Final Report

Title: Organic Transition Rotations for Northwestern Washington

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Abstract:

Two three-year rotations are being investigated for suitability for organic transition in northwestern Washington. Cover crop growth was greater and resulted in better weed suppression during 2004-05 than in 2003-04. Common chickweed was the major winter weed species, accounting for 90% of the total weed biomass during the first winter and 75% during the second. Mid-summer weed growth was greater during 2005 and 2006 than 2004. The infrared flamer provided effective postemergence weed control, although spinach and broccoli foliage were damaged. Vinegar and clove oil in shielded applications beside the crop row were less effective than flaming. Broccoli provided the poorest weed suppression in two of three years, followed by spinach/cucumber and potato in 2004 and by potato, spinach, and cucumber in 2005. In 2006, spinach seed was the poorest competitor with weeds, followed by potato and cucumber/broccoli. Mustard cover cropping prior to growing potatoes increased disease severity in 2004, particularly for compost-treated potatoes compared to potatoes receiving fish fertilizer (9.4 and 6.9% severity, respectively). Although scab severity was fairly low in 2004 (<10% regardless of fertilizer type), disease incidence in potatoes following a mustard cover crop averaged about 57%, compared to approximately 45% in potatoes following a rye + buckwheat cover crop.

Objectives:

1. Evaluate two organic transition rotations for suitability to maritime northwestern Washington.
2. Determine the effectiveness of several weed control techniques in organic transition rotational crops.
3. Evaluate the effect of several organic rotational and cover crops, as well as fertilization programs on disease incidence resulting from soil-borne pathogens.

Procedures:

Two three-year rotations are being investigated for suitability for organic transition in northwestern Washington. The two rotations are A: spinach seed, cucumber, and potato, and B: spinach seed, broccoli, and potato, with each crop being grown every year. Cover crop combinations featuring cereal rye, hairy vetch, winter wheat, winter pea, buckwheat, and mustard were seeded in September of 2003 and incorporated in April of 2004. Weed and crop biomass in the cover crop were sampled in November and again just prior to incorporation. Plots

were split and composted chicken manure was applied at 5.4 tons/acre to one split-plot and fish fertilizer (BioGro) applied to the second. Because of non-availability of BioGro in 2006, however, a different formulation of crab meal was used (similar nitrogen content). Total nitrogen applications were the same for both split-plots for a given crop, with 100 lbs N/acre applied to spinach seed and cucumber and 150 lbs N/acre applied to broccoli and potato. In plots to be planted to potato, two sub-plots in each split-plot were inoculated with *Streptomyces* prior to cover crop incorporation.

Rotational crops were seeded/transplanted during April through June of 2004. For each crop split-plot, sub-plots were marked for different weed control programs. Combinations of flaming and applications of vinegar (20% acetic acid) or clove oil (10% rate of commercially available product, Matran 2) were compared to an untreated and hand-weeded check plots. The weed control program was aimed at treating small weeds (< 4 inches tall), and the interval from initial preemergence treatment to the second postemergence treatment averaged 30 days among the four crops. After the three applications of flame, vinegar, and/or clove oil, weed cover and biomass by species as well as crop density and injury were determined. All plots were then kept relatively free of weeds by hand for the remainder of the summer. At harvest, the sub-plots were harvested separately and crop productivity (plant biomass and harvest yield) was determined for each weed control program. For potato, inoculated plots were harvested separately from non-inoculated plots and degree and severity of scab on tubers was visually estimated.

Plots were then tilled and cover crops seeded in September, 2004. Plot identity is being maintained to determine multi-year effects of cover cropping and fertility program as well as identifying which rotational crop was the best choice to begin the three-year rotation. Rotational crops were grown in 2005 and 2006 in a similar way as during 2004. Weed control treatments in the 2005 and 2006 crops were the same as in 2004, except clove oil was applied at 15%, and the duration from initial preemergence application to second postemergence application averaged 36 days among the four crops.

