ABSTRACT

Danielle Dion Treadwell. Tillage and cover crop management influence weeds, insects, soil and crop nutrients, crop development and yield in organically managed North Carolina sweetpotato *Ipomoea batatas* (L.) Lam. systems. (Under the direction of Nancy G. Creamer)

In 2004, North Carolina supplied 46% of the nations' sweetpotato and generated 79 million dollars for the state but of the 16,000 ha in production that year; only 405 ha were managed according to federal organic standards. A three-year field experiment was initiated in 2001 to evaluate organic sweetpotato 'Beauregard' production systems that varied in cover crop management and tillage. Three organic systems including 1) compost and no cover crop with tillage (Org-NC), 2) compost and cover crop incorporated prior to transplanting (Org-CI), and 3) compost and cover crop with reduced tillage (Org-RT) were compared to a conventionally managed tilled and chemical control (Conv) production system using a randomized complete block design with six replications. All sweetpotato tissue macro and micronutrient concentrations were within sufficiency ranges defined by North Carolina Department of Agriculture & Consumer Services. Sweetpotato N (4.6%), P (0.5%), and K (4.3%) tissue concentrations were greater in Org-CI compared to remaining systems at 60 DAP in 2004. Monocot and dicot weed density and biomass were similar between Org-NC and Org-CI each year, and with few exceptions were similar to Conv. In Org-RT, high monocot weed density limited sweetpotato vine above ground biomass (154 g m^{-2}) and total yield 11.2 Mg ha^{-1}) in 2002. In 2001, the percentage of No. 1 grade roots was at least 19% greater in Org-CI (65 %) and Org-NC (62 %) than Conv (50 %). In 2002, the percentage of

No. 1 roots was similar among Org-CI (74 %), Org-NC (71 %) and Conv (67 %) and similar among systems in 2004. Root quality was assessed based on degree of insect damage by wireworm-*Diabrotica*-*Systena* (WDS) complex. In 2001, Org-RT had the highest percentage of marketable roots (68 %) compared to remaining systems (19-43 %). The number of marketable roots was similar among systems in 2001 and 2004, but reduced in Org-RT (1.3 Mg ha^{-1}) compared to remaining systems. Means of wireworm (*Melanotus* and *Conoderus* spp.) densities per trap were significantly correlated with degree of root damage. Overall, organic systems performed as well as the conventionally managed system in at least one or more areas.

Tillage and cover crop management influence weeds, insects, soil and crop nutrients, crop development and yield in organically managed North Carolina sweetpotato *Ipomoea batatas* (L.) Lam. systems.

by

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DEDICATION

To my family for their faith,

my friends for their laughter,

and my colleagues for opening so many doors,

but most especially to my husband, Tim

and son, Forest, whose love

have made my dreams come true.

BIOGRAPHY

Danielle Dion Treadwell was born in 1965 in Silver Spring, Maryland. She attended Cocoa Beach High School in Cocoa Beach, Florida, and graduated from Dobyns-Bennett High School in Kingsport, Tennessee. She graduated from Clemson University in Clemson, S.C. in 1989 with a BA in fine art. After a six-year career in management, she began a second undergraduate degree in Biology at the University of North Carolina at Asheville in 1996. In 1997 she relocated to Raleigh with her husband, and after continuing her post baccalaureate studies of biology at North Carolina State University, was admitted as a master's candidate in the Department of Horticultural Science in 1998. Danielle received her MS degree in December 2000 under the direction of Nancy G. Creamer, investigating living mulches for weed suppression. Following completion of the Doctoral degree, she will begin her faculty career in the Department of Horticultural Science at the University of Florida in Gainesville, where she will be an extension specialist of organic and sustainable vegetable production.

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Additional Index Words. Hairy vetch (*Vicia villosa* Roth), rye (*Secale cereale* L.) 'Wrens Abruzzi', *Ipomoea batatas* (L.) Lam. 'Beauregard', organic production, soil N, tissue N

Abstract. Organic soil amendments such as compost and cover crops are integral components in organic vegetable production systems. A three-year field experiment was initiated in 2001 to evaluate different organic sweetpotato production systems that varied in cover crop management and tillage. Three organic systems including 1) compost and no cover crop with tillage (Org-NC), 2) compost and cover crop incorporated prior to transplanting (Org-CI), and 3) compost and cover crop with reduced tillage (Org-RT) were compared to a conventionally managed tilled and chemical control (Conv) production system using a randomized complete block design with six replications. Except for a reduction in yield in Org-RT in 2002, total yield and yield of No.1 roots was similar among systems each year. The percentage of No. 1 grade roots was at least 19% greater in Org-CI and Org-NC than Conv in 2001, and similar to Conv in 2002 and 2004. Over the course of the experiment, soil base saturation ranged from 76-85.5% and was greater in organically managed systems than Conv each year. In general, soil inorganic N reserves peaked at 30 DAP and declined accordingly with crop growth and development. At 30 days after planting (DAP) in 2002, soil inorganic N reserves were 90 kg ha^{-1} in Org-CI and 67 kg ha^{-1} in Org-NC and were greater than Org-RT (45 kg ha^{-1}) and Conv (55 kg ha^{-1}). No differences in soil inorganic N reserves were observed among systems in 2004. Differences in soil nutrient concentrations

were not consistently reflected in sweetpotato tissue nutrient uptake. Sweetpotato N, P, and K tissue concentration were different among systems only at the 60 DAP sample date in 2004. On occasion, at 60 DAP, Ca was lower in 2002, and N and K greater in 2001 and 2004 than sufficiency ranges defined by North Carolina Department of Agriculture and Consumer Services (NCDA & CS) recommendations. No other tissue macronutrient or micronutrient concentrations were limiting during this experiment. In 2001 and 2004, total sweetpotato yield and yield of No. 1 roots were similar among all systems. In 2002, total yield and yield of No. 1 roots were at least 45% lower in Org-RT than other systems. These results demonstrate organically managed systems receiving compost with or without incorporated hairy vetch and rye can produce yields equal to the conventionally managed system.

In 2004, North Carolina supplied 46% of the nations' sweetpotato market and generated 79 million dollars for the state (NCDA & CS, 2005). Although there were over 16,000 ha of sweetpotatoes in production that year, only 405 ha were managed according to federal organic standards (K. Hardison, 2005, personal communication). The USDA ERS (2003) reports that organic foods are now sold in 73% of all conventional food markets, and in those markets, organic fresh market produce sales approached 94 million in the 12-month period prior to June 2001. Despite the demand for organic produce, no production recommendations exist for organic fresh market sweetpotato from Southeastern land grant universities.

The cultivar 'Beauregard' is the predominant variety grown in the United States including North Carolina (Schultheis et al., 1999). Optimum N requirements for 'Beauregard' range from 28 to 56 kg N ha^{-1} applied two to four weeks after planting (Phillips et al., 2005; Schultheis et al., 1999). Nutrients are supplied with high analysis fertilizers and although the actual amount supplied depends on preseason soil test results, producers in North Carolina typically apply 56 kg N, 112-168 kg K, 112 kg P, as well as 0.6 kg B ha^{-1} for control of a nutrient disorder called blister. The number of days until canopy development and root initiation varies among sweetpotato cultivars (La Bonte et al., 1999; Schultheis et al., 1999). The leaf canopy of 'Beauregard' is typically fully developed around 60 DAP (Seem et al., 2003); while root initiation is thought to occur around 28 DAP (Jett and Talbot, 1998).

Sweetpotato management requires multiple tillage operations. Common primary tillage includes plowing, disking and field conditioning. Post plant cultivation is also common for control of weeds. Common rotational crops include tobacco (*Nicotiana tabacum*

L.), cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], and mixed vegetables (Toth et al., 1997). The extensive tillage and high number of vehicle passes required to manage sweetpotato as well as its associated rotational crops can lead to loss of organic matter, decline of soil structure, and soil loss due to wind and water erosion.

Organic soil amendments such as compost and cover crops are integral components in organic management systems. Compost is applied primarily to improve soil physical properties but also to supply nutrients (Gagnon et al., 1998) and suppress disease (Stone et al., 2003; Zhang et al., 1998). The addition of compost can increase soil organic C and N (Jackson et al., 2004) and consequentially reduce N losses due to leaching. Mature composts with a C:N ratio of 8-14:1 have an N availability that ranges from 0-50% in the first season; however, composts with a C:N ratio greater than 20:1 may require six to ten weeks before N is mineralized and available for plant uptake (O'Keefe et al., 1986; Baldwin and Greenfield, 2005).

Similarly, winter annual cover crops such as hairy vetch and rye reduce nitrate leaching and carbon losses (Drinkwater et al., 1998; Jackson et al., 2004; Rannells and Wagger, 1997), improve nutrient use efficiency (Delgado, 1998; Staver and Brinsfield, 1998), increase soil microbial biomass (Jackson et al., 2004; Mendes et al., 1999), increase water retention (Liebl et al., 1992; Teasdale and Mohler, 1993) and decrease soil bulk density (Jackson et al., 2004). Increasing soil organic matter with cover crop incorporation can occur with repeated applications, although in most soils the increase in measurable organic matter is slight (Stinner et al., 1983). In areas of the NC coastal plain where percent soil organic matter is very low, an increase in soil organic matter is possible with repeated incorporations of cover crop biomass over time. However, in the southeastern U.S, the objective of increasing organic matter is secondary to replacing fertilizer-N with legume-N (Rannells and Wagger, 1997).

Hairy vetch and rye are cover crop species that establish easily, overwinter successfully, produce sufficient biomass, and are easily killed in the spring by mechanical methods (Creamer et al., 1997). Crop N recovery from winter annual cover crop mixtures depends on inherent soil N, residue quality and quantity of component cover species, tillage, climate and soil characteristics. For optimum N availability to the subsequent crop, a C:N ratio of 20:1 to 30:1 at the time of kill is desired (Creamer et al., 1997; Rannells and Wagger, 1997). In the coastal plain of N.C., rye and hairy vetch are seeded in approximately a 2:1 ratio. Actual C:N ratios of hairy vetch and rye mixtures in this range of seeding rates are typically less than 30:1 (Rannells and Wagger, 1997); thus, crops following incorporation of a similar winter annual hairy vetch and rye mixture would most likely experience minimal N stress associated with N immobilization. When cover crop incorporation takes place prior to planting, subsequent crops benefit by the slow release of nutrients (Wilson and Hargrove, 1986). If allowed to remain on the surface, mixtures have slower surface decomposition than legumes alone (Creamer et al., 1997), and can provide significant suppression of weeds for the following crop (Creamer et al., 1996; Teasdale and Mohler, 1993).

Recent reports on reduced tillage vegetable systems indicate the benefits of surface mulch are best realized when the duration of the crop season is long (Hoyt, 1999). 'Beauregard' sweetpotato has a 90-110 day growing season and a moderately low fertility requirement and therefore is a suitable candidate for cover crop inclusion. In a Louisiana study of cover crop use in a conventional sweetpotato 'Beauregard' system, Jett and Talbot (1998) found that when incorporated, rye and ryegrass significantly reduced soil erosion and increased yields of sweetpotato. In a subsequent study, sweetpotatoes growing in undisturbed rye residue had a significantly greater leaf area, vine weight, root set, and yield relative to conventional tilled sweetpotatoes (Jett, 1999). The researchers hypothesized that the cover crop residue favorably modified the soil environment by eliminating early restriction to root set often caused by high soil temperatures (Jett, 1999).

Although several studies have been performed in the southeast to determine the influence of nutrient source and or rate on sweetpotato root yield under conventional management (Hammett et al., 1984; Mascianica et al., 1985; Nicholaides et al., 1985; Phillips et al., 2005; Purcell et al., 1982), no such data have been collected for organic systems. In order to assess the adequacy of nutrient supply by compost and cover crops in organic systems compared to conventional fertilizer, and to examine the influence of cover crop management on sweetpotato nutrient uptake and productivity, a three year field experiment was designed to test three organically managed systems with and without cover crops and tillage compared to a conventionally managed tilled and chemical control.

Materials and Methods

Experiments were conducted in 2001, 2002 and 2004 at the Center for Environmental Farming Systems (CEFS), Goldsboro, N.C. In all three years, the soil was a Wickham loamy sand (Fine-loamy, mixed, semiactive, thermic Typic Hapludults). This series is a representative soil of the central coastal plain in North Carolina, and is a typical soil texture of sweetpotato production areas. This soil is sedimentary in origin, acidic, low in nutrient holding capacity, and subject to occasional flooding. The experimental site in 2002 received

3922 kg ha^{-1} dolomitic lime applied the previous January, and the 2001 and 2004 sites each received 2240 kg of lime ha^{-1} in accordance with NCDA soil test recommendations one and two years prior to sweetpotato planting, respectively. In 2001, the site was previously mowed perennial pasture of ryegrass (*Lolium perenne* L.) and received no fertilizer or pesticide inputs for 20 years prior to this experiment. In 2002 and 2004, previous crops were managed conventionally with chemicals and tillage and included field corn (*Zea mays* L.)(2002) and sorghum sudangrass [*Sorghum bicolor* (L.) Moench x *S. sudanense* (Piper) Staph.] (2004). Organic production practices were followed in 2001 according to guidelines published by an independent certifying agency (Carolina Farm Stewardship Association, 1997) and the U.S. Federal standards established by the National Organic Program (USDA, AMS, 2002) in 2002 and 2004. Although the 2001 site was eligible for certification, the conventionally managed chemical control in this experiment precluded that effort. In addition, the previous crops in 2002 and 2004 were produced using synthetic inputs, therefore, over the course of this experiment, sweetpotato could not be certified organic.

The experimental design was a randomized complete block with six replications. Three organic systems including 1) compost and no cover crop with tillage (Org-NC), 2) compost and cover crop incorporated prior to transplanting (Org-CI), and 3) compost and cover crop with reduced tillage (Org-RT) were compared to a conventionally managed system that included tillage and chemical controls (Conv) to determine soil nutrients, nutrient acquisition and growth of sweetpotato foliage, and sweetpotato yield. In order to mimic conditions typical of sweetpotato farms in North Carolina, large plot sizes were used to allow ample space for full sized farm equipment. Management decisions such as equipment selections, timing of weed removal and method of cover crop planting and termination were made that would optimize the production of each system. Because site conditions varied among years in soil type, pest populations, field history, and climate, some variation of methods was necessary. Plots were 24.4 m long and composed of 12 rows on 1 m centers in 2001 and 2002, and .96 m centers in 2004. A minimum of 9.1 m (2001, 2002) and 6.1 m (2004) buffer separated replications. The area surrounding each replication was planted in ryegrass in early spring and maintained by mowing throughout the season. The total experimental area excluding buffers was approximately one hectare.

Sweetpotato management. All three organically managed treatments received compost composed of materials approved for use in organic production by the Organic Materials Review Institute (OMRI, 2005). In May 2001, the entire experimental area was plowed with a three bottom moldboard plow, but no plowing occurred in 2002 or 2004. Compost was applied at a rate of 20 Mg ha^{-1} in May of 2001 and November 2002 and 2004 (Table 1.1). Prior to application and according to North Carolina Department of Consumer Services (NCDA & CS) availability coefficients, it was estimated that 47 kg N ha^{-1} would potentially be available to the sweetpotato crop during the 2001 growing season, and 49 kg ha^{-1} in 2002 and 2004. Boron was applied to all treatments at a rate of 0.6 kg ha^{-1} [Solubor ($Na_2 \cdot B_8 \cdot O_{13} \cdot 4H_2O$) U.S. Borax Inc. Valencia headquarters, CA.] prior to planting. All other nutrients were considered adequate according to soil test results from NCDA & CS, except for the standard recommended 56 kg ha^{-1} N application rate for 'Beauregard'. Commercially grown 'Beauregard' mericlone G2 B94-14[1] cuttings were planted using a 0.27 m in row spacing on 2 July 2001, 13 June 2002 and 29 June 2004 in all treatment plots. Within two weeks of planting, sweetpotato cuttings were replanted by hand as necessary to ensure an

[1] G2 represents plants that are the second generation produced outside a virus-free greenhouse environment. B94-14 represents a Beauregard cultivar mericlone.

equal stand among treatments. Prior to harvest, sweetpotato foliage was mowed with a rotary mower (Bush Hog, L.L.C., Selma, Ala.), and soil and roots were turned with a mechanical two row digger (KMC, Tifton, Ga.).

Treatment management.

Organic, no cover crop. Plots were cultivated with a tandem disc harrow to eliminate weeds in late November. In May, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Cuttings were planted with a two row transplanter (RJ Equipment, Blenheim, Ontario). Following sweetpotato planting, seasonal weed control varied among years and included mechanical cultivation by rolling cultivator, mowing or by hand.

Organic, cover crop incorporated. In November of all three years, a cover crop mixture of 45 kg ha^{-1} hairy vetch and 67 kg ha^{-1} rye 'Wrens Abruzzi' was seeded with a grain drill on a disked flat soil surface. Cover crops were flail mowed when hairy vetch was in mid bloom (Creamer et al., 1995) and rye was in anthesis on 23 May 2001, 3 May 2002, and 3 June 2004. Cover crops were incorporated in 2001 with a moldboard plow followed by a tandem disc harrow, a tandem disc harrow in 2002 and an articulating spading machine (Celli S.p.A., Forli, Italy) in 2004. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Plots were disked twice in 2001 and 2004 and once in 2002 prior to sweetpotato planting to ensure adequate distribution and decomposition of cover crop. Cuttings were planted with the same transplanter as in the organic, no cover treatment.

Organic, reduced tillage. In November preceding the cropping season of all three years, hairy vetch and rye cover crop mixture was seeded at the same rates as the organically managed cover incorporated system on hills formed with a ripper-bedder. In 2000, cover crops were hand seeded with a broadcast seeder spreader (PlantMates Inc., Gallatin, Texas). In 2000, the germination rate of vetch was poor on the crest of the hills compared to the furrows presumably due to the inability of the round seeded vetch to remain in place. Therefore, in 2001, hand seeding was followed by seed incorporation with a seeder cultipacker with notched rollers (Brillion Iron Works, Brillion, Wis.). In 2003, the cultipacker was used to seed and incorporate the cover crop. In May 2002 and June 2004, the hairy vetch and rye mixture was killed by rolling the cultipacker over the beds. Sweetpotato cuttings were transplanted with the same transplanter as other treatments in 2001. In 2002 and 2004, cuttings were transplanted with subsurface tiller-transplanter (SST-T) (B&B No-Till, Laurel Fork, Va.) (Morse et al., 1993). This transplanter cut through surface residue with a double disk coulter, loosened soil in the plant bed with a subsurface winged knife, opened a furrow, and placed water below the sweetpotato slip, placed the slip in the row, and closed the furrow with weighted press wheels.

