Title: Evaluating the benefits of Korean Natural Farming Practice on Tropical Vegetable Crop Production in Hawaii.

Contract no: 69-9251-11-912

PI: Koon-Hui Wang

Summary of project accomplishments:

1. Evaluate plant and soil health affected by KNF in three beginning KNF vegetable farms Pahoa Area of Hawaii Island.
2. Follow up on soil health analysis on taro farm in Waianae after 18 months of Korean Natural Farming (KNF) practice.
3. Setting up tomato field trial at University of Hawaii at Manoa Poamoho Experiment Station.
4. Graduate student conducting tomato pot trial at the Magoon Greenhouse Facility, Manoa.

Evaluation of Plant and Soil Health Affected by Korean Natural Farming Practices in the Island of Hawaii (2011 Nov -2012 May)

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Three farmers initiated an evaluation of KNF for vegetable / row crops individually in Pahoa Area in Hawaii beginning December, 2011 and terminated around May, 2012. All farms practiced KNF practice and compared to a conventional farming practice of their choice. This conventional farming practice either used synthetic fertilizer and pesticides, or organic farming practices using organic fertilizer and pesticides. The three farmers are 1) Mary Lorenz from Hawaiian Clean Greens, 2) Dona Willoughby from La'akea Permaculture Community, and 3) Leanne Okamoto from Kohana Farm. Each of these farms modified their KNF practice based on their resources available and the soil type they had in their farm. In general, all of these farms have Keaukaha soil which is composed mainly of Pahoehoe lava that is extremely rocky. Thus, all the farmers had to transport top soil from soil companies or elsewhere. Crop choice and plot size for each farm are listed in Table 1. As KNF practice required soil mulching, these farmers use different type of mulch based on their convenience. Mary used sunn hemp (*Crotalaria juncea*) as preplant cover crop followed by mowing down as surface mulch, Dona used macademia nut husk from a nearby macademia nut farm, whereas Leanne purchased shredded wood chips as mulch. All farms compared KNF practice to conventional practice (CONV, i.e. synthetic fertilizer along with herbicide spray) except for La'akea Farm where their standard practice is organic permaculture practice. The organic plots were treated with organic composted chicken manure (Nutrarich Pellets 5-3-2 and 7% Ca).

Table 1. Crop choice and plot size for each farm participated in KNF evaluation.

Farm	Crop(s) planted	Plot size (# plots/treatment)
Hawaiian Clean Greens	soybean	8×20 ft^2 (4/treatment)
Laakea Permaculture	kale, beet, broccoli, onion, leek	4×100 ft^2 (2/treatment)
Kohana Farm	kabocha squash	2×2 ft^2 (10/treatment)

Three types of evaluation were conducted: 1) plant health, 2) soil health analysis, 3) weed densities measurement conducted by the PI, and 4) cost comparison conducted by the farmers. For plant health analysis, farmers recorded the yield qualitatively or descriptively. In addition, at harvest, young fully matured leaves from each treatment plots were measured for their chlorophyll content using Digital Chlorophyll SPAD meter (Spectrum Technologies, Inc., Plainfield, IL). Numbers of leaves samples were pending on plot size and number of plants planted by the farmer (Table 2). Three reading points were read per leaves. Same number of leaves were sampled and sent to CTAHR ADSC laboratory to assay for macro- and micro-nutrients. For soil health analysis, 6 soil cores of approximately 5-cm diameter and 20-cm deep were taken around the root zone of the crops from each treatment plot. Soil was composited, bagged, and brought into laboratory. Subsample of 250 cm^3 soil were taken from each soil sample and extracted for nematodes using an elutriator. All nematodes extracted were identified to genus level and counted, grouped into trophic groups for their functional analysis. In addition, three nematode community indices were calculated to understand the soil health conditions. These indices were Enrichment Index (EI) that assesses food web responses to available nutrient resources; structure index (SI) that reflects the increasing complexity of the soil food web as the system matures; and channel index that reflects the decomposition pathway in the soil food web (Ferris et al., 2001). In general, higher EI and lower CI suggested greater bacterial activity, more nutrient enrichment, whereas higher SI indicates a soil is less disturbed. To further evaluate if KNF practice could improve soil physical structure as claimed by Master Cho, we measure soil compaction using Soil Compaction Tester (Spectrum, Inc.). Weed densities were recorded at the end of cropping season using a Horsfall and Barrett (1945) scale where 1 = 0%, 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12-25%, 6 = 25-50% of ground covered, 7 = 25-50%, 8 = 12-25%, 9 = 6-12%, 10 = 3-6%, 11 = 0-3%, and 12 = 0% of ground not covered. For cost evaluation, material and labor cost were carefully recorded by the farmers.