Progress Toward Objectives (first and second year results):

Effects of cover crops on weeds:

Average dry weight among cover crops in April of 2004 averaged 1143 lbs/acre, compared to 2798 lbs/acre in 2005. The greater biomass numbers underscore the improved suppressive ability of these cover crops observed in 2004-05 than in 2003-04. Dry weed biomass in November, 2004 ranged from 241 to 348 lbs/acre among the cover crop mixes and was still only 201 to 548 lbs/acre just prior to incorporation in April, 2005. This contrasts with weed biomass ranges from 388 to 1444 lbs/acre in November, 2003 to 1230 to 2363 lbs/acre in April, 2004. Mustard and winter rye + hairy vetch provided the most weed suppression in 2005, with weeds accounting for about 10 and 7% of the total biomass, respectively. Weed biomass among all cover crop mixes accounted for 62% of total biomass incorporated in April, 2004. The predominant winter weed during 2003-04 was common chickweed (*Stellaria media*), accounting for about 90% of the weed biomass at both measurements. After one cycle of the rotation, however, chickweed was 86% of the biomass in November but only 63% in April, with populations of shepherd's-purse (*Capsella bursa-pastoris*), henbit (*Lamium amplexicaule*), common groundsel (*Senecio vulgaris*), ivyleaf speedwell (*Veronica hederifolia*), and pineappleweed (*Matricaria matricarioides*), and annual grasses (*Lolium multiflorum* and *Poa annua*) making up the remainder. The total dry weight of cover crops and weeds incorporated in

April, 2004 did not differ by cover crop type, although the plants obviously were different as based on what was seeded. Winter rye biomass in April was reduced by some 40% when grown in mixture with hairy vetch both years, compared to rye grown with buckwheat. In addition, the mustard crop suffered extensive winter kill during 2003-04, resulting in mustard biomass being reduced from 1920 to 263 lbs/acre from November to April.

Data from 2005-06 are still being analyzed.

Effects of organic herbicides on weeds:

Spring and summer weed growth was much greater during 2005 and 2006 than during 2004. Mid-season weed heights ranged from 0.4 to 6.1 inches among herbicide treatments in 2004 compared to heights from 3.3 to 18.3 inches in 2005 and 2006. Weed cover and dry weight were similarly affected, with weed dry weight within non-treated check plots measuring 1266 lbs/acre (71% cover) in 2004 compared to 3364 lbs/acre (83% cover) in 2005 and 4929 lbs/acre (79% cover) in 2006. Primary spring and summer weed species were common chickweed, henbit, shepherd's-purse, pale smartweed (*Polygonum lapathifolium*), ladysthumb (*Polygonum persicaria*), and common lambsquarters (*Chenopodium album*).

Flaming prior to crop emergence was helpful for weed control in all crops, although crop damage was particularly evident in spinach, primarily due to variable emergence between replicates and the quickness of emergence of cotyledons (some as soon as one week after seeding). Preemergence flaming gave particularly good results in potato, as weed germination was extensive this year prior to emergence of potato foliage. The infrared flamer provided effective postemergence weed control, although damage to spinach and broccoli was apparent after early postemergence use. Vinegar and clove oil in shielded applications beside the crop row were less effective than flaming. Vinegar caused slight injury to weed foliage, yellowing, but not killing, soft-leaved plants such as pale smartweed, ladysthumb, and common chickweed. Clove oil activity was substantially improved when applied at 15% in 2005 and 2006 than when used at 10% in 2004, but still was not as effective as flaming.

Effects of fertilizer source on weed and crop growth:

Fertilizer type did not greatly affect weed growth in any of the rotational crops during any year. Fertilizer effects on crop productivity have been mixed. Spinach seed yields in both rotations were increased in 2004 and 2005 with fish fertilizer compared to composted chicken manure (increases in 2006 were not statistically significant). Broccoli also seemed to respond better to fish fertilizer, with total yield and average head weight being increased two of three years, but only significantly so in 2005. Conversely, potato tuber yield and cucumber fruit yield and average fruit size was generally higher in plots receiving composted chicken manure, although increases in average tuber weights were not statistically significant. There were no significant fertilizer effects on cover crop or weed biomass during either winter from products applied early in the spring (2004 and 2005).

Rotational crop effects on weeds:

During 2004 and 2005, broccoli provided the poorest suppression of weed growth, with weed height, cover, and biomass being greatest in broccoli in those years. The reverse was true in 2006, with broccoli and cucumber showing substantial weed suppression. Weed control in spinach and cucumber in 2004 was significantly better than in broccoli, with potatoes generally providing the greatest reductions in weed height, cover, and biomass. The general relationship between crops and weeds was a little more complicated during 2005, however. Spinach and cucumber crops averaged slightly shorter and lighter weeds than in potatoes, although weed cover in cucumbers and potatoes was slightly greater than in spinach. In 2006, spinach was the

poorest competitor with weeds, primarily because the spinach crop had to be reseeded due to poor emergence. Weeds in potato were roughly similar in height to weeds in spinach, although cover and weed weight values in potato were midway between spinach and broccoli/cucumber.