Conventional. Plots were cultivated with a tandem disc harrow to eliminate weeds in late November. In May, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Recommended cultural and pest management practices for sweetpotato ‘Beauregard’ were followed throughout the season (Schultheis et al., 1999; Toth et al., 1996; Wilson et al., 1989). Plots were fumigated with (1,3-dichloropropene) at 84.5 L ha^{-1} primarily for nematode control two weeks prior to planting. EPTC (S-ethyl dipropylthiocarbamate) was applied at 2.2 kg ha^{-1} for control of annual weeds mixed with chlorpyrifos [O,O-diethyl-O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate] at 2.2 kg ha^{-1} for control of soil dwelling insects [wireworm (*Melanotus* and *Conoderus* spp.) one week prior to planting in 2001 and two weeks prior to planting in 2002 and 2004. In addition, napropramide [N,N-diethyl-2-(1-napthalenyloxy-proprionamide] at 1.1 kg ha^{-1} was applied one day after planting for weed control of dicot weeds. Ammonium nitrate (NH_4NO_3) at 68 kg ha^{-1} was surface banded and incorporated in the row 28 days after planting each year. Cuttings were planted with the same transplanter as in the organic, no cover treatment.

Data collection

Stand. To minimize variation of mechanical practices as well as the effects of pesticide drift, we collected data in the center 8 rows and 18.3 m of each plot. Stand counts were performed on each plot 2-3 days after planting by counting all plants in each of the eight data rows. Missing plants were replaced by hand, and a second stand count was performed after replanted plants were established to ensure consistent stand among treatments.

Cover crop biomass and N. Above ground biomass was removed from one randomly placed 0.5-m^2 frame per plot one day prior to cover crop kill all three years in Org-CI and Org-RT treatments. The cover crop mixture was separated by species, oven dried at 60 °C for 48 h, weighed, ground and analyzed for total (inorganic plus organic) N and C on a Perkin-Elmer 2400 CHN elemental analyzer (Norwalk, Conn.). Additionally, cover crop residue remaining in organic reduced tillage plots was collected at sweetpotato harvest, oven dried at 65 °C and weighed. Soil was removed from the residue by sifting.

Soil sampling. In the fall prior to cover crop planting, a total of 24 soil cores from each replication were collected using a manually operated 1.9 cm (inner radius) soil probe to a depth of 20 cm, combined and mixed in the field and submitted to NCDA for nutrient composition and corresponding fertilizer recommendations for fertility. Each year, results among replications were similar, and therefore each replication received similar amendment rates appropriate to each treatment. In 2002 and 2004, soil samples were also taken at crop establishment (7 DAP), 30 and 60 DAP and at sweetpotato harvest from a 2-cm (inner radius) soil probe to a 20.3 cm depth. Fertilizer nitrogen in the conventionally managed system was applied immediately following the 30 DAP sample each year. Samples were collected around the main stem of randomly selected sweetpotato plants in a radial area 2.5 cm away from the main stem to a distance of 13 cm. Twelve cores were composited from each plot, mixed in the field, and plant material was removed and separated into subsamples for soil nitrogen and soil nutrient analysis. Soil samples reserved for inorganic N determination were frozen at $< 5^{o}$C until processed. Soils were then air dried in the greenhouse, ground to pass through a 16-mm mesh screen, and extracted with 1*M* KCl. Extracts were analyzed for NH_4- and NO_3-N using a micro Kjeldahl procedure (Keeney and Nelson, 1986) using injection flow analysis (Lachat Instruments, Milwaukee, Wis.). The sum of NH_4- and NO_3-N is presented as total inorganic N. Samples for soil nutrient analysis were submitted to the NCDA & CS soil analysis lab for determination. Nutrients were extracted on a volume basis using a Mehlich-3 buffer (Mehlich, 1984). Additionally, six soil cores per plot were collected by the same method every one to two weeks for soil moisture. Gravimetric moisture content was determined using soil oven dried at 105° C for 24 h, and recorded as percent moisture on a dry weight basis.

Sweetpotato leaf tissue nutrients. At 30 and 60 DAP each year, and at sweetpotato harvest in 2004, 24 most recently mature sweetpotato leaves with petioles attached were randomly collected from each plot. Tissue was submitted for nutrient analysis to the NCDA & CS plant analysis laboratory.

Sweetpotato vine biomass. To quantify differences in the rate of foliar growth among treatments, three sweetpotato plants per plot were cut at the soil surface approximately 30, 45, and 60 DAP. Plants were oven dried at 65 °C, and dry weights recorded. Due to the extensive destructive nature of sampling for this experiment, a stratified random sampling pattern was used. A virtual grid of nine cells was established prior to planting, and one plant was removed from each of eight cells, and two plants from the remaining cell. Cells and locations within the cells were selected at random.

Yield. Sweetpotato roots were collected from a 6.1 m long section in the center of each of two adjacent rows approximately 100 days after planting. Roots were sorted by size according to USDA market grade standards (USDA, 1981), and counted and weighed for each market grade group in the field. Root quality assessments based on degree of insect damage were addressed in a subsequent paper; therefore, for the purpose of this paper, reported yields represent potential rather than marketable yield.

Statistical analysis. All data were subjected to analysis of variance using PROC GLM (SAS V.8.2, 2001) to test the main effect of management systems. Management and year were treated as fixed effects and blocks and appropriate error terms as random effects. For sweetpotato tissue nutrients and biomass, sampling dates were equally spaced and correlations between time points were assumed identical. Soil moisture data represent point in time estimates only and therefore each sample date is independent. For these data, date was considered a sub-plot factor and year as a whole plot factor in analysis of variance. When significant year by treatment interactions existed, data were analyzed and are presented by year. Mean comparisons among management systems were generated using Fisher's protected $_{LSD}$ at P = 0.05. Cover crop, weed and sweetpotato vine biomass were square root transformed to satisfy assumptions of normality and homogeneity of variances prior to analysis. Statistical conclusions were derived from transformed data, and back transformed means derived from transformed data are reported.

Results and Discussion

Weather. The average monthly precipitation from June through October 2001 measured 47 cm and was 21% less than the 30-year average for Goldsboro (Table 1.2). Precipitation was not evenly distributed, and heavy rains in May and June combined with cool temperatures contributed to slow water infiltration and evapotranspiration. As a result, standing water remained in the furrows between beds for most of the season. Temperatures were 1.9 °C lower on average throughout the season, and in particular, July was 3.2 °C lower than normal. In 2002, seasonal average monthly precipitation was 37% lower than the 30-year average. In addition, although monthly average temperatures in 2002 were approximately normal, the temperatures surrounding sweetpotato planting exceeded 37 °C for several days. Therefore, supplemental irrigation (3.2 cm) was supplied once immediately following hand replanting in all treatments in 2002. In 2004, average monthly temperature and precipitation were relatively normal throughout the season.

Compost N availability. Compost was analyzed for nutrient concentration and other characteristics prior to application each year (Table 1.3). Actual plant available nitrogen from organic sources is difficult to predict due to the effects of climate and soil characteristics on microbial activity. Additionally, N losses can occur after the material is added to the soil by leaching, denitrification and NH_3 volatilization.

Plant available nitrogen (PAN) was estimated by multiplying the total organic and inorganic N by an availability coefficient based on compost characteristics including the carbon to nitrogen (C:N) ratio and timing and method of application. For mature composts with a C:N ratio of < 14:1 and fall incorporated prior to a summer crop, mineralization during the cropping season is generally estimated at 25% of the total cover crop N under normal climactic conditions in our area (K. Baldwin, 2005, personal communication). For these same conditions, anticipated mineralization rates are reduced to < 5% if the C:N ratio is > 20.

Due to the spring application in 2001 (Table 1.1), compost was incorporated in Org-NC and Org-CI, and broadcast in Org-RT plots. Therefore, nitrogen availability could be delayed until approximately 4-6 weeks after planting in Org-NC and Org-CI systems, and longer in Org-RT. In 2001 and 2002, the C:N ratios were greater than 23:1, therefore we estimated approximately 5% of total N, or 8 kg N ha^{-1} (2001) and 5 kg N ha^{-1} (2002) would be available to sweetpotato during the season. In 2004, PAN was estimated at 27 kg N ha^{-1} using an availability coefficient of 25% due to the low C:N ratio and fall application. Reliable methods of predicting plant available phosphorus and potassium from compost have not been established.

Cover crop biomass and N availability. Each year, cover crop biomass was similar to or greater than what is typical for eastern N.C. (Rannells and Wagger, 1997) (Table 1.4). Cover crop biomass and total N content was higher in 2001 than subsequent years while biomass in 2002 was greater than in 2004 (Table 1.4).

Like compost, mineralization rates of cover crop N depend on many environmental factors, but some thresholds for N mineralization/immobilization have been suggested. For cover crops, if C:N ratios are between 25-30:1 or if N concentration is less than 16.6 g N kg^{-1} (Wagger, 1989; Rannells and Wagger, 1997), N mineralization will be reduced or delayed. In North Carolina, Rannells and Wagger (1997) predicted N release from surface residue of a desiccated cover crop mixture of hairy vetch planted to 22 kg ha^{-1} and rye planted to 56 kg ha^{-1}. Based on initial N content that ranged from 82-200 kg N ha^{-1} and C:N ratios of 14-21:1, cumulative N release was 55-58% of initial N at four weeks after kill, and 75-80% of initial N release eight weeks after kill.

In this experiment, cover crop C:N ratios were near the theoretical threshold at which mineralization occurs (Table 1.4). In 2004, although the C:N ratio was 28:1, the N concentration was 16.4 g kg^{-1}, so some immediate mineralization following incorporation was likely (Rannells and Wagger, 1997). Cover crops were killed eight weeks before planting in 2001, and approximately six weeks before planting in 2002 and 2004 (Table 1.1). Approximately 50% of total N was estimated to be available in Org-CI systems ten weeks after cover crop incorporation, which correlates to the first two weeks after sweetpotato planting in 2001 (75 kg N ha^{-1}), and to the first four weeks after sweetpotato planting in 2002 and 2004 (57 and 51 kg N ha^{-1}; respectively). Anticipated mineralization rates were reduced to 40% for Org-RT due to crop residue remaining on the surface (93, 71, and 64 kg N ha^{-1} for 2001, 2002 and 2004; respectively). Based on the initial N content of the cover crop (Table 1.4), these estimates of PAN indicate sufficient nitrogen would be available for sweetpotato during the period of peak N demands.

Soil moisture. Because sampling dates were different each year in terms of crop development, data were analyzed by year in PROC GLM (SAS V8). To test for the main effect of date, date was treated as a fixed effect, and management nested in date was used to test for date by management interactions. In 2001 and 2002, a significant sampling date by management system interaction was detected ($P<0.01$) but only a management main effect was significant in 2004 ($P<0.0001$; data not shown). For consistency, soil moisture data was analyzed by year and date. Soil moisture differences among management systems occurred sporadically throughout the experiment (Table 1.5). The Wickam soil series has an available water capacity that ranges from 11-15 % to a depth of 36 cm (USDA SCS, 1974). Soil moisture levels in 2001 and 2004 generally were within or exceeded this range, while soil moisture was limiting in the first half of the growing season in 2002. In 2001, soil moisture in Org-CI was greater than Org-RT on three occasions and greater than Org-NC on two. Abundant biomass incorporated prior to planting (Table 1.4) may have facilitated soil moisture retention in Org-CI. In 2002, the conventionally managed system had less moisture than organic systems receiving cover crops, and 61% less moisture than Org-RT in particular at 35 DAP (Table 1.5). Six days later, soil moisture levels reached a seasonal low, ranging from 4.2-5.8%. In 2004, when analyzed by date, soil moisture was different among systems only once, with Org-RT having the highest soil moisture at 31 DAP. Statistical differences were noted for only one third of the sampling dates. However, soil moisture means in organically managed treatments receiving cover crops trended higher than remaining treatments during the dry conditions in 2002.

Soil nitrogen. Soil N was influenced by year, which interacted with date and management (Table 1.6). Therefore, data were analyzed and are presented by year and sample date (Fig. 1). Finally, contrast statements averaging over sample dates and year were used to compare management (Conv vs. all three organic systems), cover crops (Org-NC vs. both organically managed with cover crops), and tillage (Org-CI vs. Org-RT)(Table 1.6).

In 2002, dry conditions punctuated by irregular precipitation influenced soil N reserves and contributed to differences among management systems. Org-CI and Org-NC had an increase in soil N compared to Org-RT early in the season (Fig.1). At 7 DAP, soil N was greatest in Org-CI, intermediate in Org-NC and Conv, and lowest in Org-RT. At 30 DAP, soil N in the Org-CI system was considerably greater than remaining systems. We observed the cover crop in Org-CI did not decompose as rapidly following incorporation as it did in other years due in part to dry soil conditions. Precipitation prior to the 30 DAP sampling date may have facilitated decomposition of the cover crop in Org-CI and consequent rapid mineralization of soil N. The addition of compost in Org-NC provided additional N over the conventionally managed system following the first week of planting. Significant plant N demands concurrent with the 60 DAP sampling date most likely contributed to the decline in soil N at 60 DAP in all systems. By harvest (100 DAP), only slight differences among systems were observed. In 2004, soil N was similar among systems at each planting date. Favorable environmental conditions moderated mineralization of organic N resulting in soil N levels that were consistent with the conventionally managed system.

Nitrogen management is important to optimize yields of sweetpotato. N deficiencies early in the season may delay foliar development thus delaying root carbohydrate acquisition (Villagarcia et al., 1998), while excess N is subject to leaching and can reduce yield (Hammett et al., 1984; Marti and Mills, 2002). Nitrogen demands vary greatly among cultivars, and yield response to fertilizer-N uptake is closely associated with climactic factors, making prediction difficult (Mascianica et al., 1985; Phillips et al., 2005). In a Virginia field trial to identify optimum fertilizer-N rate and timing of application for 'Beauregard' sweetpotato, Phillips et al. (2005) observed that under conditions of normal seasonal precipitation (390 mm from June-Sept.), only 28 kg ha^{-1} of fertilizer-N was necessary for optimum yields. When precipitation was above average, additional fertilizer N was necessary and the optimum rate increased to 58 kg N ha^{-1}. Greatest yields were observed when fertilizer-N was applied two to three weeks after planting compared to N supplied prior to planting or four to five weeks after planting. These observations suggest the N requirement for 'Beauregard' is less than current recommendations, and that N demand may occur earlier in the season than previously thought.

Soil nutrients, pH and base saturation. Management by year interactions influenced soil P, K, Ca and Mg concentrations, pH and base saturation (Table 1.7). Therefore, data were averaged over sampling dates, and analyzed by year (Table 1.7). These same soil parameters were also influenced by a significant date by year interaction; therefore, data were also analyzed by year and date. However, no consistent trends were evident and differences were most likely the result of a complex of environmental and management factors (data not shown).

In general, soil nutrient concentration was greater in organically managed systems compared to the conventional system due in part to nutrients supplied via compost and cover crops. Soil P was greater in organic systems than the conventional system in 2001 and 2004.

In 2002, a dry year, means of soil P were greater in all systems compared to 2001 and 2004 (Table 1.7). Inadequate soil moisture may have reduced P uptake by sweetpotato, resulting in higher soil P reserves.

Yield response in sweetpotato has been associated with K uptake for some cultivars. Mascianica et al. (1985) evaluated ‘Centennial’ and ‘Painter’ sweetpotato to obtain sweetpotato leaf tissue and soil N concentrations to predict yield response to N fertilization. They modeled soil NO_3-N sampled at a depth of 15 cm to relative yield at 29 DAP and reported a minimum of 74 kg ha^{-1} was required by those cultivars for adequate N nutrition. ‘Centennial’ had a positive yield response to N rates as high as 112 kg ha^{-1} but only when ample K was provided (up to 112 kg ha^{-1})(Marti and Mills, 2002). Similar observations were made by Marti and Mills (2001) and Purcell et al. (1982) who reported a yield increase with an increase in K rate for ‘Centennial’, but not ‘Jewel’. The importance of fertilizer-K on N uptake and yield in ‘Beauregard’ has not been fully explored. In this experiment, soil K was consistently greatest in Org-CI and lowest in the conventionally managed system. Over the course of the growing season, Org-CI had 126, 86 and 73 kg ha^{-1} more soil K than Conv in 2001, 2002 and 2004 respectively (Table 1.7). As discussed previously, soil N was greater in Org-CI than Conv at several sample dates in 2002, however the increase in soil N and K in Org-CI did not translate into an increase in sweetpotato N or K uptake at 30 DAP (Table 1.8) or yield (Table 1.10) compared to Conv in 2002.

In 2001, soil Ca and Mg means in all systems were higher than other years and may reflect inherent soil fertility associated with the site due to previous management as pasture (Table 1.7). Soil Ca was greater in organically managed systems each year, while soil Mg was greater in organically managed systems in 2001 only. Base saturation, the percentage of the cation exchange capacity occupied by K, Ca and Mg followed trends similar to pH in 2002, with some variations in 2001 and 2004. Compost with and without cover crops improved base saturation, since cation retention in organically managed systems exceeded the conventionally managed system each year.

A pH of 5.6 to 6.8 is a typical range for crops in southeastern soils. With the exception of a reduction in pH in Conv in 2004, pH ranged from 5.5 to 6.2 over the course of this experiment (Table 1.7). The addition of organic amendments contributed to an increase in pH compared to the conventionally managed system all three years. The pH in Org-NC was higher than other systems in 2001 and higher in Org-NC and Org-RT in 2002 and 2004.

Tissue Nutrients. All nutrients were influenced by a date by year interaction except P, which varied by year and date main effects (Table 1.8). Additionally, nutrients were influenced by a management by year interaction or a management main effect. For consistency, all nutrients were analyzed by year and date (Tables 1.8 and 1.9). Sweetpotato nutrient sufficiency ranges have not been formally established for 'Beauregard', therefore, sufficiency ranges used in this report were general recommendations for sweetpotato provided by NCDA & CS (S. Casteel, personal communication).

Differences in soil nutrient concentration among management systems within a specific year were generally not reflected in differences in sweetpotato tissue nutrient concentrations. Concentrations of leaf tissue N, P and K were different among management systems only in 2004, and only at the 60 DAP sampling date (Table 1.9). In low input systems, organic soil amendments have resulted in a decline of N concentration in plant tissue (Drinkwater et al., 1995; Scow et al., 1994), however in this experiment N concentrations in organically managed sweetpotato tissue were equal to the conventional system in 2001 and 2002 and on one occasion, greater than the conventional system in 2004 (Table 1.9). In 2001, nitrogen concentrations exceeded the N sufficiency range defined by NCDA (3.2-4.0 %) and were ranked "high" or in "excess" according to NCDA guidelines. In 2002 and 2004, N concentrations were within sufficiency ranges for all systems, and were similar to those observed for 'Jewel by Nicholaides et al. (1985) and Hammett (1984).