Results

Plant and Soil health: Among the three field experiments, Mary Lorenz's soybean showed the most significant effect of KNF. Although biomass yield of soybean was not significantly higher in KNF plots than the conventional practice plots (CONV), soybean leaf weight was heavier and darker ($P < 0.05$) in KNF plots (Table 2, Fig. 1 A, B). Leaf tissues in KNF plots also had higher N and P content, but lower Na ($P < 0.10$) than CONV plots (Table 2). Although no difference in the number of bacterivores, fungivores and herbivores, omnivores and predatory nematodes were significantly more abundant in KNF treated soil, indicating a stable, structured and less disturbed soil communities. Overall, KNF improved soil health condition at Mary Lorenz's soybean plot shown by higher SI, richness ($P < 0.05$) and tended to be higher diversity in KNF than the CONV. Interestingly, the root zone of soybean in KNF plots were densely colonized by a whitish mycorrhizal mycelium and occasionally mushroom body can be found on soil surface (Fig. 1 E). Soil surface of KNF planting bed appeared to have rise after 6 months of KNF practice as indicated by the soil depth measurement (Table 1). Although soil compaction tester did not detect difference in soil compaction between these treatments, this soil probe detected a thicker soil depth in KNF than CONV ($P < 0.01$). This was most probably due to more enchytreid worm (relatives of earthworms) in KNF than CONV, supporting the theory that KNF practices would soften soil physical structure. While earthworms are difficult to quantify using our soil sampling method, enchytreid worms, which are, are easily extracted during the elutriation process.

At Leanne Okamoto's kabocha plot (Fig. 3), effects of KNF practice was not significant. Leaf samples were taken after termination of crop harvest and kabocha plants in all treatment plots were infected by powdery mildew. Plants were wilting and senescing at the time of sampling. Thus, evaluation of KNF was confounded by heavy infestation of powdery mildew which KNF had no effect in protecting against this disease. Nonetheless, we did see some trend in KNF practice benefiting the system. Remaining healthy leaves (without powdery mildew) had higher chlorophyll content in KNF plants than those in CONV (Table 2), thus again supporting that KNF produced greener plants. However, all leaf nutrients analyzed were not higher in KNF except for Na which is not favorable. In terms of soil health, KNF significantly ($P < 0.05$) increased enchytreid worm, but did not increase all other nematode indices measured. High count of enchytreid worm could result in less compact soil and thus deeper top soil layer. Unfortunately we fail to measure soil depth in this field plot. One observation worth mentioned is that fungivorous nematodes tend to be more abundant in KNF, similar to the soybean trial; suggesting that KNF consistently stimulated more fungal population in the soil. Soil in Leanne's kabocha plot was highest in bacterivorous nematodes among the three locations, indicating that this soil was enriched with soil nutrients. Adding KNF did not further improve the nutrient enrichment conditions at this site. However, if we look at the more sensitive indices, EI, and SI, there is a trend that KNF resulted in higher EI (indicated more nutrient enrichment) and higher SI (indicated less soil disturbance and more structured soil food web). It might be interesting to examine KNF again in the same location by planting a crop less susceptible to powdery mildew.