Rotation A potatoes were significantly weedier than their Rotation B counterpart in 2005, but not in 2004 or 2006. Weed biomass in spinach A was also greater than in spinach B in 2005, although weed height and cover were greater for spinach B that year.

Incidence and severity of potato scab:

In 2004 severity of scab on potato was fairly low (<10% of entire tuber surface affected regardless of fertilizer type), but scab incidence following mustard cover crop averaged about 57% compared to ~45% following winter rye + buckwheat cover crop. No significant differences in scab incidence occurred between the two fertilizer sources, however. There was a significant cover crop by fertilizer source interaction for scab severity, and potato yield. Mustard cover cropping prior to growing potatoes significantly increased scab severity for chicken manure-treated potatoes (9.4% scab severity) compared to fish fertilizer-treated potatoes (6.9% scab severity). Winter rye + buckwheat cover cropping did not significantly affect scab severity (which was approximately 6% regardless of fertilizer souce). Mustard cropping did not significantly affect yield per potato plant, or total yield which averaged 283.5 cwt/A. With winter rye + buckwheat planted as the cover crop, though, chicken manure-treated potatoes had significantly higher yield per plant and total yield (320 cwt/A) compared to fish fertilizer-treated potatoes (268 cwt/A). Because winter kill of mustard was extreme in 2003-04 (see page 2), it is unclear how much of these observed effects were actually due to mustard. The effects of cover cropping, crop rotation, and fertilizer source on potato scab, and other diseases and defects, like black scurf, silver scurf, wire worm and flea beetle, are still being analyzed for the other two crop years.

Outputs: Plots and preliminary data were featured on the Vegetable Seed (2004 and 2005) and Potato Field Tours (2004) at the WSU Mount Vernon Northwestern Washington Research and Extension Center, as well as during a lunch stop for the National Potato Council annual field tour which was held in northwestern Washington in August, 2004. The flame weeding system we are using for this trial was also featured in an organic pest control video being put together by Oregon State University (Dr. Alex Stone, coordinator) which was previewed at the Pacific Northwest Vegetable Association annual meeting in Pasco, WA in November, 2004. Some of the data were presented at the Western WA Horticultural Association meeting in SeaTac (2006) and at the WA State Master Gardener Training in Seattle (2006).

Impact: It is premature to evaluate impact of this trial on organic transition techniques for the region. When the third year of this study is analyzed completely, we will be able to make recommendations regarding aspects of these two rotations for northwestern Washington.

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Table 1. Cover crop and weed biomass[a] in fall and spring.

Cover crop[b]	Winter rye		Winter wheat		Buckwheat		Mustard		Winter pea		Hairy vetch		Total weed		Total	
	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr	Nov	Apr
	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
2003-04																
Mustard (A)	0.0	0.0	0.0	0.0	0.0	0.0	43.1	5.9	0.0	0.0	0.0	0.0	8.7	43.4	51.8	49.3
Winter rye + hairy vetch (A)	23.6	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.3	28.4	44.8	53.6	66.5
Winter wheat + winter pea (A)	0.0	0.0	5.1	29.5	0.0	0.0	0.0	0.0	4.6	9.1	0.0	0.0	19.1	27.6	28.8	66.1
Winter rye + buckwheat (B)	14.9	39.4	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.3	32.6	36.2	72.0
Winter rye + hairy vetch (B)	16.1	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.3	32.4	53.0	49.0	64.2
Winter wheat + winter pea (B)	0.0	0.0	4.0	27.6	0.0	0.0	0.0	0.0	5.3	9.6	0.0	0.0	24.5	31.6	33.7	68.8
$LSD_{0.05}$	4.0	7.5	1.2	4.7	0.6	ns	2.3	0.6	1.0	2.5	0.4	0.8	7.0	8.2	5.8	7.2
2004-05																
Mustard (A)	0.0	0.0	0.0	0.0	0.0	0.0	32.6	62.6	0.0	0.0	0.0	0.0	5.5	6.8	38.1	69.4
Winter rye + hairy vetch (A)	18.3	32.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	36.1	6.1	4.5	31.4	72.7
Winter wheat + winter pea (A)	0.0	0.0	9.9	34.9	0.0	0.0	0.0	0.0	2.4	10.0	0.0	0.1	7.8	12.3	20.0	57.3
Winter rye + buckwheat (B)	12.1	61.8	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	11.6	18.2	73.4
Winter rye + hairy vetch (B)	15.6	34.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	35.1	5.4	5.8	28.0	74.9
Winter wheat + winter pea (B)	0.0	0.0	12.4	59.4	0.0	0.0	0.0	0.1	2.7	10.6	0.0	0.0	7.4	11.4	22.7	81.3
$LSD_{0.05}$	2.9	15.6	1.4	6.1	0.1	ns	2.7	7.4	0.6	2.5	1.2	5.8	2.2	3.2	4.9	ns