Despite differences in soil P among systems (Table 1.7), phosphorus uptake was similar among all systems in 2001 (Tables 1.8 and 1.9). In 2002, a reduction in P uptake by plants in Org-RT at 30 DAP may be due to a reduction in P availability from cover crop surface residue. Dry conditions most likely reduced soil microbial activity and consequent P availability in the soil. In 2004, P concentration in sweetpotato tissue was greatest in Org-CI compared to other systems.

Potassium concentrations were within sufficiency ranges (2.5-3.5%) in all systems each year. In 2004, K concentrations were again greatest in Org-CI compared to remaining systems, and lowest in Org-NC and Conv. Nicholaides et al (1985) observed an increase in K uptake by 'Jewel and Centennial' sweetpotato tissue with an increase in fertilizer-K application. The authors reported optimum yields for those cultivars were correlated with midseason leaf K concentrations that ranged between 38.1 - 42.9 g kg^{-1} or (3.8-4.3%). Midseason (60 DAP) tissue K concentrations in this experiment were less than 3% in 2002, providing some indication of reduced yields overall that year. Although soil Ca and Mg concentrations were considerably high in 2001, sweetpotato tissue Ca and Mg concentrations were generally sufficient, if not low. Differences among systems were observed only in 2002. An increase in Ca and Mg in sweetpotato tissue was observed for Org-RT at 30 DAP, and may be related to an increase in soil moisture in that system (Table 1.5). Concurrently, a decrease in tissue P was observed. Phosphorus can be limiting in southeastern soils due to low concentration of organic matter and low pH. During dry periods, soil P uptake is limited by reduced water movement through the soil profile.

Sweetpotato leaf tissue was also tested for micronutrients. In 2001, Fe concentration was high to excessive in leaf tissue in all treatments, but no differences among treatments was observed (data not shown). All other micronutrients tested (Fe, Mn, Zn, Cu, B, S, Na) were within sufficiency ranges (data not shown). Although there were occasional differences among systems, differences were of little biological consequence and therefore are not presented here.

Sweetpotato vine biomass. Sweetpotato vine biomass sampled at 30, 45 and 60 DAP was influenced by a management by year interaction (data not shown), therefore data were analyzed and are presented by year (Fig. 2). In 2001, vine growth was similar among treatments at 30 and 45 DAP, but by 60 DAP, foliar biomass was greatest in the Org-NC and lowest in Org-RT. The decline in dry weight of plants in Org-RT from 45 to 60 DAP in 2001 can be attributed to significant weed interference. In 2002, the conventionally managed system established faster and produced more foliar biomass at 30 DAP than organically managed systems. However, by 45 DAP and continuing through 60 DAP, foliar growth in Org-CI and Org-NC were similar to Conv. Growth in the Org-RT system was lower than other systems at each sampling date in 2002. In 2004, vine growth was considerably greater in all systems than previous years. As in 2002, foliar growth was reduced in Org-RT following planting, but by 45 DAP, vine weight was similar in all systems.

Previous work indicated ‘Beauregard’ foliage has maximum vine weight at approximately 60 DAP (Jett, 1998; Seem, 2003). Results from some systems in 2001 support previous observations, since foliar dry weight for the Org-CI and Conv systems increased only 11% and 4% respectively from 45 to 60 DAP. However, averaged over all systems, foliar dry weight increased from 45 to 60 DAP by 54.4% and 69.2% in 2002 and 2004 respectively; therefore, it is possible that a significant increase in foliar dry weight may have occurred beyond 60 DAP. The differences in foliar dry weight among systems are a partial explanation for differences in soil nutrient concentrations within each year. The frequent increase in soil P, K and Ca concentrations in Org-RT systems compared to Conv most likely reflects the reduction in foliar biomass production in Org-RT.

In 2002, complications related to the interaction of environmental and mechanical factors including the transplanting method, high temperatures and reduced soil moisture at planting contributed to delayed sweetpotato establishment in Org-RT and subsequent growth (Fig. 2). We replaced approximately 23% of sweetpotato plants by hand in the organically managed reduced tillage system but only 2 to 5% in the remaining systems. Although slips were irrigated with 2.5 cm of water 24 hours after planting, subsequent plant establishment in Org-RT was slower than other systems. In 2004, the subsurface winged knife in the SST-T was omitted, and rate of establishment, vine biomass and yield were comparable to other systems. Other researchers have observed delayed establishment and reduced foliar biomass in reduced tillage systems. In a trial to measure soil physical properties and potato yield with a summer cover crop of sorghum sudangrass (*Sorghum bicolor* (L.) Moench x *S. sudanense* (Piper) Staph.) in potato (*Solanum tuberosum* L.), Mundy et al. (2000) observed delayed establishment and reduced plant size in no-till treatments compared to conventionally managed bare soil treatments. The authors attributed these differences to increased bulk density as well as disturbance to the plant row due to mechanical complications at planting in no-till treatments.

Yield and stand. Stand counts were analyzed with SAS GLM, and following hand replanting, stand counts were found to be similar among all treatments each year (Data not shown). Although planting date varied each year, total duration of growth was similar among years. In 2001 and 2002, roots were harvested 106 days after planting, and in 2004, due to sufficient root expansion, roots were harvested 95 days after planting.

Average yields for No. 1 sweetpotato roots in North Carolina were 14,600, 17,400 and 17,900 kg ha^{-1} in 2001, 2002, and 2004, respectively (NCDA & CS, 2004). In 2001, yields of No. 1 roots were at least 54% lower than the state average (Table 1.10). Yields in 2002 and 2004 were similar to or exceeded the state average yields overall.

With the exception of Org-RT in 2002, yields of No. 1 roots were similar among systems. In 2002, lack of soil moisture during a critical period of root expansion most likely contributed to delayed canopy development and low yields in all systems compared to other years. The reduction in yield in Org-RT in 2002 can be related to slow rate of establishment of sweetpotato transplants as well as weed interference. In an associated study, high weed biomass in Org-RT in 2002 was negatively correlated with a decline in vine biomass at harvest (Treadwell et al., submitted). In 2004, no differences in yield among systems were observed, and yields were greater than previous years of the experiment.

Summary. Research on organic production systems can benefit both organic and conventional growers. For growers interested in transitioning to organic production, the inclusion of a conventionally managed tilled and chemical control is important because it provides conventional growers with a benchmark similar to their own systems for comparison. However, it is difficult to obtain results on the influence of organic management on crop response variables that are truly reflective of established organic systems when field experiments are located on land historically managed conventionally, or at best, are certified transitional. Benefits of improved nutrient cycling associated with the addition of organic matter are only fully realized in the long term, when residual effects on soil microbial activity and soil fertility become apparent (Beraud et al., 2005; Gunapala and Scow, 1998; Wander and Traina, 1997).

Since the goal of selecting a winter cover for weed suppression may lead to a different species than one for nutrient supply or erosion control, growers should identify primary objectives prior to selecting a cover crop. In this experiment, winter cover crop selection was intended to serve equally as a weed suppressive mulch in the reduced tillage system, and as a source of slow release nitrogen for sweetpotato in both the cover incorporated and reduced tillage systems. The hairy vetch and rye cover crop mixture was an appropriate mixture for sweetpotato in terms of N contribution and dry matter production. However, rye 'Wrens Abruzzi' reached heights in excess of 1.8 m each year and was difficult to incorporate in Org-CI. An earlier maturing variety with reduced stature such as 'Wheeler' may facilitate mechanical operations and provide more chemical compound for weed suppression (Reberg-Horton et al, 2005). The application of fall applied compost with or without the incorporation of hairy vetch and rye cover crop prior to planting produced results similar to the conventionally managed system each year, indicating that organically amended sweetpotato performed as well as conventionally managed sweetpotato under the conditions of this experiment.

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CHAPTER 2. Cover Crop Management Influences Weed Density, Biomass and Yield in Organically Managed Sweetpotato Systems

Additional Index Words. Hairy vetch (*Vicia villosa* Roth), rye (*Secale cereale* L.) 'Wrens Abruzzi', *Ipomoea batatas* (L.) Lam. 'Beauregard', production, tillage, mulch

Abstract. Cover crops in organic management systems can provide a source of slow release nitrogen, improve soil texture and water holding capacity, and suppress weeds. A three-year field experiment was initiated in 2001 to evaluate different organic sweetpotato production systems that varied in cover crop management and tillage. Three organic systems including 1) compost and no cover crop with tillage (Org-NC), 2) compost and cover crop incorporated prior to transplanting (Org-CI), and 3) compost and cover crop with reduced tillage (Org-RT) were compared to a conventionally managed tilled and chemical control (Conv) production system using a randomized complete block design with six replications. Monocot and dicot weed density and biomass were similar between Org-NC and Org-CI each year, and with few exceptions were similar to the conventionally managed production system. Org-RT was as effective in controlling dicot weed density and biomass as Org-NC each year, but did not suppress monocot weeds. Sweetpotato vine biomass was positively correlated with total yield and reflected the increase in monocot weed biomass in Org-RT at sweetpotato harvest. Total sweetpotato yield was similar among all treatments in 2001 and 2004, but was at least 45% lower in Org-RT than other treatments in 2002. Reduced yield in Org-RT in 2002 was most likely due to an increase in monocot weed density and biomass resulting in a decrease in sweetpotato vine biomass. These results demonstrate organically managed treatments with or

without an incorporated cover crop prior to planting can effectively suppress weeds and result in yields that are similar to conventionally managed sweetpotato.

North Carolina has produced the majority of the nation's sweetpotatoes since 1971 (USDA ERS, 2003). In 2004, North Carolina supplied 46% of the nations' market and generated 79 million dollars U.S. for the state's economy (NCDA & CS, 2005). Although there were over 16,000 ha in production that year (NCDA &CS, 2005), only 405 ha were managed according to federal organic standards (K. Hardison, 2004, personal communication). Since the early 1990's, the U.S. organic industry has grown over 20% a year (Dimitri and Greene, 2002). The USDA ERS reports that organic foods are now sold in 73% of all traditional food markets, and in those markets, organic fresh market produce sales approached U.S. 94 million dollars in the 12-month period preceding June 2001 (Dimitri and Greene, 2003). According to a 1999 survey of 27 retailers and 3 wholesalers who sold organic produce in North Carolina, annual sales from organic produce may have exceeded $U.S. 5,000,000 (retail value) in 1998 (Estes et al., 1999). Although that figure includes produce from all sources, surveyors expressed a desire to purchase an additional 408,000 kg of produce that could come from North Carolina growers, including sweetpotato. Currently, around 85% of organic sweetpotatoes sold in North Carolina come from California (T. Kleese, 1999, personal communication), yet NC is first in the nation in sweetpotato production. Despite the demand for organic produce, few production recommendations exist for organic fresh market vegetables from land grant universities.

Growers implementing best management practices for sweetpotato in North Carolina typically employ multiple tillage events including subsoiling, discing, field leveling, hilling, and cultivation. Due to heavy pest infestations typical of the warm and humid seasonal climate of southeastern NC, pest control is largely preventative rather than curative and includes soil fumigation prior to planting and multiple applications of preplant and postemergent herbicides and insecticides. According to a 1996 survey of North Carolina sweetpotato growers, 70% of respondents reported they used herbicides and 97% used cultivation to manage weeds (Toth et al., 1997). Preplant and preemergence herbicides registered for use in sweetpotato (glyphosate, EPTC, clomazone, DCPA, and napropamide) provide some control of grasses and broadleaf weeds. Currently, only four postemergence herbicides (glyphosate in row middles, clethodim, fluazifop, and sethoxydim) are registered for sweetpotato, and control is limited to annual grasses. Growers who utilize cultivation to control weeds report an average of 3.2 cultivations per season. Because cultivation becomes impractical once vines extend across the beds, and registered preplant herbicides may not provide seasonal protection against broadleaf weeds, growers frequently rely on mowing and hand removal to obtain adequate weed control.

The cultivar ‘Beauregard’ is the predominant variety grown in North Carolina as well as in the United States (Schultheis et al., 1999). ‘Beauregard’ is desirable because it yields a greater percentage of storage roots per plant than other commercial cultivars such as ‘Jewel’ or ‘Centennial’ (Rolston et al., 1987); however, rate of canopy closure is slow relative to previously grown cultivars and therefore ‘Beauregard’ is a poor competitor with weeds (La Bonte et al., 1999). Despite this potential disadvantage in organic systems, ‘Beauregard’ was selected for this experiment because it is the predominant cultivar used in sweetpotato production.

Farming practices influence soil physical and biological properties as well as pest diversity and abundance. In organic systems, the incorporation of organic matter via compost and cover crops has been shown to have a direct positive effect on weed management. An increase in species diversity and decrease in weed density has been observed in organic compared to conventional systems (Liebman and Davis, 2000; Van Elsen, 2000). These effects have been attributed to a variety of mechanisms. Cover crop residues that remain on the surface can inhibit weed seed germination due to a reduction of light penetration to the soil surface (Teasdale and Mohler, 1993) as well as physical interference (Creamer et al., 1996; Hutchinson and McGiffen, 2000). Chemical interference of weed germination has been demonstrated for a number of cover crop species including rye (Creamer et al., 1996; Reburg-Horton et al., 2005), members of the Cruciferae family (Blum et al., 1997) and crimson clover (Creamer et al., 1996). Organic amendments including compost and incorporated legumes have been associated with weed suppression due to a delay in nitrogen availability to weeds (Leibman and Ohno, 1998; Shipley and Keddy, 1988). Systems employing organic amendments also are associated with an increase in microbial activity (Fraser et al., 1988; Drinkwater et al., 1995) and subsequent predation on weed seeds and seedlings (Kremer and Souissi, 2001; Li and Kremer, 2000).

Researchers have recently begun to examine reduced tillage systems for vegetable production. For many weed species, emergence and subsequent density and biomass are reduced in the presence of crop residues (Facelli and Pickett, 1991). The success of weed suppression in these systems depends on the physical properties of the mulch (Mohler and Teasdale, 1993; Teasdale and Mohler, 2000), duration of the crop and method of planting (Hoyt, 1999), as well as site specific factors including the soil microclimate and the naturally occurring weed population.

In the NC mountains, organically managed cabbage was strip-tilled into a cover crop of crimson clover (Hoyt and Walgenbach, 1995). Although weed biomass at harvest was greater than conventional strip-tilled cabbage, the percent of marketable heads was similar. In a Louisiana study of cover crop use in a conventional sweetpotato ‘Beauregard’ system, Jett and Talbot (1998) found that when incorporated, rye and ryegrass significantly reduced soil erosion and increased yields of sweetpotato. In a similar study, sweetpotatoes growing in undisturbed rye residue had a significantly greater leaf area, vine weight, root set, and yield relative to conventional tilled sweetpotatoes (Jett, 1999). The researchers hypothesized that the cover crop residue favorably modified the soil environment by eliminating early restriction to root set often caused by high soil temperatures (Jett, 1999). Leguminous covers may provide too much nitrogen and cause excessive root growth, so choice of species should be limited to those with moderate nitrogen contributions (Jett, 1999). Mixtures of grass and legume species could be used to prolong the rate of release of nitrogen from the cover crops (Creamer et al., 1997; Ranells and Wagger, 1997).

There are few published reports on the effects of cover crops on sweetpotato. Because herbicides currently registered for postemergence use in sweetpotato are not effective on broadleaf weeds, growers implementing conventional production practices in N.C. must supplement chemical controls with cultural strategies. In addition, organic growers have a need for additional research on weed control methods in organic systems (Walz, 1999). Growers implementing conventional and organic sweetpotato systems will benefit from research on the effects of cover crops on weeds. Therefore, this experiment was designed to measure sweetpotato yield and the effectiveness of weed control in three organically managed systems with and without cover crops and tillage compared to a conventionally managed tilled and chemical control.

Materials and Methods

Experiments were conducted in 2001, 2002 and 2004 at the Center for Environmental Farming Systems (CEFS), Goldsboro, NC. In all three years, the soil was a Wickham loamy sand (Fine-loamy, mixed, thermic Typic Hapludult). This series is a representative soil of the central coastal plain in North Carolina, and is a typical soil texture of sweetpotato production areas. In 2001, the site was previously mowed perennial pasture of ryegrass (*Lolium perenne* L.) and received no fertilizer or pesticide inputs for 20 years. In 2002, the previous crop was chemical conventionally managed field corn (*Zea mays* L.) and in 2004, the site received minimal chemical inputs in the season preceding sweetpotato and the previous crop was sorghum sudangrass [*Sorghum bicolor* (L.) Moench x *S. sudanense* (Piper) Staph.]. Organic production practices were followed in 2001 according to guidelines published by an independent certifying agency (Carolina Farm Stewardship Association, 1997) and the US Federal standards established by the National Organic Program (USDA, AMS, 2002) in 2002 and 2004. Although the 2001 site was eligible for certification, the conventionally managed plots in this experiment precluded that effort. The previous crops in 2002 and 2004 were produced using synthetic inputs, therefore, sweetpotato could not be certified organic.

The experimental design was a randomized complete block with six replications. Three organically managed systems including 1) no cover crop, 2) cover crop incorporated prior to sweetpotato planting, and 3) cover crop reduced tillage were compared to a chemical conventionally managed system to determine the effects of cover crop management on weeds and sweetpotato productivity. In order to mimic conditions typical of sweetpotato farms in our area, large plot sizes were used to allow ample space for full sized farm equipment.

Management decisions such as equipment selections, timing of weed removal and method of cover crop planting and termination were made that would optimize the production of each system. Because site conditions varied among years in weed populations, field history, and climate, some variation of methods was necessary. Plots were 24.4 m long and composed of 12 rows on 1 m centers in 2001 and 2002, and .96 m centers in 2004. A minimum of 9.1 m (2001, 2002) and 6.1 m (2004) buffer separated replications. The area surrounding each replication was planted in ryegrass in early spring and maintained by mowing throughout the season. The total experimental area excluding buffers was approximately one hectare.

Sweetpotato management

All three organically managed treatments received compost composed of materials approved for use in organic production by the Organic Materials Review Institute (OMRI, 2001) at a rate of 20 Mg ha^{-1} in May of 2001 and November 2002 and 2004. In May 2001, prior to compost application, the entire experimental area was plowed with a three bottom moldboard plow, but no plowing occurred in 2002 or 2004. Prior to application and according to North Carolina Department of Consumer Services (S. Casteel, 2005, personal communication) availability coefficients, it was estimated that 45 kg N ha^{-1} would potentially be available to the sweetpotato crop during the growing season. Boron 0.56 kg ha^{-1} [Solubor ($Na_2 \cdot B_8 \cdot O_{13} \cdot 4H_2O$) U.S. Borax Inc. Valencia headquarters, CA.] was applied to all treatments prior to planting. All other nutrients were considered sufficient according to soil test results from NCDA & CS, except for the standard recommended 56 kg ha^{-1} N application rate for 'Beauregard'.