In La'akea Farm (Donna Willoughby) where permaculture had been practiced since 2005, KNF eventually increased plant biomass as compared to La'akea organic farming (ORG) practiced after some initial challenges (Table 2). Several times during the trial, heavy rainfall continued over a week. This resulted in many seedlings die back (Fig. 2) especially in KNF plots. The farmer transplanted second set of vegetable crops, and most plant survived from second planting. Initially, plants in ORG plots out performed those in KNF plots. Thus, the farmer added additional compost to KNF plots. Instead of IMO4, the farmers prepared IMO5 which composed of 10% IMO4, 10% sheep, chicken manure and fish waste, yard waste materials, and macademia nut compost by fermenting for one week. Since then, plants in KNF treatment began to look greener and healthier. They reapply IMO5 in another two occasions (2 wks after first treatment and then 3 months after first planting) when the plants appeared less than vigorous. We only examined two of the crops planted, burdock and leek). Both of which tend to have bigger and greener leaves in KNF than in ORG (Fig. 3). Several leaf nutrients were also higher ($P < 0.10$) in KNF than Org. However, no significant difference in soil health conditions were observed between KNF and ORG practices. Although we observed many earthworms during sampling throughout the whole field, few enchytreid worms were extracted from this soil. Thus, enchytreid worm is not a good indicator in this field. Fungivorous nematodes were again higher in KNF than ORG, again suggesting that KNF enhanced more fungal colonization. KNF occasionally increased ($P > 0.05$) bacterivorous and omnivorous nematodes, and increased nematode richness and diversity consistently, all of which showing a trend of healthier soil conditions, but none were significant. None of the indices measured (EI, SI, CI) were showing KNF had healthier conditions than ORG. Nonetheless, KNF practice again resulted in a less compact soil as the soil depth measured were deeper in KNF than ORG plots.

Weed densities: Due to the heavy use of organic surface mulch to protect the IMO4 from sun light, indirectly KNF also resulted in less weed pressure than CONV practice. At Okamoto's farm, weed densities were significantly lower in KNF than no-herbicide control plots, and were not different from herbicide (glyphosate) treated CONV plots (Table 2, Fig. 4). In Lorenz's farm, weed densities in KNF after soybean harvest were even lower than that in CONV plots (Fig. 1 C, D). Willoughby also indicated that less weeding was necessary in KNF plots vs ORG plots despite macademia nut mulch were used for both treatments.

Soil analysis: ADSC soil properties analysis from Lorenz's trial revealed that KNF at pre-soybean planting increased soil P and K, reduced the recommendation rate of gypsum and Mg-sulphate. Safe cost on gypsum would be most benefiting to growers due to their higher price compared to other fertilizers.

Assay for mycorrhizae: There had been speculation that mycorrhizal fungi are the key indigenous microorganisms contributed to the benefits of KNF. We collect root samples from Lorenz's soybean, and stain with acid Fuchsin. Vesicular and arbuscular structures (Fig. 1 F) in soybean root tissues were counted under an inverted microscope. Unfortunately no significant difference was observed between KNF and CONV treatments.

Cost evaluation: Costs of production reported by Lorenz (Table 4) and Okamoto (Table 5) indicated that CONV cost more in materials than KNF. This is mainly due to expensive cost of synthetic fertilizer or soil amendment such as ammonia sulfate, urea and gypsum as well as herbicide. However, labor cost is much higher in KNF practice especially in year 1. However cost in year 2 would be significantly reduced due to left over supplies of inputs from year 1.

Summary of results

In general, KNF improved plant health in all trials in Puna but with some circumstances. The effect was most significant at Lorenz's soybean trial. KNF practice at La'akea Farm was challenged by heavy rain fall and more seedling die back in KNF plots. Long term sustainable practice of La'akea organic farming created a higher standard for KNF to meet. However, when Willoughby modified the KNF practice to incorporate animal manure in the IMO5 compost, plant responded positively and resulted in better growth at harvest. Heavy infestation of powdery mildew, fruit fly and pickle worm on kabocha in Leanne's trial interfered with the evaluation of KNF. KNF practice did not protect plants from diseases and insect pests, and should be avoided from heavy rainfall area. Otherwise shelter might be needed for planting in wet area. In fact, KNF required less irrigation than CONV practice. Future research should look into integration of KNF with other pest management strategies. Mulching practice in KNF significantly reduced weed pressure, omitted the need of further weed management. KNF also enhanced earthworm or enchytreid worm activities. More data on mycorrhizae colonization is needed. Earthworm and mycroohizae could be contributing to increase in soil tilth. Integration of sunn hemp cover cropping prior to KNF might have resulted in significant improvement of soil health condition in Lorenz's KNF plots.

Table 2. Comparing plant and soil health measurements between conventional farming (CONV) and Korean Natural Farming (KNF) practices on soybean[a], kale[b], and kabocha squash[c] in Pahoa.