[a]All plants within 0.25 m^2 quadrats were clipped at the soil level, separated by species, dried in ovens, and dry weight determined.

[b]Cover crops seeded in late September of 2003 and 2004; the “mustard” used was a blend of high glucosinolate white and oriental mustards.

Table 2. Effect of organic herbicides on weed growth (summer, 2004).

Treatment[a]	Weed height	Weed cover	Weed dry weight[b]					
			Common chickweed	Henbit	Weedy grasses	Common lambsquarters	Other weeds	All weeds
	cm	%	g	g	g	g	g	g
F F F	3.4 f	10 f	0.7 f	0.5 h	0.01 b	0.03	0.3 ef	1.5 fg
F F V	3.6 f	21 e	1.7 f	0.6 gh	0.05 b	0.11	0.4 ef	2.8 fg
F V F	4.7 e	21 e	4.3 d	1.6 efg	0.04 b	0.01	0.6 def	6.5 d
F V V	7.5 cd	48 c	7.5 bc	2.9 cd	0.10 ab	0.14	1.3 bcde	11.9 c
F C F	5.2 e	21 e	3.9 de	0.8 fgh	0.07 ab	0.03	1.0 cdef	5.8 de
F C V	7.7 c	48 c	7.3 bc	2.3 de	0.14 a	0.14	1.7 bc	11.5 c
F Hand	1.1 g	2 g	0.2 f	0.1 h	0.02 b	0.02	0.1 f	0.4 g
N F F	4.6 e	12 f	1.7 f	0.7 gh	0.03 b	0.04	0.6 cdef	3.1 efg
N F V	4.8 e	21 e	1.9 ef	1.0 fgh	0.07 ab	0.31	0.6 def	3.8 def
N V F	6.9 d	30 d	6.5 c	2.4 de	0.05 b	0.09	0.8 cdef	9.9 c
N V V	11.2 b	58 b	9.6 a	3.8 bc	0.14 a	0.62	1.6 bcd	15.8 b
N C F	8.0 c	31 d	6.5 c	1.8 ef	0.08 ab	0.47	2.2 ab	11.0 c
N C V	11.8 b	59 b	9.2 ab	4.0 b	0.09 ab	0.40	3.1 a	16.7 b
N Hand	1.1 g	2 g	0.7 f	0.3 h	0.02 b	0.00	0.1 f	1.1 fg
Weedy	15.6 a	71 a	10.5 a	6.5 a	0.15 a	0.93	3.2 a	21.3 a
$LSD_{0.05}$	0.7	7	2.0	1.0	0.09	ns	1.1	2.8

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

[b]Dry weight determined by clipping all weeds within a 0.25 m^2 quadrat placed over the crop row at mid season, separating them by species, and oven-drying them.

Table 3. Effect of organic herbicides on weed growth (summer, 2005).