From a management perspective, decreasing row spacing or postponing planting to a delayed date can decrease the amount of time required to close a sweetpotato canopy

(Schultheis et al., 1999; Seem et al., 2003). In a North Carolina study on the effects of 'Beauregard' plant spacing and harvest date on yield, in-row spacing of 15 cm was found to generate the most US No. 1 grade roots when harvested 90 – 110 days after planting (Schultheis et al., 1999). The typical planting guideline for growers in North Carolina is between mid May and mid June (Wilson et al., 1989). Because rapid canopy closure may inhibit weed emergence due to light inhibition, planting later may facilitate vine growth due a concurrent seasonal increase in heat units. Therefore, we selected a late planting date and minimized in row spacing. Commercially grown 'Beauregard' G2 B94-14[2] cuttings (slips) were planted to 0.27 m in-row spacing on 2 July 2001, 13 June 2002 and 29 June 2004 in weed-free plots in all treatments. Within two weeks of planting, sweetpotato slips were replanted by hand (5-10%) as necessary to ensure an equal stand among treatments.

Treatment management.

Organic, no cover crop. Plots were cultivated with a tandem disc harrow to eliminate weeds in late November (Table 2.1). In May, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Slips were planted with a two row transplanter (RJ Equipment, Blenheim, Ontario). Following sweetpotato planting, seasonal weed control was by rolling cultivator until prohibited by sweetpotato vine growth, at which time weeds were removed by mowing or by hand.

Organic, cover crop incorporated. In November preceding the cropping season of all three years, a cover crop mixture of 45 kg ha^{-1} hairy vetch inoculated with *Rhizobium* spp. and 67 kg ha^{-1} rye 'Wrens Abruzzi' was seeded with a grain drill on a disked flat soil surface.

[2] G2 represents plants that are obtained from the second generation of "seed" produced in a virus-free greenhouse environment. B94-14 represents a Beauregard cultivar mericlone.

Cover crops were flail mowed when hairy vetch was in mid bloom (Creamer et al., 1995) on 23 May 2001, 3 May 2002, and 3 June 2004. Cover crops were incorporated in 2001 with a moldboard plow followed by a tandem disc harrow, a tandem disc harrow in 2002 and an articulating spading machine (Celli S.p.A., Forli, Italy) in 2004. Based on analysis and assuming 50% of N was available for plant uptake during the season (Baldwin and Creamer, 2005), N contributions from incorporated cover crop were estimated to be approximately 93, 71, and 64 kg N ha^{-1} in 2001, 2002 and 2004, respectively. Plots were disked twice in 2001 and 2004 and once in 2002 prior to sweetpotato planting to ensure adequate distribution and decomposition of cover crop. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Slips were planted in hills with the same transplanter as in the organic, no cover treatment.

Organic, reduced tillage. In November of all three years, a hairy vetch and rye cover crop mixture was seeded at the same rates as Org-CI on preformed hills. In 2000, cover crops were hand seeded with a broadcast seeder spreader (PlantMates Inc., Gallatin, TX). In 2000, the germination rate of vetch was poor on the crest of the hills compared to the furrows, presumably due to the inability of the round seeded vetch to remain in place. Therefore, in 2001, hand seeding was followed by seed incorporation with a seeder cultipacker with notched rollers (SS-10, Brillion Iron Works, Brillion, Wis.). In 2003, the cultipacker was used to seed and incorporate the cover crop. In May 2001, the hairy vetch and rye mixture was killed with a flail mower. In May 2002 and June 2004, the hairy vetch and rye mixture was killed by rolling using the cultipacker. Plant available nitrogen from cover crop residues that remain on the soil surface is typically less than that of incorporated residue (Baldwin and Creamer, 2005). Therefore, based on analysis, a predicted maximum of 40% of reported nitrogen would potentially be available for plant uptake (75, 57 and 51 kg N ha^{-1} for 2001, 2002 and 2004, respectively). Sweetpotato slips were transplanted with the same transplanter as other treatments in 2001. In 2002 and 2004, slips were transplanted with a subsurface tiller-transplanter (SST-T) (B&B No-Till, Laurel Fork, Va.) (Morse et. al., 1993). This transplanter cut through surface residue with a double disk coulter, opened a furrow, and placed water below the sweetpotato slip, placed the slip in the row, and closed the furrow with weighted press wheels.

Conventional. Recommended cultural and pest management practices for 'Beauregard' sweetpotato were followed throughout the season (Schultheis et. al, 1999; NCSU, 2005; Wilson et al., 1989). Plots were cultivated with a tandem disc harrow to eliminate weeds in late November. In May, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Plots were fumigated with (1,3-dichloropropene) at 84.5 L ha^{-1} primarily for nematode control two weeks prior to planting. EPTC (S-ethyl dipropylthiocarbamate) was applied at 2.2 kg ha^{-1} for control of annual weeds and mixed with chlorpyrifos [O,O-diethyl-O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate] at 2.2 kg ha^{-1} for control of soil dwelling insects [wireworm larvae (*Melanotus* and *Conoderus* spp.)] one week prior to planting in 2001 and two weeks prior to planting in 2002 and 2004. In addition, napropramide [N,N-diethyl-2-(1-napthalenyloxy-proprionamide] at 1.1 kg ha^{-1} was applied to control dicot weeds one day after planting for weed control. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Slips were planted with the same transplanter as in the organic, no cover treatment.

Following sweetpotato planting, seasonal weed control was by rolling cultivator until prohibited by sweetpotato vine growth, at which time weeds were removed by mowing or by hand. Ammonium nitrate (NH_4NO_3) at 68 kg ha^{-1} was surface banded and incorporated 28 days after planting each year. Slips were planted with the same transplanter as in the organic, no cover treatment.

Data collection. To minimize variation of mechanical practices as well as the effects of pesticide drift, we collected data in the center eight rows and 18.3 m of each plot. Due to the extensive destructive nature of sampling for this experiment, a stratified random sampling pattern was used. A virtual grid of twelve cells was established in the sampling area prior to planting, so that each cell consisted of 6.1 m long sections of two adjacent rows, or an area approximately 12.4 m^2. Cells and locations within the cells were selected at random.

Preplant cover crop and weed biomass. Above ground biomass was removed from one randomly placed 0.5-m^2 frame per plot one day prior to cover crop kill all three years. Biomass was separated into rye, vetch, and weed samples prior to oven drying. Cover crop mixture was separated by species, oven dried at 60 °C for 48 h and weighed. The dried samples were analyzed for total N using a micro-Kjeldahl procedure (Keeney and Nelson, 1986) with a Perkin-Elmer (Norwalk, Conn.) model 2400 CHN elemental analyzer.

Weed density and composition. Prior to weed removal events (Table 2.1) and biomass sampling at harvest, two 0.5-m^2 frames were randomly placed perpendicular to the row in each plot, and weeds were identified and counted.

Sweetpotato vine biomass and weed biomass. To determine if foliar growth was different among treatments, and to assess the proportion of weed biomass to sweetpotato foliar biomass, sweetpotato vines and weeds were removed at harvest from the same previously counted areas mentioned above by cutting at the soil surface. Biomass was oven dried at 65 °C, and dry weights recorded separately for sweetpotato, monocot, and dicot weed species.

Cover crop residue. Cover crop residue remaining in organic reduced tillage treatments were collected at harvest, oven dried at 65 °C and weighed. Soil was removed from the residue by sifting.

Yield. Sweetpotato roots were collected from a 6.1 m long previously undisturbed section in the center of each of two adjacent rows approximately 100 days after planting. Roots were sorted by size according to USDA market grade standards and weighed by grade in the field (USDA, 1981). Root quality assessments based on degree of insect damage were addressed in a subsequent paper; therefore, for the purpose of this paper, reported yields represent potential rather than marketable yield.

Statistical analysis. All data were subjected to analysis of variance using PROC GLM (SAS V.8.2, 2001) to test the main effect of management systems. Management and year were treated as fixed effects and blocks and appropriate error terms as random effects. Mean comparisons among management systems were generated using Fisher's protected $_{\mathrm{LSD}}$ at P = 0.05. When significant year by treatment interactions existed, data were analyzed and are presented by year. Weed density, dicot and total weed biomass and sweetpotato vine biomass were square root transformed to satisfy assumptions of normality and homogeneity of variances prior to analysis. For these data, statistical conclusions were derived from transformed data, and back transformed means derived from transformed data are reported here. To describe the relationship between weed biomass and yield as well as cover crop residue and weed density, SAS regression analysis (PROC REG) was used to identify significant relationships among pairs of response variables, and analysis of variance (PROC GLM) was used to test for equality of slopes among management systems. In addition, Pearson product-moment correlation coefficients (PROC CORR PEARSON) were determined for significant paired comparisons.

Results and Discussion

Weather. The average monthly precipitation from June through October 2001 measured 47 cm and was similar to the 30-year average for Goldsboro (60 cm), however precipitation were not evenly distributed. Temperatures were 1.9 °C lower on average throughout the season, and in particular, July was 3.2 °C lower than normal. Heavy rains in May and June combined with cool temperatures contributed to slow water evapotranspiration. As a result, standing water remained in the furrows between beds for most of the season. Conversely, in 2002, seasonal average monthly precipitation was 22 cm lower than normal. In addition, although monthly average temperatures in 2002 were approximately normal, the temperatures surrounding sweetpotato plant establishment exceeded 37 °C for several days. Therefore, supplemental irrigation (3.175 cm) was supplied only once immediately following hand replanting in all treatments in 2002 to ensure the desired plant stand. In 2004, temperature and precipitation (61 cm) were relatively normal and evenly distributed throughout the season.

Cover crop and weed biomass at cover crop kill. Cover crop biomass at cover crop kill was similar between Org-CI and Org-RT treatments each year (Table 2.2). In 2001, the sum of hairy vetch and rye biomass exceeded 13,000 kg ha^{-1} in both treatments; however, biomass was less in subsequent years. By weight, rye comprised 70% on average of the total cover crop biomass (data not shown).

During the winter and until cover crop kill in the early spring, the cover crops were successful competitors as no weeds were collected at sampling in any of the Org-CI or Org-RT plots all three years (Table 2.2). Analysis of variance of weed biomass at cover crop kill included Conv and Org-NC treatments only due to zero values for organically managed treatments in cover crops. Mean separations were applied to all four treatments based on LSD values generated from the comparison of Conv and Org-NC treatments. Similar weed biomass was observed in both Org-NC and Conv treatments in 2002 and 2004.

Weed density. To quantify season long interference, weed density data were summed over data collection dates within treatments and years. Weed control was assumed to be complete following each weed removal event, and that individual weeds were counted only once. Weed species were grouped into monocots and dicots for density and biomass analyses. Cumulative densities of monocot and dicot weed species as well as weed biomass at harvest had significant treatment by year interactions (Table 2.3) and therefore are presented by year (Table 2.4).

Weed density in organically managed treatments varied with cover crop and tillage. In 2001 and 2002, monocot weed densities were greatest in Org-RT than other treatments (Table 2.4). The high frequency of goose grass in 2001 was especially difficult to manage in Org-RT, and control was achieved by hand removal. In 2001, the cover crop was flail mowed and it was difficult to remove the weeds by hand without removing the residue. Monocot weed densities were similar in Org-CI and Org-NC each year, and similar to Conv in 2004.

In 2001 and 2002, dicot weed densities were consistently the highest, statistically and numerically, in the Org-RT system and lowest in Conv (Table 2.4). In general, dicot weeds responded similarly to Org-NC and Org-CI treatments and densities were intermediate between Org-RT and Conv. Although some weeds were observed in the conventional system, cultivation and herbicides proved effective throughout the season, and weed density in this treatment was lower or similar to density in organically managed treatments. In 2004, there were no differences in weed density among all four management systems. An increase in the number of weed control events, and implementing cultural controls earlier in the season contributed to optimal weed management in all systems.

Weed species composition. Cumulative weed species composition was assessed for each treatment and year. Weed species (Table 2.5) are expressed as a percent of the total (cumulative) weed density for the season within treatment and year (Table 2.6). Species that composed less than one percent of the total weed density were not presented (COPDI, PHTAM, POLPY, POROL, and RUMCR), but their densities were included in the total cumulative weed density for the given treatment and year. Therefore, due to rounding, the percent of species occurrence within a year and treatment may not total 100. During the course of this experiment, there were a total of six monocot and 29 dicot weed species. Several species of *Amaranthus* and *Ipomoea* were present among treatments each year, and species composition of each genus was relatively similar among systems. Therefore, species densities within each genera are presented as the sum of species for that genus and are represented by the symbols AMAZZ and IPOZZ for *Amaranthus* and *Ipomoea*, respectively.

Throughout the experiment, pigweed species and carpetweed (*Mollugo verticullata* L. MOLVE) were among the most frequently occurring weeds in all treatments. Other dominant weeds included goose grass [*Eleusine indica* (L.) Gaertn. ELEIN] and arrowleaf sida (*Sida rhombifolia* L. SIDRH) in 2001, broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash BRAPP], yellow nutsedge (*Cyperus esculentus* L. CYPES) and prickly sida (*Sida spinosa* L. SIDSP) in 2002, and goose grass and Virginia pepperweed (*Lepidium virginicum* L. LEPVI) in 2004. These species are problematic to sweetpotato growers in North Carolina (Bridges, 1992; Seem et al., 2003). In addition to the naturally occurring weed population, volunteer sorghum sudangrass from the previous crop was present in all treatments in 2004 (Table 2.6). Statistical analysis of weed density and biomass including and excluding sorghum sudangrass provided the same results, therefore sorghum sudangrass did not contribute to treatment differences. Because sorghum sudangrass was not a part of the experimental design but rather an artifact from a previous rotation it was omitted from weed density and biomass analysis.

Factors that influence changes in weed species composition include rotation, tillage, herbicide use and climate (Andersson and Milberg, 1995; Barberi et al., 1997; Legere and Samson, 2004). In production systems where tillage is reduced, qualitative changes in weed species composition (Zanin et al., 1997) including an increase in species diversity, or richness (Legere and Samson, 2004) have been observed. In this experiment, species richness was greatest in the reduced tillage system in 2001 and 2004 on sites recently managed as pasture (Table 2.7). However, the additional species observed in Org-RT occurred at very low densities and composed less than 1% of the total weed density either year (data not shown). The location in 2002 was historically managed conventionally in a field corn (*Zea mays* L.)–soybean [*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L.) rotation. No differences in species diversity were observed among treatments in 2002, although the total number of species observed over all treatments was lower than other years. Previous site history in addition to below average precipitation may have reduced weed species diversity that year.

Weed biomass at harvest. Monocot and dicot weed biomass responded differently to management systems by year (Table 2.3). Monocot weed biomass was similar among Org-NC, Org-CI and Conv each year (Table 2.4). In 2001 and 2002, Org-RT was not effective in suppressing monocot weeds, and by harvest, weed weight was several orders of magnitude greater than remaining treatments. Dicot weed biomass was similar among organically managed treatments in 2001 and 2004, but in 2002, treatments with cover crops had greater dicot weed biomass than conventionally managed treatments.

Because weed biomass at harvest reflects the total weed production in each management system following the last weed control event, the method of weed removal, timing of removal relative to weed emergence and number of events are important considerations when comparing the effectiveness of weed management among systems. Weed management decisions were made to optimize control in each system, therefore, the method, timing and number of weed control events varied among treatments and years. Excluding fumigation, the conventionally managed treatment required four, five and six weed prevention/removal events in 2001, 2002 and 2004 respectively (Table 2.1). Because herbicide applications were omitted, the organically managed treatments received fewer weed control events than the conventional control each year. Org-RT received the fewest number of weed removal events, and except for one occurrence of mowing in 2001, the methods were limited to hand removal.

Residue remaining in organic reduced tillage treatments. Cover crop residue remaining on the surface in Org-RT treatments at harvest were higher in 2004 (505 kg ha^{-1}) and 2002 (398 kg ha^{-1}) than 2001 (108 kg ha^{-1}). The increase in residue can be attributed in part to improvements in management. In 2001, cover crops were killed by flail chopping, which cut the biomass into small pieces and facilitated decomposition. The height of the rye at the time of kill exceeded 1.8 m each year, and in 2001, several passes of the mower were required. In 2002 and 2004, the rye vetch mixture was rolled in a uniform direction that was matched by the tractor direction at transplanting. This preferred method allowed the tall rye plants to remain uncut on the bed surface, distributed the cover uniformly across the beds and interrow areas, and eliminated unnecessary disturbance at planting.

Occurrence of annual grasses after transition to a reduced tillage system is a common observance (Clemments et al., 1996). In this experiment, annual grasses including goose grass and broadleaf signal grass were present in all treatments, but were not well controlled in Org-RT. A regression analysis of residue as a function of total weed density combined over years resulted in a significant (P= 0.0001) reduction in weed density with an increase in residue dry weight (Figure 2.1). Correlation analysis of residue and weed biomass at harvest was not significant, suggesting that too little residue remained on the surface to suppress the growth of late emerging weeds (data not shown).

Sweetpotato vine biomass. Sweetpotato vine biomass at harvest responded differently to treatments among years (Table 2.8) and therefore data were analyzed by year. A decline in sweetpotato vine biomass Org-RT in 2001 and 2002 was most likely the result of high monocot weed biomass throughout the season (Table 2.4). In 2004, no differences in weed biomass or sweetpotato vine biomass were observed, and means of sweetpotato vine biomass were nearly two times greater than previous years. Although densities were substantial, high temperatures in 2002 and improved sweetpotato vine growth in 2004 helped suppress rye regrowth. Sweetpotato vine biomass was negatively correlated with total weed biomass as well as yield and positively correlated with cover crop residue (Table 2.9).

In research to identify the critical weed-free period of ‘Beauregard’, sweetpotato was planted at an early and late planting date, and weed density and biomass were assessed in weed removal and weed grow back treatments (Seem et al., 2003). Although yield was reduced in the late planting date because of a reduction in heat units during a critical period of root expansion, late planted sweetpotatoes were more resistant to weed interference due to the initial rapid vine growth related to an increase in average daily temperature. It is not known if planting earlier would have increased yields in these systems, or if an earlier planting date would be associated with an increase in weed interference in organically managed systems. Future research could address the influence of planting date and cultivar selection on weed suppression in organically managed systems.

Yield. Total root yield is reported as the sum of No. 1s, canners and jumbo market grades. Due to a reduction in yield in Org-RT in 2002, there was a significant treatment by year interaction (Table 2.8) and results are presented by year. Mean yields were lowest in 2001 compared to subsequent years of the experiment. Despite an increase in weed density and biomass, and a decline in sweetpotato biomass in Org-RT in 2001, total yield was similar among treatments. In 2002, total yield in organic-reduced tillage was lower than other treatments. Due to dry conditions, poor initial stand and consequent delayed plant establishment in this treatment, we observed root expansion and canopy closure occurred later in the season compared to other treatments. Favorable climactic conditions and improved weed control in 2004 contributed to high yields that were similar among treatments.