	Mary Lorenz[a]		Dona Willoughby[b]		Dona Willoughby		Leanne Okamoto[c]	
	CONV	KNF	Org	KNF	Org	KNF	CONV	KNF
Plant Health Analysis	Soybean		Burdock		Leek		Kabocha	
Yield (kg)	25.08	32.23	-	-	-	-	31.78	23.15
Leaf weight (5 leaves, g)	1.37	2.49 **	5.70	8.52	1.59	3.49@	1.76	1.76
Chlorophyll content	25.52	37.27 **	31.9	36.14 *	52.78	55.2	26.84	32.93 **
N (%)	3.69	5.38 *	3.90	4.45@	3.30	4.01@	4.97	5.21
P (%)	0.30	0.38@	0.59	0.71	0.55	0.61	1.28	1.03
K (%)	2.35	2.41	4.51	6.03*	3.90	3.00	3.68	3.69
Ca (%)	1.03	1.01	1.15	0.38	0.74	0.80	1.58	0.84*
Mg (%)	0.45	0.42	0.36	0.32	0.32	0.38*	0.80	0.49*
Na (%)	0.05	0.03 *	0.04	0.05	0.06	0.13**	0.06	0.05
Fe (ppm)	88	91.75	84	123.00@	79.00	82.33	69	76
Mn (ppm)	61.67	62.75	17.33	24.67*	18	21.67	31.67	44.33
Zn (ppm)	62.33	53.50	36	39	67.33	58.33	102	80
Cu (ppm)	9	9	8.67	12.00	10	9.33	19	12
Bo (ppm)	37.67	40.50	40.67	31.33**	39.00	38.33	43.67	34
Soil Health Indicators								
Enchytraeid worm[z]	3	33	7	0	0	0	0	157 **
Nematodes[z]								
Bacterivores	153	320	123	780	127	127	1813	1470
Fungivores	163	300	30	360	23	133@	23	50
Herbivores	20	0	140	303	267	577	0	0
Omnivores	3	27 **	57	53	0	20	157	127
Predators	0	40 **	0	0	0	0	0	0
richness	8	15 **	8	15	7	10	12	9

Table 1 (Continued)

	Mary Lorenz[a]		Dona Willoughby[b]		Dona Willoughby		Leanne Okamoto[c]	
	CONV	KNF	Org	KNF	Org	KNF	CONV	KNF
Diversity	3.43	5.86	4.05	4.80	3.78	4.00	3.68	2.57
EI	39.39	39.58	92.87	73.70	86.52	74.42	92.05	97.45
SI	12.13	55.70 *	85.92	49.93	78.41	54.36	66.28	82.14
CI	87	82	6.11	28.51	11.89	26.36	0.63	1.57
Soil depth	17.48	22.86**	11.0	17.8**	13.2	17.0*	-	-
Over all did KNF improve plant and soil health?	YES		Plant health: Yes Soil health: No		Plant health: Yes Soil health: NS[y]		Plant health: greener Soil health: slightly, NS	

[z] Numbers in 250 cm^3 soil.

[y] NS=Not significant.

@, *, and ** indicate significant difference between CONV and KNF based on one-way analysis of variance at P < 0.10, 0.05, and 0.010 level, respectively.

Table 2. Weed densities at the end of one cash crop cycle in Korean Natural Farming vs conventional farming using herbicide.

Farming Practices	Leanne Okamoto
Untreated control[z] (no herbicide)	7.30 a
Conventional (with herbicide)	4.20 b
KNF	4.10 b

Table 3 Soil properties and nutrient analysis and fertilization recommendation on soil before and after Korean Natural Farming practice in Mary Lorenz's farm.

	Before soil treatment	Pre-soybean planting		At harvest	
		KNF	Conv	KNF	Conv
pH	6	6	6	6.1	5.6
P (ppm)	31	47	35	34	39
K (ppm)	73	127	57	108	458
Ca (ppm)	375	534	365	901	1053
Mg (ppm)	187	257	163	415	243
Fertilizer recommendation					
46-0-0	0.358	0.358	0.358	455	455
Gypsum	14.3	12.7	14.4	4969	4472
Mg-sulphate	1.72	0.229	1.84	100	200
Cost of fertilizer ($/100 sq ft)					
46-0-0	0.0757	0.0757	0.0757	105	105
Gypsum	2.58	2.28	2.59	1093	984
Mg-sulphate	0.688	0.0918	0.734	40	80

Table 4. Cost comparison between KNF and CONV practices for soybean production at Mary Lorenz's trial.