Treatment[a]	Weed height	Weed cover	Weed dry weight[b]					
			Common chickweed	Henbit	Weedy grasses	Common lambsquarters	Other weeds	All weeds
	Cm	%	g	g	g	g	g	g
F F F	18.1 d	34 f	4.1 ef	10.0 abcde	0.38	1.6	4.9 cd	21.1 cd
F F V	18.7 d	36 ef	4.9 de	7.1 cdefg	0.10	2.4	5.9 bcd	20.4 cd
F V F	17.9 d	47 d	7.2 bcd	5.4 defg	0.05	0.8	2.9 d	16.3 d
F V V	18.2 d	47 d	6.3 bcde	4.9 efg	0.24	1.2	4.5 cd	17.2 d
F C F	19.1 d	46 d	6.3 bcde	5.1 defg	0.11	0.7	7.5 bcd	19.6 cd
F C V	18.1 d	44 de	5.5 cde	5.8 defg	0.12	0.7	3.7 d	15.9 d
F Hand	8.4 f	17 g	1.5 f	1.7 g	0.02	1.0	4.8 cd	8.9 d
N F F	29.4 c	62 c	5.1 cde	8.2 bcdef	0.05	1.0	22.8 ab	37.2 bc
N F V	33.3 b	63 c	7.8 bc	9.2 abcdef	0.09	1.8	25.4 a	44.3 ab
N V F	34.0 b	71 b	6.9 bcd	14.0 a	0.13	1.6	21.6 abc	44.1 ab
N V V	32.4 b	77 ab	8.7 ab	13.4 ab	0.12	0.6	17.2 abcd	40.0 ab
N C F	34.0 b	76 ab	7.4 bcd	10.5 abcd	0.05	1.7	21.8 abc	41.4 ab
N C V	36.9 a	76 ab	6.4 bcde	12.3 abc	0.06	1.6	33.8 a	54.1 ab
N Hand	11.9 e	21 g	1.8 f	3.9 fg	0.11	0.8	6.2 bcd	13.1 d
Weedy	37.9 a	83 a	10.7 a	14.2 a	0.11	2.1	29.5 a	56.6 a
$LSD_{0.05}$	1.7	8	2.7	5.5	ns	ns	17.4	17.8

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

[b]Dry weight determined by clipping all weeds within a 0.25 m^2 quadrat placed over the crop row at mid season, separating them by species, and oven-drying them.

Table 4. Effect of organic herbicides on weed growth (summer, 2006, weeds in spinach crop not included in data set).

			Weed dry weight[b]					
Treatment[a]	Weed height	Weed cover	Common chickweed	Henbit	Weedy grasses	Common lambsquarters	Other weeds	All weeds
	cm	%	g	g	g	g	g	g
F F F	33.7 e	44.1 c	0.9	4.8 ef	0.01	6.0	17.3 e	28.9 d
F F V	34.4 e	46.1 c	8.8	8.7 cde	0.01	2.1	23.9 de	43.5 c
F V F	29.4 f	44.8 c	2.6	7.1 def	0.03	2.1	18.4 e	28.6 d
F V V	30.6 f	42.5 c	2.0	5.1 ef	0.01	6.4	16.9 e	27.5 d
F C F	33.6 e	47.9 c	1.9	7.2 def	0.01	5.2	25.0 de	39.5 cd
F C V	34.2 e	47.0 c	1.2	6.7 ef	0.05	2.2	22.6 de	32.8 cd
F Hand	8.7 g	7.0 d	0.4	2.9 ef	0.01	0.5	1.9 f	5.7 e
N F F	40.7 d	76.3 ab	6.0	19.9 ab	0.04	11.3	37.7 bc	75.0 ab
N F V	45.0 ab	78.3 ab	4.5	24.9 a	0.03	9.0	42.7 abc	81.2 a
N V F	40.0 d	71.9 b	5.0	15.7 b	0.03	14.1	37.6 bc	72.2 ab
N V V	43.8 bc	76.1 ab	3.7	13.5 bcd	0.25	15.6	47.3 ab	80.2 a
N C F	42.1 cd	75.4 ab	4.1	13.9 bc	0.01	10.8	32.1 cd	62.1 b
N C V	43.6 bc	75.2 ab	4.7	18.6 ab	0.05	10.5	39.7 bc	72.4 ab
N Hand	9.6 g	9.1 d	0.6	1.3 f	0.01	0.7	5.1 f	7.7 e
Weedy	46.5 a	79.3 a	4.2	16.2 b	0.02	8.0	54.3 a	82.8 a
$LSD_{0.05}$	2.6	6.8	ns	6.5	ns	ns	11.8	13.8

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

[b]Dry weight determined by clipping all weeds within a 0.25 m^2 quadrat placed over the crop row at mid season, separating them by species, and oven-drying them.

Table 5. Effect of fertilizer treatment on weed growth (weeds in spinach crop not included in data set).