Regression analysis was significant for total yield as a function of total weed biomass ($P < 0.0001$), however an analysis of variance to test for equality of slopes indicated there were no differences among treatments in the rate of reduction of yield due to an increase in weed biomass (Figure 2.2). Therefore, the linear regression equation was determined by combining data from all treatments and years. The combined regression indicates that yield declines as weed biomass increases at a rate of approximately 38%. However, the R-square value for this regression was very low, indicating that weed biomass alone was a poor predictor of yield. Pearson correlation coefficients showed positive correlations for cover crop residue and yield (Table 10). In the Org-RT treatments, residue most likely had an indirect positive effect on yield due to its negative correlation with weed density. Carrera et al. (2004) examined the effectiveness of weed suppression in a reduced tillage sweet corn system using a cover crop mixture of hairy vetch and rye with and without herbicide compared to bare soil with and without herbicide. In both years of that experiment, yield was negatively correlated with weed biomass. Although there were no differences in slopes among treatments the first year of the experiment, the slope was significantly steeper for the bare soil treatments than for the cover crop treatments, indicating an improved competitive response of sweet corn to weeds in the cover crop treatment. In this experiment, similar slopes among treatments implies that despite the absence of herbicides, and perhaps due in part to the addition of organic matter and/or cover crops in organically managed treatments, response of sweetpotato to weed biomass was no different in organic treatments than conventional.

Weed interference in sweetpotato is associated with a decline in yield. Seem et al. (2003) reported a measurable decline in yield if sweetpotato was allowed to remain weedy for as little as 2 weeks after transplanting. Canopy growth alone may not be as important to root expansion as other factors. For example, in this experiment, sweetpotato foliar biomass at harvest was lower in Org-RT plots in 2001 than other treatments, yet no differences in yield were observed. Because sweetpotato storage root initiation is markedly influenced by environmental conditions in the first 20 days after planting, small changes in the soil environment, such as those possible with reduced tillage, may lead to large changes in marketable yield. In Louisiana, several cover crop species were examined for use in reduced tillage sweetpotato production (Jett and Talbot, 1998). Mixtures of hairy vetch and rye, hairy vetch and wheat, and ryegrass were found to be most effective in suppressing weeds without a reduction in yield. Additionally, sweetpotatoes grown in undisturbed rye residue had significantly greater leaf area, vine weight, root set, and yield relative to conventionally tilled sweetpotatoes.

Summary. Frequently throughout the course of this experiment, Org-NC and Org-CI suppressed weeds as well as the conventionally managed treatment. Under the conditions of this experiment, overwintering hairy vetch and rye completely suppressed winter and spring weeds. Weed suppression by cover crop residue in Org-NT provided inadequate suppression for annual and summer perennial grasses, but was more effective for dicot species. Although weed density and biomass were at times substantially greater in Org-RT than other systems, yields were similar among systems two out of the three years. However, hand removal in Org-RT was time consuming, and reliance on this method of weed control for this system may not be practical or economically feasible for growers. This research demonstrates the potential for organically managed sweetpotato with or without an incorporated cover crop to produce storage root yields equal to conventionally managed systems. Additional study could explore planting date as well as cultivar selection to identify those cultural practices best suited for organic production.

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CHAPTER 3. Effects of Cover Crop and Tillage on Wireworm (Coleoptera: Elateridae) Density and Yield Quality in Organically Managed Sweetpotato.

KEY WORDS *Ipomoea batatas* (L.) Lam., *Melanotus* spp., *Conoderus* spp., sampling, damage, soil moisture

Abstract. Cover crops influence pest abundance and diversity by modifying habitats at and below the soil surface. A three-year field experiment was initiated in 2001 to evaluate different organic sweetpotato production systems that varied in cover crop management and tillage. Three organic systems including 1) compost and no cover crop with tillage (Org-NC), 2) compost and cover crop incorporated prior to transplanting (Org-CI), and 3) compost and cover crop with reduced tillage (Org-RT) were compared to a conventionally managed tilled and chemical control (Conv) production system using a randomized complete block design with six replications. Wireworms (*Conoderus* and *Melanotus* spp.) were captured in baited traps prior to sweetpotato planting and throughout the season. Wireworm species composition was primarily *M*. *communis* in 2001 and 2004, and *Conoderus* spp. in 2002. The number of *M*. *communis* captured during the season was lowest in Org-RT in 2001 (1.14 $trap^{-1}$), and similar among systems in 2002 and 2004. Wireworm response to management systems differed between genera and site location. *Conoderus* spp. were highest in Org-CI in 2001 (0.82 $trap^{-1}$) and 2002 (1.45 $trap^{-1}$) but capture was similar among systems in 2004. Total sweetpotato yield was similar among all treatments in 2001 and 2004, but was at least 45% lower in Org-RT than other treatments in 2002. The percentage of No. 1 roots damaged by wireworm – *Diabrotica* – *Systena* (WDS) complex was high and ranged from 32-79% through the course of this experiment. In 2001, Org-RT had 27% fewer damaged roots and

Org-CI had 23% more damaged No. 1 roots compared to Conv. In 2002, Org-NC and Conv had similar amounts of marketable roots, while the number of marketable roots in cover cropped systems was at least 13% lower than the conventionally managed system. Means of wireworm (*Melanotus* and *Conoderus* spp.) seasonal densities were significantly correlated with degree of root damage.

Sweetpotato is the most economically important vegetable crop in North Carolina. In 2004, sales of N.C. sweetpotato accounted for 46% of the national market share and earned 79 million dollars for the state (NCDA & CS, 2005). 'Beauregard' is the predominant variety grown in N.C. and the United States (Schultheis et al., 1999). Although susceptible to insects, it is high yielding and therefore preferred over other varieties resistant to insects such as 'Jewel' and 'Centennial'. In N.C., 'Beauregard' is typically planted in mid-May to mid-June, and harvested 90-110 days later (Wilson et al., 1989). The long growing season of sweetpotato makes it especially vulnerable to damage by soil dwelling insect pests.

Wireworms and larvae of cucumber beetle (*Diabrotica undecimpunctata howardi* Barber and *Diabrotica balteata* LeConte) and flea beetle (*Systena* spp.) feed on sweetpotato roots and reduce root quality by leaving holes, shallow tunnels, and scars. This complex is typically referred to as the Wireworm - *Diabrotica* - *Systena* complex (WDS) due to similarities in feeding injury among species (Schalk et al., 1986). In addition to wireworm, many other soil dwelling pests feed on sweetpotato roots and reduce root quality including root knot nematodes (*Meloidogyne* spp.), whitefringed beetle (*Graphonanthus* spp.) and white grubs of various beetles, including the green June beetle (*Cotinis nitida* L.) and the Japanese beetle (*Popillia japonica* Newman). Sweetpotato weevil (*Cylas formicarius elegantulus* Summers), a serious pest of some southern states, is largely absent in areas of commercial production in N.C. (Sorensen, 2005b).

In N.C. and many parts of the southeastern U.S., wireworm larvae are among the most destructive pests of sweetpotato (Chalfant et al., 1990) and C*onoderus* and *Melanotus* spp. are the most common genera in sweetpotato fields (Seal et al., 1992a; Sorensen 2005a; Williams, 2004). Alate adults do not feed on sweetpotato but rather lay their eggs in mid-late summer in the soil on land covered by grass, weeds, or other vegetation. The life cycles of *Melanotus* spp. are believed to last longer than 1 year, while *Conoderus* spp. complete their life cycle in six months to 3 years (Chalfant et al., 1990). Wireworm larvae decline in the soil during the winter and rise to upper levels of the soil horizon as soil temperatures increase (Fisher et al., 1975). Fluctuations in populations occur in mid-late summer as eggs hatch after a short incubation period (7-14 days) and older larvae pupate (Chalfant and Seal, 1991). Most *Conoderus* spp. including *C. bellus* and *C. lividus* (Fisher et al., 1975), *C. vespertinus* (Raab, 1963) and *C. scissus* (Chalfant and Seal, 1991) overwinter as larvae while others overwinter as pupae or adults.

Methods for baiting wireworms have been well documented (Apablaza et al., 1977; Cherry and Alvarez, 1995; Horton and Landolt, 2002; Jansson and Lecrone, 1989; Parker, 1994; Simmons et al., 1998 and Ward and Keaster, 1977). Although growers in N.C. are advised to bait fields in late winter (Sorensen, 2005), scouting for these larvae is laborious and the results are highly variable. Seal et al. (1992) performed a experiment to predict seasonal abundance of *Conoderus* spp. based on sample size. They determined the number of traps per area needed to obtain a desired level of precision (0.10, 0.20, 0.40). The number of traps increased as mean larval capture decreased and as plot size increased. Based on an anticipated mean number of one larva per trap, they estimated 54 traps would be needed on a one ha field to achieve a precision level of 0.40. This number increased to 214 if the precision level was increased to 0.20, and to 856 when precision was 0.10. Clearly, reliance on baiting to detect wireworms is a time consuming process. Because the formal establishment of wireworm thresholds is impractical due to the difficulty of predicting absolute densities accurately, the presence of one captured wireworm is often justification for the additional cost of chemical insecticide.

Several researchers have developed models to predict wireworm preferred habitat and therefore ideal baiting locations based on site characteristics. In these studies, wireworm abundance was positively correlated with an increase in the duration of managed pasture (up to 75 years), a decrease in bulk density (Parker and Seeney, 1977) as well as soil moisture content greater than 17% (Lefko et al., 1998). The likelihood of larval capture depends on previous crop history (Jansson and Lecrone, 1991; Seal et al., 1992a), time of year (Ward and Keaster, 1977), preceding tillage events (Seal et al, 1992a), and for some species, soil moisture (Lefko et al., 1997) and temperature (Fisher et al., 1975; Hall and Cherry, 1993). To date, attempts to relate seasonal or preseason larval densities and feeding damage to crops at harvest is variable (Parker, 1996; Samson and Calder, 2003) and serves as a gross predictor at best.

A combination of chemical and cultural controls is employed by sweetpotato growers to reduce the occurrence of insect damage. According to a 1996 survey of sweetpotato grower practices in N.C., 66% of respondents reported using insecticides to control soil dwelling insect pests (Toth et al., 1997). Furthermore, of respondents using insecticides, 76% stated wireworm was their primary insect pest. Materials registered for use in sweetpotato to control soil dwelling insects are limited to the soil fumigant 1,3-Dichloropropene (Telone II), for control of root knot nematode (*Meloidogyne* spp.) and the preplant soil incorporated organophosphate (OP) chlorpyrifos (Lorsban) and ethoprop (Mocap) for control of wireworm and flea beetle larvae (Williams, 2004; NCSU, 2005). In an effort to reduce the number of larvae, foliar applications of the OP phosmet (Imidan), the carbamate (Sevin) and the chlorinated hydrocarbon endosulfan (Thiodan) can be applied to reduce the adult egg-laying populations of insect pests. Most of these materials (OPs, carbamates, and hydrocarbons) are currently being reviewed under the Food Quality Protection Act because of their potential for environmental harm (US EPA, 1999) and no suitable replacements are currently available.

Growers implementing best management practices for sweetpotato in North Carolina typically employ multiple tillage events including subsoiling, discing, field leveling, hilling, and cultivation. Cultivation has been associated with a decline in wireworm larval densities (Seal et al., 1992b), but it is only effective when larvae are active within the depth of tillage. Mortality is caused by direct injury, predation or exposure to environmental elements (Seal et al., 1992b). Common rotational crops include tobacco (*Nicotiana tabacum* L.), soybean [*Glycine max* (l.) Merr.], corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.). Because several important wireworm species have a life cycle greater than 2 years, sweetpotato is not double-cropped due to concerns of residual populations (Seal et al., 1992b). Additionally, it is generally recommended that fields previously in cover crops, pasture or weeds be avoided (Wilson et al., 1989).

Cover crops are an integral component of organic farming systems. The benefits are well documented and include a reduction in weed density (Creamer et al., 1996), an increase in soil water retention (Teasdale and Mohler, 1993), a decrease in bulk density (Jackson et al., 2004), an increase in soil microbial biomass (Jackson et al., 2004) and a reduction in carbon and nitrogen losses (Drinkwater et al., 1995). Cover crops influence insect abundance and diversity by modifying habitats at the soil surface (Hummel et al., 2002), altering weed composition and density (Rutledge, 1999), and changing soil physical properties, all of which depend on the degree of tillage (Stinner and House, 1990). Due to the complexity of interactions among insects, vegetation and the soil environment, it is difficult to generalize about the effects of cover crop management on insect dynamics (Burton and Burd, 1994) Rather, the relationships between each production system and insect species should be considered on an individual basis (Burton and Burd, 1994).

Although the number of reports is limited, cover crops and tillage have been demonstrated to influence wireworm abundance and subsequent crop damage. In a Florida study on the effects of summer cover crop management on wireworm density and damage to potato (*Solanum tuberosum* L.), Jansson and Lecrone (1991) evaluated eight management systems of sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench x *S. arundinaceum* (Desv.) Stapf. var. *sudanese* (Stapf) Hitchc.) that varied in planting date and mowing frequency. Using a food bait of rolled oats, wireworm *M. communis* was the predominant species (>97%) followed by *Conoderus* spp. (*C. rudis*, *C. amplicollis*, and *C. falli*) (<3%). The authors observed *M. communis* abundance and potato tuber damage declined significantly when mowing frequency increased and when planting of sorghum-sudangrass was postponed until July verses April preceding a December planting of potato. Because the peak flight activity of *M. communis* adults is July-August in Homestead, April-planted cover crops were attractive to egg-laying females and therefore higher wireworm densities and tuber damage were observed in this treatment. However, potatoes in July-planted cover crop had similar yields, tuber quality and thus economic return than potatoes in the fallow control.

In a series of field trials in Georgia, Seal et al. (1992a) studied the effects of various cultural practices on wireworm abundance in sweetpotato. One study examined the effect of no tillage verses tillage to a depth of 20 cm on wireworm abundance in fields known to be infested with *C. rudis*. Five corn-wheat baits were collected from each of five (1.5 m^2) plots.

Plots were sampled immediately following each of three tillage events that occurred at 3-week intervals. The number of wireworms captured in tilled fields declined significantly by 88% compared to plots without tillage. The authors hypothesized that plowing may favor termination of *C. rudis* since that species tends to reside in the top 10 cm of the soil.

The USDA ERS (2003) reports that organic foods are now sold in 73% of all conventional food markets, and in those markets, organic fresh market produce sales approached 94 million dollars in the 12-month period preceding June 2001. Despite the demand for organic produce, no production recommendations exist for organic fresh market sweetpotato from land grant universities. Due to the potential for the EPA to restrict or cancel use of insecticidal materials, growers are interested in economically viable reduced risk alternatives (Curtis, 2003). Additionally, lack of information on cultural practices involving tillage and cover crop management in sweetpotato systems is minimal and current recommendations may unjustifiably limit grower options. Therefore, this experiment was conducted to study the effects of cover crop management and tillage in three organically managed systems on wireworm larval densities, sweetpotato yield and root quality compared to a conventionally managed tilled and chemical production system.

Materials and Methods

Experiments were conducted in 2001, 2002 and 2004 at the Center for Environmental Farming Systems (CEFS), Goldsboro, N.C. In all three years, the soil was a Wickham loamy sand (Fine-loamy, mixed, semiactive, thermic Typic Hapludults). This series is a representative soil of the central coastal plain in North Carolina, and is typical soil texture in sweetpotato production areas. This soil is sedimentary in origin, acidic, low in nutrient holding capacity, and subject to occasional flooding. The experimental site in 2002 received 3922 kg ha^{-1} dolomitic lime applied the previous January, and the 2002 and 2004 sites each received 2240 kg of lime ha^{-1} in accordance with NCDA soil test recommendations one and two years prior to sweetpotato planting, respectively. In 2001, the site was previously mowed perennial pasture of ryegrass (*Lolium perenne* L.) and received no fertilizer or pesticide inputs for 20 years prior to this experiment. In 2002, the previous crop was conventionally managed field corn (*Zea mays* L.) and in 2004, the previous crop was sorghum sudangrass [*Sorghum bicolor* (L.) Moench x *S. sudanense* (Piper) Staph.]. Sweetpotatoes were never previously produced on any of the experimental locations. Organic production practices were followed in 2001 according to guidelines published by an independent certifying agency (Carolina Farm Stewardship Association, 1997) and the U.S. Federal standards established by the National Organic Program (USDA, AMS, 2002) in 2002 and 2004. Although the 2001 site was eligible for certification, the conventionally managed production system in this experiment precluded that effort. In addition, the previous crops in 2002 and 2004 were produced using synthetic inputs, therefore, over the course of this experiment, sweetpotato could not be certified organic.

The experimental design was a randomized complete block with six replications. Three organically managed systems including 1) no cover crop (Org-NC), 2) cover crop incorporated prior to sweetpotato planting (Org-CI), and 3) cover crop reduced tillage (Org-RT) were compared to a conventionally managed production system (Conv) to determine soil nutrients, nutrient acquisition and growth of sweetpotato foliage, and sweetpotato yield. In order to mimic conditions typical of sweetpotato farms in our area, large plot sizes were used to allow ample space for full sized equipment. Management decisions such as equipment selections, timing of weed removal and method of cover crop planting and termination were made that would optimize the production of each system. Because site conditions varied among years in soil type, pest populations, field history, and climate, some variation of methods was necessary. Plots were 24.4 m long and composed of 12 rows on 1 m centers in 2001 and 2002, and .96 m centers in 2004. A minimum of 9.1 m (2001, 2002) and 6.1 m (2004) buffer separated replications. The area surrounding each replication was planted in ryegrass in early spring and maintained by mowing throughout the season. The total experimental area excluding buffers was approximately one hectare.

