. Boote, P. V. V. Prasad, S. S. Seini, and J. W. Jones. 2009. Influence of fungicide and sowing density on the growth and yield of two groundnut cultivars. J. Agricultural Science 147:179-191.

Naab, J. B., P. V. V. Prasad, K. J. Boote, and J. W. Jones. 2009. Response of peanut to fungicide and phosphorus in on-station and on-farm tests in Ghana. Peanut Science 36:157-164.

Naab, J. B., S. S. Seini, K. O. Gyasi, G. Y. Mahama, P. V. V. Prasad, K. J. Boote, and J. W. Jones. 2009. Groundnut yield response and economic benefits of fungicide and phosphorus application in farmer-managed trials in Northern Ghana. Expl. Agric. 45:385-399.

Singh, M. P., J. E. Erickson, K. J. Boote, B. L. Tillman, J. W. Jones, and A. H. C. van Bruggen. 2011. Late leafspot effects on growth, photosynthesis, and yield of peanut cultivars of differing resistance. Agron. J. 103:85-91.

Singh, M. P., J. E. Erickson, K. J. Boote, B. L. Tillman, A. H. C. van Bruggen, and J. W. Jones. 2011. Photosynthetic consequences of late leafspot differ between two peanut cultivars with variable levels of resistance. Crop Sci. 51:2741-2748.

Kumar, U., P. Singh, and K. J. Boote. 2012. Effect of climate change factors on processes of crop growth and development and yield of groundnut (*Arachis hypogaea* L.) Advances in Agronomy 116:41-69.

Singh, P., K. J. Boote, U. Kumar, K. Srinivas, S. N. Nigam, and J. W. Jones. 2012. Evaluation of genetic traits for improving productivity and adaptation of groundnut to climate change in India. J. of Agronomy and Crop Sci. 1-15.

Naab, J. B., K. J. Boote, J. W. Jones, and C. H. Porter. 2013. Adapting and evaluating the CROPGRO-Peanut model for response to phosphorus. Field Crops Res. (in review).

Singh, M. P., J. E. Erickson, K. J. Boote, B. L. Tillman, A. H. C. van Bruggen, and J. W. Jones. 2013. Using the CROPGRO-Peanut model to simulate growth and yield in peanut cultivars with variable levels of resistance to late leaf spot. Agron. J. (accepted, pending revision).

II. Final Interpretation

a. Importance of Technical Achievements

Host country and USA: **The multi-location variety trial** has been a huge success in several ways: 1) first, it identified cultivars with disease resistance and 80% higher yield than current farmer cultivars, thus showing tremendous potential, 2) it created a true multi-investigator and multi-country collaboration (even multi-CRSP among three US PIs) who have all appreciated and shared the goals and progress of this effort, 3) it also emphasized the need for more trust in the value of ICRISAT releases. However, the future status of the multi-location variety trial is crucial to consider, as it needs to be an on-going activity that leads to distribution of improved cultivars to farmers. Ghanian and Burkina collaborators continued the trial in 2012 with residual funds. But without Peanut CRSP support, they may give up on the trial for 2013, thus losing the momentum started. From the results of the cultivar comparisons and visits with farmers, it is absolutely apparent that improved cultivars have failed to penetrate to the farmers, because of lack of seed multiplication/distribution system, because of frequent turn-over of plant breeders, and lack of on-farm trials. The Ghanian Ministry of Agriculture (MOF), which has responsibility for farmer contact, is quite disconnected from real information or scientists who know about new cultivars, so improved cultivars fail to be distributed. Momentum is there right now for starting a seed multiplication/distribution system with on-farm trials with these new lines, but this is in danger of being cancelled by delay and lack of funding by USAID-Peanut CRSP or its replacement (including FTF brand-new re-start attempts that will not make this connection either for years). Narh's study of genetic yield improvement traits and leafspot resistance traits will be valuable to both *host countries and the USA.*

The herbicide by fungicide evaluations were important for the collaboration that resulted and for introducing the concept that herbicides actually could be useful in peanut production, although the first herbicide used was not the optimum choice (because we could not get better ones into the country). The research on fungicide use was not new, but it reinforced the continued value (69% yield improvement) of using fungicides across these four sites. Probably most important was that this trial started scientists to thinking about how to use combinations of hand weeding with herbicides to reduce labor cost, how to screen additional herbicides for use, and the need to mechanize application of herbicides and fungicides at farmer level. The labor cost for weeding was compared to herbicide cost for weed control, and illustrated that herbicide use could be a good future solution to rising labor cost and shortage.

The off-season winter irrigation project was a great success story that provided high value market peanut production during the winter season, at a time when fresh market peanut is not available. Most importantly, the irrigation effort is fully in the hands of the farmers who are doing the practice on their own. In addition to fresh market production value, winter season irrigation has the potential benefit of providing a valuable back up time-of-year for producing good quality seed source if the regular season is poor.

b. Importance of human capacity development

Host country: Stephen Narh, Ghanian, will obtain his Ph.D. degree in Agronomy in August 2013. Stephen is confident, self-motivated, eager to learn, responsible, and importantly, has a position with the Savannah Agricultural Research Institute when he returns. He will be an excellent researcher and representative with advanced scientific and systems modeling capacity for Ghana's agricultural scientific community.