Treatment[a]	Weed height	Weed cover	Weed dry weight[b]					
			Common chickweed	Henbit	Weedy grasses	Common lambsquarters	Other weeds	All weeds
	cm	%	g	g	g	g	g	g
2004								
Chicken manure compost	6.7 a	31	4.6	2.0	0.06	0.3 a	1.2	8.2
fish fertilizer	6.4 b	29	5.0	1.9	0.09	0.1 b	1.1	8.1
$LSD_{0.05}$	0.2	ns	ns	ns	ns	0.2	ns	ns
2005								
chicken manure compost	24.9 a	54	5.5 b	10.5	0.08	1.4	14.7	32.3
fish fertilizer	24.2 b	53	6.6 a	6.3	0.15	1.2	13.6	37.8
$LSD_{0.05}$	0.6	ns	1.0	2.0	ns	ns	ns	ns
2006								
chicken manure compost	35.6	54	3.6	12.2	0.04	7.4	32.6	46.3
fish fertilizer	36.6	55	3.1	10.0	0.03	6.5	23.7	52.2
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	4.3	ns

[a]Chicken manure compost at 5.4 tons/acre applied to half of each plot (equivalent to about 100 lbs N/acre). BioGro fish fertilizer applied to the other half of each plot to contribute 100 lbs N/acre for spinach and cucumber and 150 lbs N/acre for potatoes and broccoli. BioGro also applied to the composted half-plots to potatoes and broccoli to provide an additional 50 lbs N/acre (target application of 150 lbs N/acre total).

[b]Dry weight determined by clipping all weeds within a 0.25 m^2 quadrat placed over the crop row at mid season, separating them by species, and oven-drying them.

Table 6. Effect of the crop on weed growth (weeds in spinach crop not included in data set).

Treatment[a]	Weed height	Weed cover	Weed dry weight[b]					
			Common chickweed	Henbit	Weedy grasses	Common lambsquarters	Other weeds	All weeds
	cm	%	g	g	g	g	g	g
2004								
Broccoli (B)	12.0 a	52 a	13.9 a	3.1 a	0.05	0.11	1.3 bc	18.5 a
Cucumber (A)	6.1 b	27 c	1.9 c	3.5 a	0.08	0.57	1.7 b	7.7 b
Potato (A)	4.9 c	14 d	1.8 c	0.6 c	0.01	0.15	0.3 d	2.9 c
Potato (B)	5.2 c	15 d	1.6 c	0.7 c	0.05	0.00	0.3 d	2.6 c
Spinach (A)	5.3 c	35 b	5.3 b	1.9 b	0.13	0.23	0.8 cd	8.4 b
Spinach (B)	6.0 b	38 b	4.5 b	1.5 b	0.13	0.24	2.7 a	9.0 b
$LSD_{0.05}$	0.4	4	1.3	0.7	ns	ns	0.7	1.8
2005								
Broccoli (B)	42.9 a	86 a	17.5 a	16.4 a	0.17	1.8	22.8 b	59.1 a
Cucumber (A)	20.9 c	37 e	0.5 d	2.5 c	0.11	1.4	7.3 c	11.9 c
Potato (A)	26.9 b	38 de	1.6 d	9.1 b	0.01	1.0	43.2 a	54.8 a
Potato (B)	20.0 cd	43 d	3.5 c	1.0 b	0.01	0.1	5.3 c	18.8 bc
Spinach (A)	17.9 e	55 c	8.7 b	10.8 b	0.08	1.0	6.2 c	26.7 b
Spinach (B)	19.0 d	61 b	4.4 c	1.7 c	0.33	2.7	0.1 c	9.3 c
$LSD_{0.05}$	1.1	5	1.7	3.5	ns	ns	11.0	11.3
2006								
Broccoli (B)	24.8 d	47 b	1.5 cd	3.7 b	< 0.01	1.4 c	14.7 d	21.5 c
Cucumber (A)	27.8 c	37 d	< 0.1 d	1.9 b	0.01	7.0 b	14.9 d	23.8 c
Potato (A)	40.0 b	35 d	2.4 bcd	12.8 a	0.17	12.8 a	16.8 d	45.0 b
Potato (B)	40.7 b	42 c	3.3 bc	16.5 a	0.02	5.6 bc	27.3 c	52.7 b
Spinach (A)	41.7 ab	82 a	7.6 a	16.1 a	< 0.01	8.6 ab	43.8 b	76.2 a
Spinach (B)	43.3 a	83 a	5.3 ab	15.8 a	0.01	6.1 b	51.8 a	78.4 a
$LSD_{0.05}$	1.7	4	3.2	4.1	ns	4.6	7.5	8.7

[a]Crop grown as a part of two three-year rotations: Rotation A is spinach , cucumber, and potato; Rotation B is spinach, broccoli, and potato. During 2004, each crop was tested as the first crop to be grown in a given three-year rotation. The second rotational crop was grown in 2005 and the third rotational crop will be grown in 2006.