Sweetpotato management. All three organically managed treatments received compost composed of materials approved for use in organic production by the Organic Materials Review Institute (OMRI) at a rate of 20 Mg ha^{-1} in May of 2001 and November 2002 and 2004 (Table 3.1). In May 2001, prior to compost incorporation, the entire experimental area was plowed with a three bottom moldboard plow, but no plowing occurred in 2002 or 2004. Prior to application and according to North Carolina Department of Consumer Services (NCDA & CS, 2005) availability coefficients, it was estimated that 47 kg N ha^{-1} would potentially be available to the sweetpotato crop during 2001 growing season, and 49 kg ha^{-1} in 2002 and 2004. Boron (0.6 kg ha^{-1}) [Solubor ($Na_2 \cdot B_8 \cdot O_{13} \cdot 4H_2O$) U.S. Borax Inc. Valencia headquarters, CA.] was applied to all systems prior to planting. Except for the standard recommended 56 kg ha^{-1} N application rate for 'Beauregard', all other nutrients were considered adequate according to NCDA & CS. Commercially grown 'Beauregard' G2

B94-14[3] cuttings were planted to a 0.27 m in row spacing on 2 July 2001, 13 June 2002 and 29 June 2004 in weed-free plots in all treatments. Within two weeks of planting, sweetpotato cuttings were replanted by hand as necessary to ensure an equal stand among treatments. Although chemical insecticides and herbicides were applied to Conv, no pesticides of any kind were applied to the organically managed systems. Prior to harvest, sweetpotato foliage was mowed with a rotary mower (Bush Hog, L.L.C., Selma, Ala.), and soil and roots were turned with a mechanical two row digger (KMC, Tifton, Ga.).

Treatment management.

Organic, no cover crop. Plots were cultivated with a tandem disc harrow to eliminate weeds in late November. In May each year, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Cuttings were planted with a two row transplanter (RJ Equipment, Blenheim, Ontario). Following sweetpotato planting, seasonal weed control was by rolling cultivator, mowing or by hand.

Organic, cover crop incorporated. In November preceding the cropping season of all three years, a cover crop mixture of 45 kg ha^{-1} hairy vetch and 67 kg ha^{-1} rye ‘Wrens Abruzzi’ was seeded with a grain drill on a disked flat soil surface. Cover crops were flail mowed when hairy vetch was in mid bloom (Creamer et al., 1996) and rye was in anthesis on 23 May 2001, 3 May 2002, and 3 June 2004. Cover crops were incorporated in 2001 with a moldboard plow followed by a tandem disc harrow, a tandem disc harrow in 2002 and an articulating spading machine (Celli S.p.A., Forli, Italy) in 2004. Plots were disked twice in 2001 and 2004 and once in 2002 prior to sweetpotato planting to ensure adequate distribution

[3] G2 represents plants that produced for two seasons in field following establishment inside a virus-free greenhouse environment. B94-14 represents a Beauregard cultivar mericlone.

and decomposition of cover crop. Cuttings were planted with the same transplanter as in the organic, no cover treatment.

Organic, reduced tillage. In November of all three years, a hairy vetch and rye cover crop mixture was seeded at the same rates as Org-CI on preformed hills. In 2000, cover crops were hand seeded with a broadcast seeder spreader (PlantMates Inc., Gallatin, Texas). In 2000, the germination rate of vetch was unsatisfactory on the crest of the hills compared to the furrows presumably due to the inability of the round seeded vetch to remain in place. Therefore, in 2001, hand seeding was followed by seed incorporation with a seeder cultipacker with notched rollers (Brillion Iron Works, Brillion, Wis.). In 2003, the cultipacker was used to seed and incorporate the cover crop. In May 2001, the cover crop was killed with a flail mower, and in 2002 and June 2004, cover crop was killed by rolling using the cultipacker. Sweetpotato cuttings were transplanted with the same transplanter as described earlier for other treatments in 2001. In 2002 and 2004, cuttings were transplanted with subsurface tiller-transplanter (SST-T) (B&B No-Till, Laurel Fork, Va.) (Morse et. al., 1993). This transplanter cut through surface residue with a double disk coulter, opened a furrow, and placed water below the sweetpotato slip, placed the slip in the row, and closed the furrow with weighted press wheels.

Conventional. Recommended cultural and pest management practices for sweetpotato ‘Beauregard’ were followed throughout the season (Schultheis et al, 1999; Toth et al., 1997; Wilson et al., 1989). Plots were cultivated with a tandem disc harrow to eliminate weeds in late November. In May, overwintering weeds were incorporated with a tandem disc harrow, followed by one additional discing approximately two weeks later. Plots were fumigated (1,3-dichloropropene) at (84.5 L ha^{-1}) primarily for nematode control two weeks prior to planting. EPTC (S-ethyl dipropylthiocarbamate) was applied at 2.2 kg h^{-1} for control of annual weeds mixed with chlorpyrifos [O,O-diethyl-O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate] at 2.2 kg h^{-1} for control of soil dwelling insects [wireworm (*Melanotus* and *Conoderus* spp.) one week prior to planting in 2001 and two weeks prior to planting in 2002 and 2004. In addition, napropramide [N,N-diethyl-2-(1-napthalenyloxy-proprionamide] at 1.1 kg h^{-1} was applied to control dicot weeds one day after plant for weed control. Hills were formed with a ripper-bedder several days prior to sweetpotato planting. Slips were planted with the same transplanter as in the organic, no cover treatment.

Following sweetpotato planting, seasonal weed control was by rolling cultivator until prohibited by sweetpotato vine growth, at which time weeds were removed by mowing or by hand. Ammonium nitrate (NH_4NO_3) at 68 kg ha^{-1} was banded and incorporated 28 days after planting each year. Slips were planted with the same transplanter as in the organic, no cover treatment.

Data collection

Stand. Stand counts were made on each plot 2-3 days after planting by counting all plants in each of the eight data rows. Missing plants were replaced by hand, and a second stand count was performed after replanted plants were established to ensure a consistent stand among treatments. Data were analyzed with SAS GLM, and following hand replanting, stand counts were found to be similar among all treatments each year (Data not shown).

Cover crop biomass. Above ground biomass was removed from one randomly placed 0.5-m^2 frame per plot one day prior to cover crop kill all three years. The cover crop mixture was separated by species, oven dried at 60 °C for 48 h and weighed. Additionally, cover crop residue remaining in organic reduced tillage plots was collected, oven dried at 65 °C and weighed. Soil was removed from the residue by sifting.

Wireworm abundance. To minimize variation of mechanical practices as well as the effects of pesticide drift, we collected data in the center eight rows and 18.3 m of each plot. Due to the extensive destructive nature of sampling for this experiment, a stratified random sampling pattern was used. A virtual grid of twelve cells was established in the sampling area prior to planting, so that each cell consisted of 6.1 m long sections of two adjacent rows, or an area approximately 12.4 m^2. Cells and locations within the cells were selected at random, however; baits were placed within the cell so baiting stations of previously sampled areas were at least 3.0 m from each other. Two bait stations were placed in each plot. Therefore, at each sampling date, a total of 12 traps on a 0.18 ha^{-1} area were set for each treatment.

Baits were composed of a 1:1 ratio of untreated germinable soft wheat (*Triticum aestivum* L.) and 'Trucker's Favorite' sweet corn (*Zea mays* L.) soaked for 12 hours in tap water prior to use (Seal et al., 1992a). Excess water was drained, and approximately 200 ml of seed was placed in each hole. Soil was cored from sites using a manually operated steel soil probe 5.0 cm in diameter and 10 cm deep (206 cm^3). Care was taken not to induce additional compaction through the coring action, nor increase bulk density of the soil in the area surrounding the bait. After bait was placed in the hole, approximately half of the excavated soil was used to cover the bait. Soil and bait were removed using a second probe 10 cm in diameter and 10 cm deep (823 cm^3). Samples were removed when corn and wheat leaves broke the surface of the soil, typically 5-7 days after soil baiting, depending on climactic conditions. The soil and bait matrix were placed in 3.8 L plastic freezer bags, and transported to the laboratory in an iced cooler. Larvae were removed from the soil within three days, placed in a 70% ethanol solution mixed with deionized water, and stored in a 4.4 °C cooler until identified using keys described by Raab (1963), Riley and Keaster (1979) and Seal (1990).

Wireworms were sampled 4, 5 and 6 times in 2001, 2002 and 2004, respectively. Sampling began at least 2 weeks after sweetpotato planting, and the last sampling was 1 week prior to harvest. Additionally, sampling occurred prior to cover crop kill each year in each system (April 2001, 2002 and May 2004). Due to cool soil temperatures, baits were covered in a single layer of 10 mil clear plastic cut to 0.5 m^2 and centered over the bait (Ward and Keaster, 1977). Except for the addition of the plastic, methods were as previously described.

Soil moisture. Concurrent to seasonal wireworm baiting, soil moisture and temperature data were also collected. Soil temperature was taken with a digital thermometer with a 20 cm long probe to a depth of 10 cm. The probe was placed within 10 to 20 cm from the bait immediately following completion of bait set, and immediately prior to bait removal. Additionally, six soil cores were composited from each plot using a manually operated soil probe with a 2-cm diameter (inner radius) to a depth of 20 cm. Soil was oven dried at 105 °C for 24 h, and recorded as percent moisture on a dry weight basis.

Yield. Sweetpotato roots were collected from a 6.1 m long section in the center of each of two adjacent rows approximately 100 days after planting. Roots were sorted by size according to USDA market grade standards (USDA, 1981). The number of roots in each plot-sample per grade was counted and each group of roots was weighed by grade in the field.

Root quality. A subsample of 50 No. 1 roots per plot was reserved for visual inspection to assess damage by insects. Feeding scars were attributed to three sources of insects that included grubs, flea beetle, or the WDS complex based on the depth, width and shape of the injury (Sorensen, 2005; Sorensen and Holmes, 2002). Although white fringe beetle (*Graphognathus* spp.) damage is frequently observed on sweetpotato roots in NC, there was no evidence of white fringe beetle damage during this experiment. Each year, the number of feeding scars on each root was counted and attributed to the source of damage. Because we were primarily interested in damage to roots caused by WDS, roots were further assigned into damage categories based solely on WDS scar depth and diameter using a rating method adopted from Jansson and Lecrone (1991): marketable (M), with no to negligible damage, some damage (D) but suitable for processing, and not marketable (NM) with extensive damage. In 2001 and 2002, damage categories were defined as M = roots with less than or equal to three feeding scars per root with a combined depth or diameter of less than 1 cm; D = roots with less than or equal to three feeding scars with a combined depth or diameter greater than 1 cm, or NM = greater than three feeding scars. This rating system was not a good reflection of actual buyer's preferences and overestimated the amount of damage that was typically acceptable (Brill, 2005), therefore, in 2004, a similar rating system was used but with more stringent criteria. Damage categories were adjusted to reflect buyer preferences as follows: M = less than or equal to three feeding scars per root with a combined diameter of 3 mm, D = less than or equal to three feeding scars per root with a combined diameter of greater than 3 to less than 6 mm, and NM = scars with a combined depth and diameter of greater than 6 mm. In 2004, scar diameters were measured using a standard draftsman's circle template, and the diameter of each WDS feeding scar was recorded in mm.

Statistical analysis. All data were subjected to analysis of variance using PROC GLM (SAS V.8.2, 2001) to test the main effect of management system. Management and year were treated as fixed effects and blocks and appropriate error terms as random effects. Mean comparisons among management systems were generated using Fisher's protected LSD at $P = 0.05$. When significant year by treatment interactions existed, data were analyzed and are presented by year. Wireworm density was log base 10 (number +1) transformed and cover crop biomass and weed biomass prior to planting and cover crop residue at sweetpotato harvest were square root transformed to satisfy assumptions of normality and homogeneity of variances prior to analysis. For these data, statistical conclusions were derived from transformed data, and back transformed means derived from transformed data are reported here. To describe the relationship between soil moisture and wireworm density as well as soil temperature and wireworm density, SAS regression analysis (PROC REG) was used to identify significant relationships among pairs of response variables, and analysis of variance (PROC GLM) was used to test for equality of slopes among management systems. For both soil moisture and soil temperature, management was not significant, therefore, data are presented with years and management combined. The number of holes per root were analyzed using general linear models (PROC GLM). To assess the proportion of roots in each damage category in each subsample, roots were assigned a numeric value (0=M, 1=D and 2=NM) and analyzed in PROC GLM. Root quality is expressed as the percentage of No. 1 roots determined to be marketable based on criteria discussed above. In addition, Pearson product-moment correlation coefficients (PROC CORR PEARSON) were determined for significant paired comparisons.

Results and Discussion

Weather. The average monthly precipitation from June through October 2001 measured 47 cm and was similar to the 30-year average for Goldsboro (60 cm), however precipitation was not evenly distributed. Temperatures were 1.9 °C lower on average throughout the season, and in particular, July was 3.2 °C lower than normal. Heavy rains in May and June combined with cool temperatures contributed to slow water evapotranspiration. As a result, standing water remained in the furrows between beds for most of the season. Conversely, in 2002, seasonal average monthly precipitation was 22 cm lower than normal. In addition, although monthly average temperatures in 2002 were approximately normal, the temperatures surrounding sweetpotato planting exceeded 37 °C for several days. Therefore, supplemental irrigation (3.175 cm) was supplied only once immediately following hand replanting in all treatments in 2002. In 2004, temperature and precipitation (61 cm) were relatively normal throughout the season.

Cover crop biomass and residue. Cover crop biomass at cover crop kill was similar between Org-CI and Org-RT treatments each year (Table 3.1). In 2001, the sum of hairy vetch and rye biomass exceeded 13,000 kg ha^{-1} in both treatments, however, biomass was less in subsequent years. By weight, rye composed 70% on average of the total cover crop biomass.

During the winter and early spring until cover crop kill, the cover crops were successful competitors and no weeds were collected at sampling in any of the Org-CI or Org-RT plots all three years (Table 3.1). Analysis of variance of weed biomass at cover crop kill included Conv and Org-NC treatments only due to zero values for organically managed treatments in cover crops. Mean separations were applied to all treatments based on LSD values generated from that analysis. Similar weed biomass was observed in both Org-NC and Conv treatments in 2002 and 2004. Cover crop residue remaining on the surface in Org-RT treatments at sweetpotato harvest were higher in 2004 (505 kg ha^{-1}) and 2002 (398 kg ha^{-1}) than 2001 (108 kg ha^{-1}) (data not shown). The increase in residue in 2002 and 2004 can be attributed in part to improvements in management. In 2001, cover crops were killed by flail chopping, which cut the biomass into small pieces and facilitated decomposition. The height of the rye at the time of kill exceeded 1.8 m each year, and in 2001, several passes of the mower were required. In 2002 and 2004, the rye vetch mixture was rolled in a uniform direction that was matched by the tractor direction at transplanting. This preferred method allowed the tall rye plants to remain uncut on the bed surface, distributed the cover uniformly across the beds and interrow areas, and eliminated unnecessary disturbance at planting.

Soil moisture. Because sampling dates were different each year in terms of crop development, data were analyzed by year in PROC GLM (SAS V8). To test for the main effect of date, date was treated as a fixed effect, and management nested in date was used to test for date by management interactions. In 2001 and 2002, a significant sampling date by management system interaction was detected ($P<0.01$) but only a management main effect was significant in 2004 ($P<0.0001$; data not shown). For consistency, soil moisture data were analyzed by year and date.

Soil moisture differences among management systems occurred sporadically throughout the experiment (Table 3.2). The Wickam soil series has an available water capacity that ranges from 11-15 % to a depth of 36 cm (USDA SCS, 1974). Soil moisture levels in 2001 and 2004 generally were within or exceeded this range, while soil moisture was limiting in the first half of the growing season in 2002. In 2001, soil moisture in Org-CI was greater than Org-RT on three occasions and greater than Org-NC on two. Abundant biomass incorporated prior to planting (Table 3.1) may have facilitated soil moisture retention in Org-CI. In 2002, the conventionally managed system had less moisture than organic systems receiving cover crops at 35 and 51 DAP (Table 3.2). There was 61% less moisture than Org-RT at 35 DAP (Table 3.2). Six days later, soil moisture levels reached a seasonal low, ranging from 4.2-5.8%. In 2004, when analyzed by date, soil moisture was different among systems only once, with Org-RT having the highest soil moisture at 31 DAP. Although statistical differences were noted for only one third of the sampling dates, soil moisture means in organically managed treatments receiving cover crops trended higher than remaining treatments throughout the experiment. Activity of wireworms has been demonstrated to increase when soil moisture values range from 14-20% (Lefko et al., 1998). It is believed wireworms become inactive outside of this range.

Wireworm abundance. Wireworms captured in the early spring prior to sweetpotato planting were lower in cover crop systems than Conv, and lowest in Org-CI (Table 3.3). Seasonal wireworm abundance was influenced by a year and management interaction (Table 3.4) and therefore was analyzed by year (Table 3.5). Over the course of this experiment, 475 wireworms were captured in 720 baited traps, and at least 11 species in five genera were observed. Wireworm response to management systems differed between *Melanotus* and *Conoderus* genera. Wireworm capture was greater in 2001 than other years. Wireworm species composition was primarily *M. communis* in 2001 and 2004, and *Conoderus* spp. in 2002.

In 2001, the number of *M. communis* captured during the season was lowest in Org-RT (1.14 $trap^{-1}$), similar between Org-NC and Conv, and greatest in Org-CI (13.44 $trap^{-1}$).

Surprisingly, there were no differences in the number of *M. communis* captured in 2002 and 2004. One partial explanation for lack of significance is the high variation in trap means (Table 3.5). *Conoderus* spp. were highest in Org-CI in 2001 (0.82 $trap^{-1}$) and 2002 (1.45 $trap^{-1}$) but capture was similar among systems in 2004.

Because the mechanisms of movement and dispersal are not completely understood, interpreting larval capture densities is difficult. Wireworms may move towards a food source because they detect CO_2 from respiration of germinating bait (Doane et al., 1975) or they may detect carbohydrates from roots or fermenting bait moving through soil solution. These stimuli are greatly influenced by the soil bulk density, temperature, and moisture content. Bait attractiveness is also influenced by the abundance of alternate and possibly preferred food sources. It stands to reason if baits are present in a soil that lacks alternate food sources, then the probability that larvae will move towards the bait increases. A substantial amount of cover crop biomass was attained in Org-CI and Org-RT systems (Table 3.1). Although cover crop kill occurred several weeks prior to sweetpotato planting, some decomposition was still taking place in Org-CI. Decomposing organic matter has been associated with an increase in wireworm capture for some species (Chalfant et al., 1990), but it is not known if wireworm populations are higher in these conditions, or if the larvae are simply more attracted to the bait. Preseason wireworm baiting took place prior to cover crop kill each year. Because preseason densities were similar between systems in cover crops (Table 3.3), it appears that tillage and the consequent introduction of biomass into the soil in Org-CI compared to Org-RT was the primary influence of wireworm capture, rather than the cover crop.

The relative capture of wireworms in baits among systems in this experiment does not entirely reflect the actual density of wireworms in each treatment, but rather some combination of the inherent population densities as well as the effectiveness of the bait. For example, soil moisture was lower in 2002 than other years, and may partially account for differences in species capture. Availability of alternate food sources such as roots of cereal and legume cover crops and grassy weeds in Org-RT decompose slowly during the season. Availability of decomposing and living roots for feeding may have reduced the rate of capture, and reduced sweetpotato root damage in Org-RT in 2001.