	Input/ft^2	Labor/ft^2	Total/ft^2
	---------------------	Cost ($/sq ft) -------	-----------------
CONV	$ 0.073	$ 0.094	$ 0.167
KNF (Optional input)	$ 0.044	$ 0.21	$ 0.26
KNF (without optional input)	$ 0.04	$ 0.132	$ 0.17

Table 5. Cost comparison between KNF, CONV and untreated control practices for kabocha production at Leanne Okamoto's farm.

	Total yield (kg)	Year 1 input ($/2000 ft^2)	Estimate Year 2 input ($/2000 ft^2)
KNF	23.15	2,155	400
CONV	31.78	2,320	600
Untreated Control	0.57	1,510	200

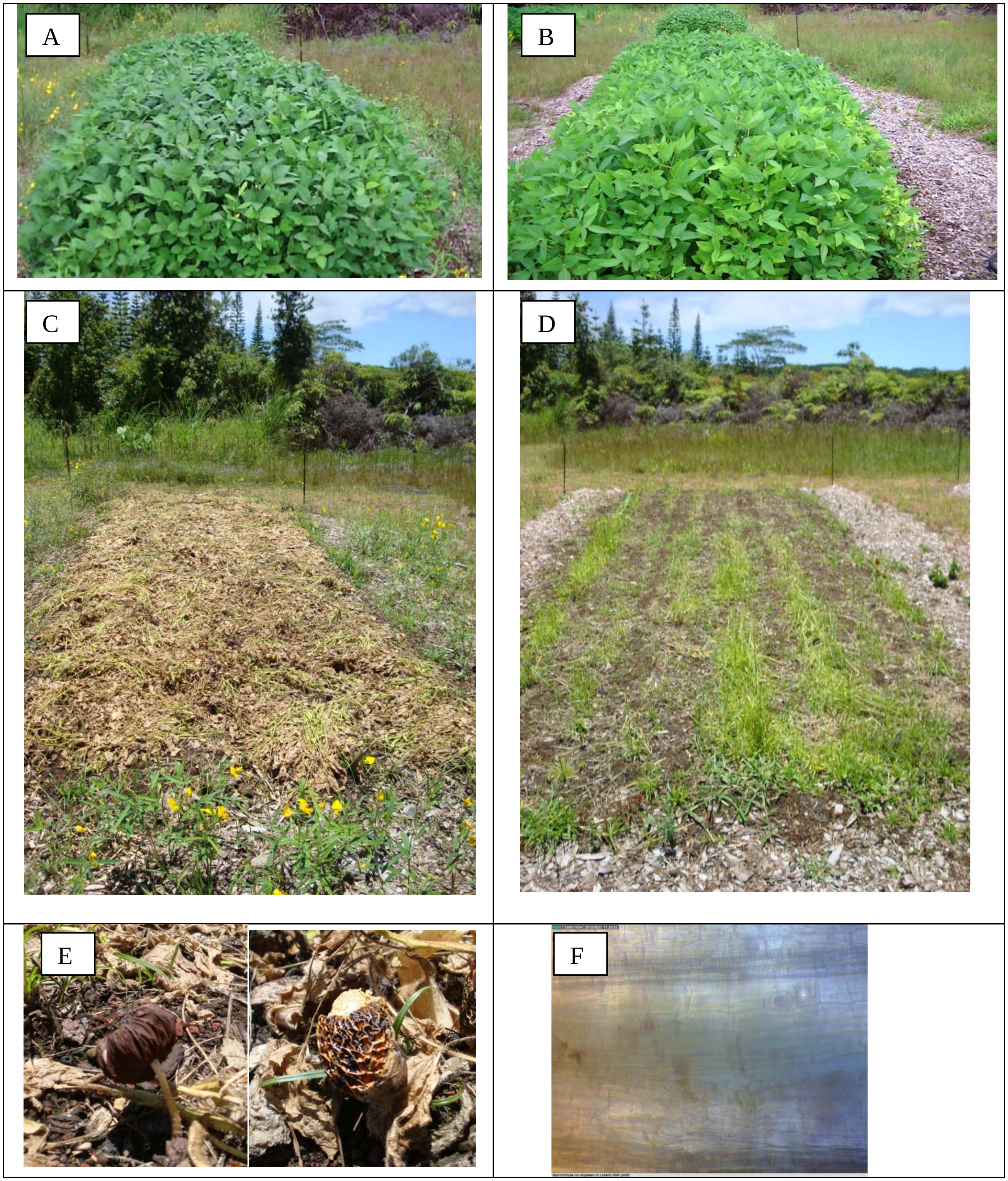

Fig. 1. Experiment at Mary Lorenz's farm: soybean growth in Korean Natural Farming (KNF) practice (A) and conventional (CONV) farming practice; weed densities after soybean harvest in KNF (C) vs CONV using herbicide spray (D). Mushrooms volunteered from KNF plots (E). Vesicles of mycorrhizae on soybean roots (F).