[b]Dry weight determined by clipping all weeds within a 0.25 m^2 quadrat placed over the crop row at mid season, separating them by species, and oven-drying them.

Table 7. Average crop productivity from several weed control programs.

Treatment[a]	Broccoli avg. head weight			Cucumber avg. fruit weight			Potato A avg. tuber weight			Potato B avg. tuber weight		
	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
	g	g	g	g	g	g	g	g	g	g	g	g
F F F	351	301	379	50	158	51	90	96	102	107	95	106
F F V	415	259	373	66	158	52	95	91	88	105	93	104
F V F	357	312	367	73	149	44	100	92	91	107	84	116
F V V	356	349	332	77	199	59	90	95	105	103	87	114
F C F	354	362	366	71	197	51	110	87	114	98	92	116
F C V	459	333	354	51	170	45	98	89	105	110	96	99
F Hand	439	382	362	71	181	51	102	74	146	110	81	110
N F F	426	297	416	51	151	54	100	77	80	105	98	77
N F V	292	301	326	65	149	50	101	78	76	100	83	66
N V F	330	368	380	65	150	54	107	86	74	106	89	76
N V V	324	357	379	57	155	55	108	79	58	114	92	70
N C F	303	315	355	72	162	43	128	77	68	120	85	68
N C V	346	286	350	67	142	31	107	68	77	109	82	85
N Hand	434	326	345	73	155	64	130	91	108	111	83	76
Weedy	274	291	339	40	176	50	112	70	81	123	80	61
$LSD_{0.05}$	ns	65	ns	22	ns	ns	20	18	ns	27	ns	27

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

Table 8. Broccoli and cucumber yield from several weed control programs.

Treatment[a]	Broccoli Yield			Cucumber yield		
	2004	2005	2006	2004	2005	2006
	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot
F F F	2.26	1.67	2.43	0.62	2.36	0.34 abcd
F F V	2.32	1.56	2.35	0.55	2.92	0.38 abc
F V F	2.07	1.83	2.49	0.81	2.25	0.37 abc
F V V	1.66	2.14	2.39	0.84	2.67	0.27 bcd
F C F	2.15	2.20	2.37	0.95	2.33	0.40 abc
F C V	2.88	1.95	2.30	0.73	2.05	0.34 abcd
F Hand	2.62	2.18	2.42	1.23	1.45	0.51 a
N F F	2.41	1.71	2.70	0.66	2.09	0.43 ab
N F V	1.85	1.60	2.12	0.68	2.48	0.34 abcd
N V F	1.88	2.12	2.48	0.83	1.94	0.35 abcd
N V V	1.81	2.18	2.49	0.64	1.81	0.39 abc
N C F	1.75	1.73	2.34	0.83	1.55	0.24 bcd
N C V	1.79	1.78	2.31	0.73	2.02	0.16 cd
N Hand	2.63	1.94	2.33	1.16	1.57	0.39 abc
Weedy	1.50	1.64	2.27	0.37	1.21	0.14 d
$LSD_{0.05}$	ns	0.43	ns	0.30	0.60	0.23

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

Table 9. Spinach and potato yield from several weed control programs.

Treatment[a]	Spinach A seed yield			Spinach B seed yield			Potato A tuber yield			Potato B tuber yield		
	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
	g/plot	g/plot	g/plot	g/plot	kg/plot	g/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot
F F F	81	73	0.4	65	73	9.2	2.21	1.05	1.34 ab	1.92	1.13	1.37 ab
F F V	70	80	0.3	94	77	5.3	1.97	1.11	1.24 abcd	2.01	1.07	1.44 a
F V F	75	68	1.1	55	61	3.7	1.95	1.26	1.22 abcd	2.07	1.12	1.20 abcd
F V V	69	78	0.8	65	60	12.8	1.78	1.41	1.27 ab	2.11	1.14	1.37 ab
F C F	68	70	0.2	57	66	4.6	2.08	1.04	1.30 ab	2.11	1.03	1.63 a
F C V	58	70	0.1	77	72	2.7	1.88	1.24	1.24 abcd	1.96	1.02	1.24 abc
F Hand	72	89	0.5	84	74	8.2	1.71	0.98	1.25 abc	1.87	1.05	1.24 abc
N F F	65	88	0.1	85	80	7.3	2.07	0.80	0.87 bcdef	2.12	1.02	0.63 e
N F V	83	77	< 0.1	84	80	9.5	2.01	0.74	0.92 abcde	1.89	0.91	0.74 cde
N V F	72	83	0.2	79	70	4.2	2.37	0.60	0.76 def	2.09	0.93	0.64 e
N V V	72	74	0.1	65	77	0.8	2.32	0.83	0.43 f	1.90	0.98	0.86 bcde
N C F	93	85	0.2	79	78	10.6	2.31	0.67	0.61 ef	2.33	0.84	0.78 cde
N C V	94	73	0.3	66	62	8.2	2.13	0.54	0.89 abcdef	2.24	0.96	1.12 abcde
N Hand	102	84	0.4	87	81	10.3	2.18	0.90	1.36 a	2.19	0.87	1.23 abc
Weedy	71	52	< 0.1	44	49	13.2	2.01	0.68	0.78 cdef	2.24	0.80	0.68 de
$LSD_{0.05}$	ns	ns	ns	29	ns	ns	ns	0.28	0.48	ns	0.24	0.52