Wireworm species composition. The distribution of wireworm species varies regionally. In a Georgia survey of sweetpotato production areas, four species of wireworm were predominant, including *Conoderus amplicollis* (Gyllenhal), *C. falli* (Lane), *C. rudis* (Brown) and *C. scissus* (Schaeffer) (Seal, 1990). Three species are known to occur in N.C. sweetpotato fields including *C. vespertinus*, *C. falli*, and *M. communis* (Sorenson, 2005). Additionally, *C. vespertinus* has been documented as a problem in tobacco and corn (Raab, 1963). Although there are no published reports documenting wireworm species in sweetpotato areas in N.C., wireworms have been surveyed in peanut (*Arachis hypogaea* L.) (Herbert et al., 1992). In that study, 60 peanut fields in N.C. and Virginia were observed over a two year period, and wireworms were detected using baited traps. Five traps were placed in each field, and fields were baited twice during each growing season. Overall, wireworm capture was low and only 59 specimens were collected. The majority of identified species were *Conoderus vespertinus* (F.) 58%, followed by *C. lividus* (De Greer) 20%, *Glyphonyx* spp. 8%, *Melanotus communis* (Gyllenhal) 7%, and *C. bellus* (Say) 2%. Although the authors concluded that wireworms did not significantly contribute to peanut pod damage, the survey information is valuable because it demonstrates the diversity of wireworms present in N.C. production fields.

In this experiment, at least 12 species in five genera were observed (Table 2.6). Due to a lack of published keys for the species in the genera *Glyphonyx*, *Aeolus* and *Limonius*, these insects were identified to genus only. The most common species were *M. communis*, *C. vespertinus*, and *C. amplicollis.* However, actual species composition varied by year and management system. In 2001, *M. communis* accounted for at least 83.6% of species composition in each system. In general, the most diverse composition occurred in 2002, and *Conoderus* spp. were most frequently found in baits. In addition to *M. communis*, *C. vespertinus*, *C. amplicollis*, *C. bellus*, *C. rudis* and *Aeolus* spp. were present in all systems. In 2004, *C. falli* was most predominant in the Org-CI system, and *C. vespertinus* and *C. amplicollis* were commonly found in Org-RT. *M. communis* composed at least 70% of all species captured in Org-NC and Conv.

In N.C., peak flight activity of *Melanotus* and *Conoderus* spp. occurs in July-August (Sorensen, 2005, personal communication). Because most sweetpotato fields are planted by mid June, a winter cover crop preceding sweetpotato would not be considered a risk factor if one considers solely the attraction of females to the cover. However, the increase in decomposing organic matter following incorporation of a cover crop may attract female wireworms, or provide optimum soil conditions for larvae activity. Decomposing organic matter has been observed to enhance populations of *C. amplicollis*, *C. falli*, and *Glyphonyx* spp. (Chalfant et al., 1990). In the sandy soils of sweetpotato producing areas of N.C., it is possible for the addition of organic matter to improve soil moisture retention over the short term. As wireworm species are known to be sensitive to soil humidity (Parker and Seeney, 1997), cover incorporation prior to planting may favor larvae activity or preference of ovipositing females if the cover crop is not incorporated adequately or early enough prior to planting sweetpotato.

In a series of field trials in Georgia, Seal et al. (1992a) studied the effects of various cultural practices on wireworm abundance in sweetpotato. Five corn-wheat baits were collected from each of five (1.5 m^2) plots in weed-free and weedy fields primarily composed of Johnson grass (*Sorghum halpense* L.) and pigweed (*Amaranthus spinosa* L.). The number of *C. rudis* was greater in weedy compared to weed-free fields, but the abundance of *C. scissus*, *C. amplicollis*, *C. falli* and *Glyphonyx* spp. were not different between treatments. In this experiment, *C. rudis* was present during 2002 in all systems (Table 3.6). Although weeds were scant in Conv due to tillage and herbicides, we observed many weeds in Org-RT including pigweed species. In Conv, *C. rudis* accounted for 19% of the species composition, while only 9.1% was observed in Org-RT.

Yield. Total yield is reported as the sum of No. 1s, canners and jumbo market grades. Due to a reduction in yield in Org-RT in 2002, there was a significant treatment by year interaction (Table 3.7) and treatment means and differences are presented by year. Yields were lowest in 2001 compared to subsequent years of the experiment, and similar among treatments. In 2002, total yield and yields of No. 1 roots in Org-RT was lower than other treatments. Due to dry conditions, poor initial stand and consequent delayed plant establishment in this treatment, we observed root expansion and canopy closure occurred later in the season compared to other treatments. Favorable climactic conditions and improved weed control practices in 2004 contributed to high yields that were similar among treatments.

Root quality. The number of marketable No. 1 roots was different among management systems in 2001 and 2002 but not 2004 (Table 3.7). In 2001, Org-RT had 27% fewer damaged roots and Org-CI had 23% more damaged No. 1 roots compared to Conv. In 2002, Org-NC and Conv had similar amounts of marketable roots, while the number of marketable roots in cover cropped systems was at least 13% lower than the control. When expressed on a per hectare basis, there were no differences among systems.

In order to gain some insight to the relative damage caused by wireworm compared to other sources, roots were assigned to three damage categories (M, D, NM) in each of three sources (WDS, grubs and flea beetle) (Table 3.8). Each damage source was analyzed separately, and the number of roots assigned to each damage category and source is expressed as a percent of the subsample and presented as the means of six replications by management system and year. Many roots had injury that could be attributed to more than one source; therefore, some roots are represented in more than one source category. The proportion of roots designated as NM in 2001 is largely attributed to WDS. Grub damage reduced marketability in roots primarily in 2002. Flea beetle damage was a problem only in the Conv system in 2004.

Due to the high number of traps required to achieve satisfactory precision, it is difficult to correlate wireworm capture with subsequent crop damage. In Australia, 32 rolled oat baits were placed in each of 18 sugarcane one-hectare fields prior to planting (Samson and Calder, 2003). A positive and significant correlation between the number of wireworms captured and the percent reduction in yield due to wireworm damage occurred in only one out of four site-years. Although wireworm damage was minor overall, one field in particular suffered wireworm damage even though no wireworms were captured prior to planting. The authors attributed this to a reduction in bait effectiveness due in part to the heavy wet soils found at that site. Similarly, Parker (1996) found no correlation between preplant wireworm abundance and subsequent damage to potato but observed crop damage due to wireworms even when no insects were captured.

Summary. Thresholds have not been established for wireworm in sweetpotato due in part to a lack of knowledge on the biology of wireworms and difficulty predicting absolute densities due to labor constraints associated with the current sampling methods. In order for sampling and thresholds to be used successfully in sweetpotato insect management, an understanding of the biology of these pests is critical to the establishment of threshold criteria. This criteria would need to be established for a number of larval pests including grubs, WDS complex, and flea beetle. Furthermore, the development of an improved sampling technique that is quick, inexpensive, and reliable would greatly improve the chances that growers would sample prior to insecticide application. Growers currently rely on broad spectrum preplant soil incorporated fumigants (Telone II) and organophosphate insecticides (Lorsban) to control insect pests. Due to the variability of life history characteristics for the complex of wireworms, no single cultural or chemical solution will result in a decline of populations in sweetpotato production systems.

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Table 1.1 Dates of cultural practices relevant to nutrient management in management systems in 2001, 2002 and 2004.

	Date of cultural practice		
Treatment	2001	2002	2004
Organic-NC[z]			
Apply compost	19-Jun	6-Nov	12-Nov
Tandem disk harrow	22-Jun	8-Nov	13-Nov
Tandem disk harrow	---	3-May	3-Jun
Disk-ridge hills	27-Jun	10-Jun	22-Jun
Tandem disk harrow	---	12-Jun	---
Organic-CI			
Apply compost	19-Jun	6-Nov	12-Nov
Tandem disk harrow	22-Jun	8-Nov	13-Nov
Plant cover crop	30-Nov	8-Nov	13-Nov
Kill cover crop	9-May	1-May	11-May
Incorporate cover	23-May	3-May	11-May
Tandem disk harrow	---	---	3-Jun
Disk-ridge hills	27-Jun	10-Jun	22-Jun
Tandem disk harrow	---	12-Jun	---
Organic-RT			
Apply compost	19-Jun	6-Nov	12-Nov
Tandem disk harrow	---	8-Nov	13-Nov
Disk-ridge hills	30-Nov	8-Nov	13-Nov
Plant cover crop	30-Nov	8-Nov	13-Nov
Kill cover crop	2-Jul	1-May	20-May
Conventional			
Tandem disk harrow	---	3-May	---
Tandem disk harrow	27-Jun	12-Jun	3-Jun
Apply NH_4NO_3	30-Jul	10-Jul	27-Jul
Disk-ridge hills	27-Jun	10-Jun	22-Jun
All treatments			
Apply boron	24-May	4-May	20-May
Plant	2-Jul	13-Jun	29-Jun
Harvest	15-Oct	26-Sep	1-Oct

[z]Organic-NC = organically managed with compost, tillage and no cover crop; Organic-CI = organically managed with compost and cover crop preplant incorporated; Organic-RT = organically managed with compost and cover crop reduced tillage; Conventional = conventionally managed with tillage and chemical controls.

Table 1.2 Average monthly precipitation and temperature for 2001, 2002 and 2004 and the 30-yr average for Goldsboro, NC.

	Average Monthly Precipitation			
	2001	2002	2004	30-yr Av.
Month	mm			
June	124.2	36.8	124.5	100.8
July	111.5	144.3	126.2	136.9
August	123.2	98.0	179.3	144.8
September	86.1	65.8	154.9	135.6
October	23.9	29.7	24.9	78.0
Sum	468.9	374.7	609.9	596.1
	Average Monthly Temperature			
	2001	2002	2004	30-yr Av.
Month	°C			
June	24.7	24.9	24.2	25.2
July	24.1	26.7	26.3	27.3
August	25.0	25.6	24.0	26.4
September	20.7	22.8	22.1	23.3
October	15.4	17.3	16.7	17.1
Average	22.0	23.4	22.6	23.9

Table 1.3 Selected characteristics of compost used in organic management systems in 2001, 2002 and 2004.

Year	Total N	P	K	Ca	Mg	pH	C:N	Dry matter
			$g\ kg^{-1}$					%
2001	16.3	9.9	12.6	18.0	2.7	5.9	25.9	52.7
2002	12.4	5.6	4.8	27.2	2.1	6.8	23.3	60.4
2004	14.3	14.7	15.3	60.9	4.3	7.8	13.1	61.9

[z]Total N (Urea + NO_3 + NH_4) reported on a dry weight basis

Table 1.4. Hairy vetch and rye dry matter production (above ground biomass), C:N ratio, N concentration and N content in Org-CI and Org-RT in 2001, 2002 and 2004.

	Above ground biomass[z]		C:N ratio		N concentration[x]		N content	
Year	Mg ha^{-1}				%		kg ha^{-1}	
2001	13.6	a[y]	32.1	a	13.7	a	186.4	a
2002	9.8	b	30.2	a	14.9	a	142.4	b
2004	8.0	c	28.1	a	16.4	a	127.9	b

[z]Cover crop biomass and N content were square root transformed for homogeneity of variance.

[x]N concentration is the sum of inorganic and organic N.

[y]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table 1.5 Gravimetric soil moisture (%) in management systems at six sample dates indicated here as days after planting (DAP) in 2001, 2002 and 2004.

	Soil moisture (%)											
Management	Date 1		Date 2		Date 3		Date 4		Date 5		Date 6	
2001	14 DAP		45 DAP		58 DAP		68 DAP		76 DAP		103 DAP	
Organic-NC	14.1	b[z]	17.7	b	15.7	a	18.3	a	16.6	a	15.6	a
Organic-CI	16.0	a	20.7	a	16.3	a	19.0	a	18.1	a	16.4	a
Organic-RT	13.6	b	16.9	b	13.6	a	15.1	b	14.7	a	14.8	a
Conventional	14.4	ab	18.4	ab	14.9	a	17.6	ab	15.7	a	14.5	a
2002	8 DAP		35 DAP		41 DAP		51 DAP		69 DAP		105 DAP	
Organic-NC	10.0	a	7.5	bc	4.4	a	6.2	ab	10.6	a	9.1	a
Organic-CI	10.9	a	8.8	b	5.0	a	6.6	ab	10.6	a	10.8	a
Organic-RT	9.9	a	11.3	a	5.8	a	7.2	a	11.3	a	10.9	a
Conventional	9.0	a	6.9	c	4.2	a	5.2	b	11.9	a	10.3	a
2004	18 DAP		31 DAP		44 DAP		56 DAP		74 DAP		93 DAP	
Organic-NC	9.7	a	11.4	b	9.8	a	14.8	a	14.1	a	15.0	a
Organic-CI	10.1	a	13.1	ab	10.5	a	16.3	a	15.9	a	15.9	a
Organic-RT	11.4	a	14.0	a	10.5	a	14.7	a	14.2	a	14.9	a
Conventional	10.4	a	12.6	ab	10.3	a	15.4	a	14.9	a	16.9	a

[z]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table 1.6 Analysis of variance combined over 2 years (2002 and 2004) for total inorganic (NH_4 + NO_3) soil nitrogen (kg N ha^{-1}).

Source of variation	df	Significance
Year (Y)	1	NS
Error a	10	---
Date (D)	3	***
D*Y	3	***
Error b	30	---
Management (M)	3	***
M*D	9	***
M*Y	3	**
M*D*Y	9	*
Error c	120	---
Contrasts		
Conv vs. Org (3)		*
No cover (2) vs. cover (2)		**
Tillage organic (2) vs. no tillage organic (1)		***

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 1.7 Analysis of variance combined over 3 years (2001, 2002, and 2004) and protected LSDs averaged over sampling dates in management systems by year for soil nutrient content (kg ha^{-1}) , pH and base saturation (%).

Management	P		K		Ca		Mg		pH		Basesat	
	Nutrient content (kg ha^{-1})										(%)	
2001												
Organic-NC	734.1	b[z]	411.8	b	21850.5	a	5208.5	a	6.0	a	85.5	a
Organic-CI	802.4	a	492.9	a	21766.7	a	5086.9	b	5.9	b	84.2	ab
Organic-RT	831.8	a	466.4	a	22016.7	a	5005.9	b	5.9	b	83.5	b
Conventional	513.2	c	366.7	c	20983.3	b	4813.3	c	5.8	b	81.2	c
2002												
Organic-NC	1258.4	c	358.4	b	1423.7	b	333.4	a	6.2	a	84.9	a
Organic-CI	1279.4	c	389.0	a	1459.7	ab	390.0	a	6.0	b	83.4	b
Organic-RT	1369.9	a	355.8	b	1497.3	a	329.6	a	6.2	a	84.5	a
Conventional	1329.1	b	302.7	c	1202.5	c	315.9	a	5.9	c	80.1	c
2004												
Organic-NC	701.7	a	365.3	a	1413.1	a	205.6	a	5.6	ab	83.0	a
Organic-CI	663.6	a	387.9	a	1421.6	a	210.5	a	5.5	b	82.3	ab
Organic-RT	700.4	a	380.1	a	1449.0	a	214.5	a	5.6	a	81.8	b
Conventional	575.7	b	314.7	b	1069.6	b	204.8	a	5.3	c	76.0	c

Statistics

Source of variation	df	P	K	Ca	Mg	pH	Basesat
Year (Y)	2	***	NS	***	***	***	NS
Error a	15	---	---	---	---	---	---
Date (D)	3	**	***	NS	**	***	***
D*Y	6	**	***	**	**	***	***
Error b	45	---	---	---	---	---	---
Management (M)	3	**	**	***	**	***	***
M*D	9	NS	NS	NS	NS	NS	***
M*Y	6	***	*	*	**	*	*
M*D*Y	18	NS	NS	NS	NS	NS	NS
Error c	180	---	---	---	---	---	---

[z]Base saturation is the percentage of the cation exchange capacity occupied by the basic cations calcium, magnesium and potassium.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table 1.8. Analysis of variance and protected LSDs at 30 DAP and year (2001, 2002 and 2004) of sweetpotato leaf nutrient concentrations.

	N		P		K		Ca		Mg	
	30 DAP		30 DAP		30 DAP		30 DAP		30 DAP	
Management	Concentration (%)									
2001										
Organic-NC	5.50	a[z]	0.51	a	3.64	a	0.42	a	0.32	a
Organic-CI	5.45	a	0.50	a	3.46	a	0.46	a	0.32	a
Organic-RT	5.52	a	0.50	a	3.36	a	0.50	a	0.33	a
Conventional	5.56	a	0.51	a	3.66	a	0.40	a	0.33	a
2002										
Organic-NC	5.51	a	0.41	a	3.60	a	0.61	c	0.43	b
Organic-CI	5.56	a	0.41	a	3.65	a	0.72	b	0.48	b
Organic-RT	5.57	a	0.37	b	3.53	a	0.92	a	0.64	a
Conventional	5.56	a	0.40	a	3.28	a	0.67	bc	0.47	b
2004										
Organic-NC	5.37	a	0.51	a	3.88	a	0.51	a	0.34	a
Organic-CI	5.76	a	0.50	a	3.80	a	0.52	a	0.33	a
Organic-RT	5.53	a	0.49	a	3.94	a	0.55	a	0.34	a
Conventional	5.45	a	0.48	a	3.82	a	0.51	a	0.34	a

Statistics		N	P	K	Ca	Mg
Source of variation	df	Significance				
Year (Y)	2	***	***	***	***	***
Error a	15	---	---	---	---	---
Date (D)	1	***	***	NS	**	***
D*Y	2	***	NS	***	***	***
Error b	15	---	---	---	---	---
Management (M)	3	*	*	NS	***	***
M*D	3	NS	NS	NS	**	**
M*Y	6	NS	NS	**	***	***
M*D*Y	6	NS	NS	NS	*	**
Error c	90	---	---	---	---	---

[z]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS],*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 1.9. Protected LSDs at 60 DAP and year (2001, 2002 and 2004) of sweetpotato leaf nutrient concentrations.

	N		P		K		Ca		Mg	
	60 DAP		60 DAP		60 DAP		60 DAP		60 DAP	
Management										
2001										
Organic-NC	5.76	a[z]	0.46	a	3.95	a	0.53	a	0.37	a
Organic-CI	5.95	a	0.50	a	3.87	a	0.52	a	0.38	a
Organic-RT	5.38	a	0.45	a	3.82	a	0.55	a	0.37	a
Conventional	4.99	a	0.45	a	4.12	a	0.54	a	0.32	a
2002										
Organic-NC	3.90	a	0.33	a	2.93	a	0.49	b	0.36	a
Organic-CI	3.97	a	0.35	a	2.94	a	0.59	a	0.39	a
Organic-RT	3.72	a	0.34	a	2.90	a	0.63	a	0.41	a
Conventional	4.11	a	0.36	a	2.74	a	0.64	a	0.44	a
2004										
Organic-NC	4.10	b	0.45	b	3.79	c	0.44	a	0.30	a
Organic-CI	4.56	a	0.51	a	4.34	a	0.44	a	0.31	a
Organic-RT	4.09	b	0.46	b	4.02	b	0.42	a	0.31	a
Conventional	4.19	b	0.45	b	3.92	bc	0.43	a	0.31	a

[z]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table 1.10. Analysis of variance and protected LSDs of sweetpotato yield by market grade in management systems in 2001, 2002 and 2004.