United States: Philip Alderman, a US citizen, is interested in international development agriculture, as witnessed by his research conducted in Ghana on crop rotations and value of grain legumes. Philip already has a position with CIMMYT as a crop modeler with a wheat genetic improvement team, and will certainly play an important role in agricultural development activities, but will likely return to USA in a scientist position. Maninder Singh, is Indian, and is staying in the US as a new hire in sugarcane cultivar screening at Bel Glade, Florida. So that heritage benefit will accrue to the USA. But he has international development interests as well, in peanut, sweet sorghum, and sugarcane.

c. Heritage left from short-term training

Host country: The short-term visits of Dr. Naab and Dr. Sankara have helped them to better evaluate their past research and to write papers for publication. Maybe even more important, both scientists have an expanded view on facilitating and mentoring future agricultural research and young researchers. Dr. Sankara is doing this in a major way as a student advisor with the University of Quagadougou. Dr. Naab has gained so much experience that he is in high demand and has accepted a 1-year appointment to move to Quagadougou to assist the WASCAL program (European program for advanced agricultural scientific training relative to climate change). In that program, he is advising on selection and placement of African graduate students in WASCAL programs at universities in Africa.

d. Heritage left in publications

Host country: The papers have well documented the prospects for increasing peanut yield in West Africa with use of fungicide, phosphorus fertilization, and improved cultivars. Phosphorus deficiency is a problem for most West African soils. The benefit of fungicide use is an annually recurring benefit because leafspot is so endemic every season, and fungicide was shown to be economically viable in terms of cost-benefit ratio in Naab's publication. The recent multi-location trial demonstrates promise for substantial yield improvement for West African cultivars, and provides knowledge that a moderate degree of leafspot resistance is present in new peanut cultivars.

United States: Papers on modeling leafspot damage effects will lead to improved strategies for control of leafspot in the USA, with assistance of systems modeling tools. Papers on genetic improvement of peanut demonstrate that there is considerable room for genetic improvement of peanut for current climate as well as future climate change, considering relatively small (10%) changes in genetic traits.

III. Final Summary of Accomplishments by Objective:

Objectives 1 (and 2): To evaluate improved technologies in farmer fields in Ghana (Burkina Faso) with goal of increasing production and profit margin. Technologies include evaluating improved cultivars, soil-testing-fertilization, sowing dates, and especially equipment and practices of applying fungicides and herbicides to control disease and weeds.

The herbicide by fungicide trials were successful in demonstrating the value of fungicide for increasing yield, as the yield response was 69% averaged over 4 sites and 2 years. The herbicide pendimethalin was only partially effective on grassy weeds and control varied with site and weed pressure. A herbicide screening program conducted for 2 years at 2 sites in Ghana and for 1 year at 2 sites in Burkina Faso showed that other herbicides were as good or better than pendimethalin for controlling grassy weeds. These grass-controlling herbicides have potential value in a combined program using herbicides with hand-weeding, as they considerably reduce hand weeding, and that will help farmers faced with labor shortage. An additional need is to facilitate improved application by farmers of herbicide and fungicide with small mechanical implements rather than backpack sprayers, to reduce the labor and improve uniformity.

Objectives 3 (and 4): To evaluate peanut cultivars for yield potential and leafspot resistance in on-station trials in Ghana (Burkina Faso), with the goal of identifying several cultivars to test in on-farm trials.

Multi-location variety trials with 20 cultivars were successfully conducted for three seasons at 4 sites (Wa and Nyankpala in Ghana; Farakoba and Gampela in Burkina Faso). The top two cultivars, ICGV-96814 and Nkatesari, yielded 85% more than the short season farmer check cultivars, Chinese, TS 32-1, and Doumbala. In fact, 7 of the top 8 cultivars were either ICRISAT lines or crosses derived from ICRISAT lines, and they were significantly higher yielding than the farmer checks. The higher yielding lines had longer life cycle (100 to 115 days compared to 90 days for farmer checks). They had significantly greater leafspot resistance, greater biomass accumulation, and higher partitioning to pods (pod harvest index). Some of these lines such as Nkatesari are already released for Ghana. There is a crying need for a seed multiplication and distribution system with on-farm trials to get these cultivars out to the farmers.

Objective 5: To enhance production of high-value fresh market peanut crop in off-season in Ghana by irrigated production via determination of optimum sowing dates and irrigation practices. (Objective 6 in Burkina Faso was never activated).

Winter season irrigation of peanut was highly successful in enhancing production of high value fresh market peanut in the off-season. It was successful in several ways: 1) yields were higher than summer because disease pressure was reduced, 2) drip irrigation was successful as a method of water distribution, and 3) the farmers took up the practice and continued the winter irrigation of fresh market peanut after the research phase was

completed. Dr. Naab held a demonstration for farmers and public and the Ghana Times wrote up a story on the off-season irrigation of peanut for fresh market.

Objective 7: To use crop growth modeling as a tool to evaluate research results, to predict leafspot progression, to evaluate legume N contribution to subsequent cereal crop, and to predict peanut growth and yield response to weather, soil water, sowing date, and diseases

The CROPGRO-Peanut model was successfully used for evaluating research results conducted in Ghana, USA, and around the world. The Ghana data was used to improve and parameterize the model for response to P fertilization and soil test P (Naab paper in review). The model was also used to help evaluate the consequences of leafspot disease on peanut growth and yield in the experiments in Florida, as well as the studies in Africa on the herbicide by fungicide treatments, and in the multi-location variety trial. Stephen Narh used the model in an optimization mode to solve for genetic traits contributing to yield improvement among the 20 peanut cultivars. P. Singh and K. Boote used the peanut model to study hypothetical genetic improvement of peanut cultivars under climate change for India and West Africa.