[a]First letter is PRE treatment (in row), second is EPOST treatment (beside row), and third is LPOST treatment (beside row); F= flame; V = vinegar (20% acetic acid); C = clove oil (10% in 2004, 15% in 2005); N = no PRE flame treatment; Hand = hand weeding; Weedy = no treatments.

Table 10. Average crop productivity from different fertilizers.

Treatment[a]	Broccoli avg. head weight			Cucumber avg. fruit weight			Potato A avg. tuber weight			Potato B avg. tuber weight		
	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
	g	g	g	g	g	g	g	g	g	g	g	g
Chicken manure compost	338	288 b	368	69 a	170 a	50	104	86	88	108	93	89
fish fertilizer	390	357 a	355	58 b	157 b	51	106	81	95	109	83	91
$LSD_{0.05}$	ns	24	ns	8	19	ns	ns	ns	ns	ns	ns	ns

[a]Chicken manure compost at 5.4 tons/acre applied to half of each plot (equivalent to about 100 lbs N/acre). BioGro fish fertilizer applied to the other half of each plot to contribute 100 lbs N/acre for spinach and cucumber and 150 lbs N/acre for potatoes and broccoli. BioGro also applied to the composted half-plots to potatoes and broccoli to provide an additional 50 lbs N/acre (target application of 150 lbs N/acre total).

Table 11. Broccoli and cucumber yield from different fertilizers.

Treatment[a]	Broccoli yield			Cucumber yield		
	2004	2005	2006	2004	2005	2006
	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot
chicken manure compost	1.94	1.68 b	2.45	0.753	2.51 a	0.350
fish fertilizer	2.27	2.09 a	2.32	0.796	1.58 b	0.320
$LSD_{0.05}$	ns	0.16	ns	ns	0.22	ns

[a]Chicken manure compost at 5.4 tons/acre applied to half of each plot (equivalent to about 100 lbs N/acre). BioGro fish fertilizer applied to the other half of each plot to contribute 100 lbs N/acre for spinach and cucumber and 150 lbs N/acre for potatoes and broccoli. BioGro also applied to the composted half-plots to potatoes and broccoli to provide an additional 50 lbs N/acre (target application of 150 lbs N/acre total).

Table 12. Spinach seed and potato yield from different fertilizers.

Treatment[a]	Spinach A seed yield			Spinach B seed yield			Potato A tuber yield			Potato B tuber yield		
	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
	g/plot	g/plot	g/plot	kg/plot	g/plot	g/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot	kg/plot
chicken manure compost	74 b	68 b	0.2	49 b	63 b	0.8 b	2.07	0.97 a	1.00	2.14	1.05 a	1.11
fish fertilizer	78 a	84 a	0.4	96 a	78 a	13.7 a	2.06	0.88 b	1.06	2.00	0.93 b	1.05
$LSD_{0.05}$	14	10	ns	11	10	6.0	ns	0.10	ns	ns	0.09	ns

[a]Chicken manure compost at 5.4 tons/acre applied to half of each plot (equivalent to about 100 lbs N/acre). BioGro fish fertilizer applied to the other half of each plot to contribute 100 lbs N/acre for spinach and cucumber and 150 lbs N/acre for potatoes and broccoli. BioGro also applied to the composted half-plots to potatoes and broccoli to provide an additional 50 lbs N/acre (target application of 150 lbs N/acre total).