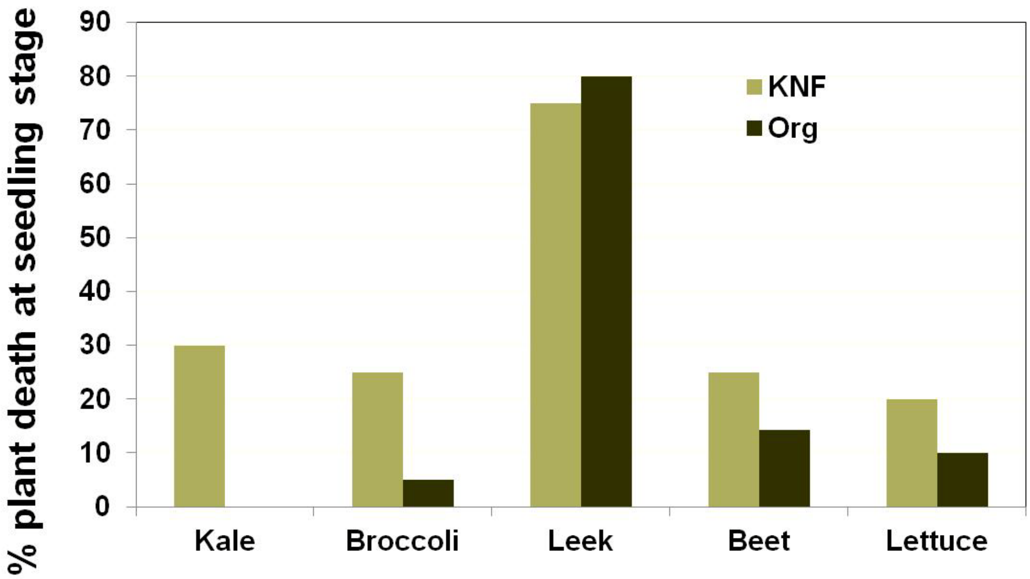

Fig. 2. Seedling death at La'ake Farm Experiment comparing Korean Natural Farming to La'akea organic farming practices.

La'akea Organic

Korean Natural Farming

Fig. 3. Korean Natural Farming trial at Laakea Farm operated by Dona Willoughby. Crop grown from the front to the back of the rows are leek, burdock, beet, and curly kale.

		
KNF	CONV	Untreated Control

Fig. 4. Weed densities at termination of kabocha trial at Leanne Okamoto’s farm.

Pictures showing various stages of the project

		
Making IMO4	Making FPJ and OHN	Making WCA

Fig. 5. PI Wang and a graduate student attended a Natural Farming Inputs workshop on May 11-13 and May 18-20, 2012 to learn about making inputs for KNF.

	
Greenhouse experiment at Magoon Facility	Making IMO4 for Poamoho trial.

Fig. 6. Various research activities of the project.

	
Mary Lorenz, Mike Duponte and Kim Chang at Hawaiian Clean Green Nursery	Sugarcane and taro planted with KNF practice at John Kevelly and Jackie Prell’s farm at Onamea Stream.

Fig. 10. Taking samples from various farms in Big Island that practice KNF.

Statement of work for the next 3-6 months

July, 2012	Initiated a tomato field trial at Poamoho Experiment station comparing KNF vs CONV using SH vs weed mat mulch.
Aug, 2012	Present a power point video for Hawaii Swine Day and Farm Tour, Aupuni Center, Hilo, HI on August 15 -16, 2012.
Sept, 2012	Prepare an extension article on benefits of KNF for crop production.
Oct, 2011	Continue to maintain and collect data on tomato trial at Poamoho. Schedule field day event.
Nov, 2012	Upload outreach materials about KNF for crop production on website.
Dec, 2012	Final report