	Total[z]		Jumbos		Canners		No. 1s		No. 1s	
Management			kg ha^{-1}						%	
2001										
Organic-NC	15447	a[x]	40	a	5693	ab	9457	a	61.5	ab
Organic-CI	15405	a	67	a	4944	b	10008	a	64.5	ab
Organic-RT	14285	a	12	a	7601	a	6405	a	44.5	c
Conventional	15468	a	16	a	7574	a	7679	a	50.0	bc
2002										
Organic-NC	21774	a	665	a	8139	a	30944	a	70.8	a
Organic-CI	19216	a	620	a	7678	a	26680	a	73.6	a
Organic-RT	4948	b	85	a	4332	a	9862	b	47.9	b
Conventional	16718	a	174	a	7546	a	24831	a	67.2	a
2004										
Organic-NC	31036	a	1830	a	7796	a	20976	a	67.3	a
Organic-CI	29577	a	3303	a	7239	a	18898	a	64.0	a
Organic-RT	28822	a	1350	a	8082	a	18876	a	65.6	a
Conventional	28362	a	769	a	9765	a	17085	a	60.8	a

Statistics		Total	Jumbos	Canners	No. 1s	No.1s
			kg ha^{-1}			%
Source of variation	df			Significance		
Year	2	**	***	NS	**	**
Error a	15	---	---	---	---	---
Management	3	**	*	NS	***	**
Management*year	6	**	NS	**	**	*
Error b	45	---	---	---	---	---

[z]Yield variables were square root transformed for homogeniety of variance prior to analysis.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 2.1. Dates of cultural practices used in weed control of management systems in 2001, 2002, and 2004.

	Date of weed control event		
Treatment	2001	2002	2004
Organic-NC[z]			
Rolling cultivator	10-Jul	25-Jun	6-Jul
Rolling cultivator	2-Aug	7-Jul	12-Jul
Rolling cultivator	---	10-Jul	20-Jul
Hand removal	---	1-Jul	20-Jul
Mow	18-Aug	---	---
Organic-CI			
Rolling cultivator	10-Jul	25-Jun	6-Jul
Rolling cultivator	2-Aug	10-Jul	12-Jul
Rolling cultivator	---	---	20-Jul
Hand removal	---	1-Jul	20-Jul
Mow	18-Aug	---	---
Organic-RT			
Hand removal	10-Jul	25-Jun	6-Jul
Hand removal	24-Jul	1-Jul	12-Jul
Hand removal	---	---	20-Jul
Mow	18-Aug	---	---
Conventional			
Fumigation[x]	19-Jun	15-May	10-Jun
Herbicide 1	26-Jun	31-May	24-Jun
Herbicide 2	3-Jul	14-Jun	29-Jun
Rolling cultivator	10-Jul	25-Jun	6-Jul
Rolling cultivator	2-Aug	10-Jul	12-Jul
Rolling cultivator	---	---	20-Jul
Hand removal	---	1-Jul	20-Jul
All treatments			
Plant	2-Jul	13-Jun	29-Jun
Harvest	15-Oct	26-Sep	1-Oct

[z]Organic-NC = organically managed, no cover crop; Organic-CI = organically managed, cover crop incorporated; Organic-RT = organically managed, reduced tillage; Conventional = conventionally managed check.

[x]Fumigation = 1,3-Dichloropropene; Herbicide 1 = S-ethyl dipropylthiocarbamate; Herbicide 2 = Napropramide.

Table 2.2. Analysis of variance combined over 3 years (2001, 2002, and 2004) and means by year for cover crop and weed biomass sampled prior to mechanical kill.

Treatment	Cover crop biomass[z] 2001		Cover crop biomass[z] 2002		Cover crop biomass[z] 2004		Weed dry biomass[x] 2001	Weed dry biomass[x] 2002		Weed dry biomass[x] 2004	
	$g\ m^{-2}$										
Organic-NC	N/A		N/A		N/A		no data	227	a	452	a
Organic-CI	1353	a[y]	967	a	741	a	0	0	b	0	b
Organic-RT	1382	a	1037	a	875	a	0	0	b	0	b
Conventional	N/A		N/A		N/A		no data	259	a	367	a

Analysis of variance

Source of variation	Cover crop biomass df	Cover crop biomass Significance	Weed biomass df	Weed biomass Significance
Year	2	**	1	NS
Error a	15	---	10	---
Management	1	NS	1	NS
Management*year	2	NS	1	NS
Error b	15	---	10	---

[z]Variables were square root transformed for homogeniety of variance.

[x]Data for 2002 and 2004 only.

[y]Values followed by different letters within column and year are different by Fisher's protected LSD, $P \leq 0.05$.

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 2.3. Analysis of variance combined over 3 years (2001, 2002, and 2004) for cumulative monocot and dicot weed density and weed biomass at sweetpotato harvest.

		Cumulative weed density[z]		Weed biomass	
		Monocot[y]	Dicot	Monocot	Dicot
Source of variation	df	no. season^{-1}		g m^{-2}	
Year	2	**	***	*	NS
Error a	15	---	---	---	---
Management	3	***	*	***	***
Management*year	6	*	*	***	NS
Error b	45	---	---	---	---

[z]Density of monocot and dicot weeds summed over all sample dates.

[y]Monocot and dicot weed density and dicot dry weight were square root transformed for homogeniety of variance.

NS.*.**.***Nonsignificant or significant at P≤ 0.05, 0.01, or 0.0001, respectively.

Table 2.4. Cumulative monocot and dicot weed density and monocot and dicot biomass at harvest in 2001, 2002 and 2004.

	Cumulative weed density				Weed biomass			
	Monocot[z]		Dicot		Monocot		Dicot	
Management	no. $season^{-1}$				$g\ m^{-2}$			
2001								
Organic-NC	102.4	b	220.0	a	83.2	b	65.0	a
Organic-CI	91.9	b	202.5	ab	52.2	b	95.2	a
Organic-RT	298.7	a	322.4	a	344.7	a	79.0	a
Conventional	8.8	c	101.4	b	8.1	b	1.2	b
2002								
Organic-NC	11.4	b	72.8	a	0.0	b	7.8	bc
Organic-CI	20.3	ab	57.3	a	9.1	b	35.8	ab
Organic-RT	50.1	a	19.7	b	364.7	a	50.9	a
Conventional	8.3	b	18.0	b	1.3	b	0.6	c
2004								
Organic-NC	58.0	a	875.5	a	32.5	a	80.9	a
Organic-CI	45.8	a	1170.5	a	1.0	a	34.4	a
Organic-RT	104.9	a	411.2	a	53.9	a	42.0	a
Conventional	18.2	a	749.0	a	27.4	a	0.7	a

[z]Monocot and dicot weed density were square root transformed for homogeniety of variance. Backtransformed data are presented here.

[x]Values followed by different letters within column and year are different by Fisher's protected LSD, P≤ 0.05.

Table 2.5. Scientific name, BAYER code[z], and common name of weed species grouped according to similar characteristics and present in at least one treatment and year at locations in 2001, 2002, and 2004.

Scientific name	BAYER Code	Common name
Amaranthus spp.[y]	AMAZZ	Pigweed species
Urochloa platyphylla (Nash) R.D. Webster	BRAPP	Broadleaf signalgrass
Capsella bursa-pastoris (L.) Medik.	CAPBP	Shepard's-purse
Senna obtusifolia (L.) H.S. Irwin & Barneby	CASOB	Sicklepod
Chenopodium album L.	CHEAL	Common lambsquarters
Coronopus didymus (L.) Sm.	COPDI	Lesser swinecress
Cynodon dactylon (L.) Pers.	CYNDA	Bermudagrass
Cyperus esculentus L.	CYPES	Yellow nutsedge
Digitaria sanguinalis (L.) Scop.	DIGSA	Large crabgrass
Eleusine indica (L.) Gaertner	ELEIN	Goose grass
Gamochaeta purpurea (L.) Cabrera	GNAPU	Purple cudweed
Ipomoea spp.[x]	IPOZZ	Morning glory species
Lamium amplexicaule L.	LAMAM	Henbit
Lepidium virginicum L.	LEPVI	Virgina pepperweed
Mollugo verticillata L.	MOLVE	Carpetweed
Oxalis stricta L.	OXAST	Yellow woodsorrel
Phytolacca americana L.	PHTAM	Pokeweed
Plantago lanceolata L.	PLALA	Buckhorn plantain
Polygonum pensylvanicum L.	POLPY	Pennsylvania smart weed
Portulaca oleraceae L.	POROL	Common purslane
Raphanus raphanistrum L.	RAPRA	Wild raddish
Rumex cripus L.	RUMCR	Curly dock
Sida rhombifolia L.	SIDRH	Arrowleaf sida
Sida spinosa L.	SIDSP	Prickly sida
Solanum carolinense L.	SOLCA	Horsenettle
Solanum nigrum L.	SOLNI	Eastern black nightshade
Solidago fistulosa Mill.	SOOFI	Hollow goldenrod
Sorghum halepense (L.) Pers.	SORHA	Johnsongrass
Sorghum bicolor (L.) Moench **X** *S. sudanense* (Piper) Staph.	SORVU	Sorghum sudangrass
Vicia angustifolia L.	VICAN	Narrow leaf vetch

[z]WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available on computer disk from WSSA, Lawrence, KS.

[y]*Amaranthus spp. = Amaranthus hybridus* L. (AMACH) smooth pigweed, *Amaranthus palmeri* S. Wats. (AMAPA) palmer amaranth, *Amaranthus retroflexus* L. (AMARE) redroot pigweed and *Amaranthus spinosus* L. (AMASP) spiny pigweed.

[x]*Ipomoea* spp. = *Ipomoea coccinea* L. (IPOCC) red morningglory, *Ipomoea hederacea* Jacq. (IPOHE) ivyleaf morningglory, *Ipomoea lacunosa* L. (IPOLA) pitted morningglory, *Ipomoea purpurea* (L.) Roth (PHBPU) tall morningglory.

Table 2.6. Weed composition within management systems in 2001, 2002, and 2004. Mean density for each treatment and year expressed as a percentage of cumulative total weed density (CTWD).

	2001				2002			
	Org-NC	Org-CI	Org-RT	Conv	Org-NC	Org-CI	Org-RT	Conv
Weeds	Percent (%)							
AMAZZ[z]	11.8	11.1	8.5	14.2	20.0	12.8	5.0	6.8
BRAPP	4.4	3.3	5.5	1.1	21.0	32.5	57.4	38.1
CAPBP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASOB	0.0	0.5	0.1	0.7	0.6	0.3	0.0	0.0
CHEAL	0.0	1.3	0.1	0.0	0.0	0.0	0.0	0.0
CYNDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CYPES	1.0	0.8	9.3	1.2	3.9	4.0	13.1	5.9
DIGSA	1.6	4.1	7.0	0.7	0.0	0.8	0.6	0.0
ELEIN	44.7	44.5	39.9	19.9	1.1	0.0	0.0	0.0
GNAPU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IPOZZ[y]	5.1	9.1	3.3	11.1	7.5	9.1	7.8	11.6
LAMAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEPVI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MOLVE	9.5	4.1	8.6	19.9	16.9	22.2	0.0	12.8
OXAST	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
PLALA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RAPRA	0.0	0.0	0.0	0.0	10.3	2.4	0.0	12.8
SIDRH	14.7	10.7	6.0	20.4	0.0	0.0	0.0	0.0
SIDSP	5.8	3.5	3.3	4.3	15.6	15.6	4.4	11.9
SOLCA	0.9	6.9	6.2	6.2	0.0	0.0	0.0	0.0
SOLNI	0.5	0.2	0.1	0.4	0.0	0.0	0.0	0.0
SOOFI	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
SORHA	0.0	0.0	0.0	0.0	1.1	0.3	0.0	0.0
SORVU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VICAN	0.0	0.0	1.0	0.0	1.9	0.0	9.1	0.0
Monocot	51.7	52.6	61.8	22.9	27.1	37.6	71.2	44.0
Dicot	48.3	47.4	38.2	77.1	72.9	62.4	28.9	56.0
	No. m^{-2} per season							
CTWD	113.3	87.1	195.7	35.5	32.8	38.4	51.2	16.5

[y]*Amaranthus* spp. = *Amaranthus hybridus* L. (AMACH) smooth pigweed, *Amaranthus palmeri* S. Wats. (AMAPA) palmer amaranth, *Amaranthus retroflexus* L. (AMARE) redroot pigweed and *Amaranthus spinosus* L. (AMASP) spiny pigweed.

[y]*Ipomoea* spp. = *Ipomoea coccinea* L. (IPOCC) red morningglory, *Ipomoea hederacea* Jacq. (IPOHE) ivyleaf morningglory, *Ipomoea lacunosa* L. (IPOLA) pitted morningglory, *Ipomoea purpurea* (L.) Roth (PHBPU) tall morningglory.

Table 2.6. (Continued)

	2004			
	Org-NC	Org-CI	Org-RT	Conv
Weeds	Percent (%)			
AMAZZ[z]	5.4	2.7	0.4	14.4
BRAPP	0.5	0.1	3.9	0.2
CAPBP	3.2	0.2	0.6	0.9
CASOB	0.0	0.0	0.0	0.0
CHEAL	0.0	0.0	0.0	0.0
CYNDA	0.0	0.3	0.1	0.0
CYPES	1.5	0.2	6.9	6.8
DIGSA	0.1	0.1	5.1	0.2
ELEIN	9.9	7.2	5.1	3.4
GNAPU	2.6	1.9	0.1	0.8
IPOZZ[y]	1.8	0.2	1.4	4.3
LAMAM	5.0	0.0	2.2	9.9
LEPVI	10.3	2.6	2.4	4.5
MOLVE	52.9	77.0	38.4	42.9
OXAST	0.1	1.0	1.9	0.8
PLALA	0.0	0.0	1.8	0.0
RAPRA	0.0	0.0	0.0	0.0
SIDRH	1.3	1.2	2.0	0.8
SIDSP	0.8	0.8	0.5	1.4
SOLCA	0.0	0.0	0.0	0.0
SOLNI	0.1	0.1	0.3	0.5
SOOFI	0.0	0.0	0.0	0.0
SORHA	0.0	0.0	0.0	0.0
SORVU	4.0	4.7	12.2	7.5
VICAN	0.6	0.2	15.5	0.6
Monocot	16.1	12.3	33.2	18.2
Dicot	83.9	87.7	66.8	81.8
	No. m^{-2} per season			
CTWD	237.8	312.0	586.5	157.0

Table 2.7. Weed species diversity in management systems in 2001, 2002 and 2004.

Management	Species diversity no. species	
2001		
Organic-NC	7.7	bc[z]
Organic-CI	9.2	ab
Organic-RT	10.2	a
Conventional	6.0	c
2002		
Organic-NC	5.8	a
Organic-CI	5.3	a
Organic-RT	4.7	a
Conventional	3.8	a
2004		
Organic-NC	9.2	b
Organic-CI	8.3	b
Organic-RT	11.0	a
Conventional	8.5	b

Analysis of variance

Source of variation	df	Significance
Year	2	***
Error a	15	---
Management	3	**
Management*year	6	*
Error b	45	---

[y]Values followed by different letters within column and year are different by Fisher's protected LSD, P≤ 0.05.

NS.*.**.***Nonsignificant or significant at P≤ 0.05, 0.01, or 0.0001, respectively.

Table 2.8. Sweetpotato vine biomass (g m^{-2}) at harvest and total sweetpotato yield in 2001, 2002 and 2004.

Management	Sweetpotato vine		Total yield	
	g m^{-2}		hg ha^{-1}	
2001				
Organic-NC	328.7	a	15938	a
Organic-CI	305.6	a	16053	a
Organic-RT	144.5	b	14492	a
Conventional	357.1	a	15777	a
2002				
Organic-NC	361.2	a	31090	a
Organic-CI	376.0	a	27492	a
Organic-RT	153.8	b	11177	b
Conventional	390.1	a	24943	a
2004				
Organic-NC	704.7	a	31572	a
Organic-CI	776.2	a	29813	a
Organic-RT	694.9	a	28949	a
Conventional	742.7	a	28530	a

Analysis of variance

Source of variation	df	Significance
Year	2	***
Error a	15	---
Management	3	**
Management*year	6	*
Error b	45	---

[z]Sweetpotato vine dry weight was square root transformed for homogeniety of variance. Backtransformed data are presented here.

[x]Values followed by different letters within column and year are different by Fisher's protected LSD, P≤ 0.05.

NS.*.**.***Nonsignificant or significant at P≤ 0.05, 0.01, or 0.0001, respectively.

Table 2.9. Pearson correlation coefficients for selected comparisons during 2001, 2002 and 2004.

Comparisons	r	Significance
All treatments		
Total weed biomass*sweetpotato vine biomass[z]	-0.31	**
Total weed biomass*total yield	-0.30	*
Sweetpotato vine biomass*total yield	0.55	***
Organic-RT		
Cover crop residue*total weed density	-0.60	**
Cover crop residue*sweetpotato vine biomass	0.66	**
Cover crop residue*total yield	0.55	*

[z]Total weed biomass = sum of monocot and dicot weed biomass; total weed density = sum of monocot and dicot seasonal weed density.

[NS,*,**,***]Nonsignificant or significant at P≤ 0.05, 0.01, or 0.0001, respectively.

Table 3.1. Analysis of variance combined over 3 years (2001, 2002, and 2004) and means by year for cover crop and weed biomass sampled prior to mechanical kill.

	Cover crop biomass[z]						Weed dry biomass[x]				
Treatment	2001		2002		2004		2001	2002		2004	
	g m^{-2}										
Organic-NC	N/A		N/A		N/A		no data	227	a	452	a
Organic-CI	1353	a[y]	967	a	741	a	0	0	b	0	b
Organic-RT	1382	a	1037	a	875	a	0	0	b	0	b
Conventional	N/A		N/A		N/A		no data	259	a	367	a

Analysis of variance

	Cover crop biomass		Weed biomass	
Source of variation	df	Significance	df	Significance
Year	2	**	1	NS
Error a	15	---	10	---
Management	1	NS	1	NS
Management*year	2	NS	1	NS
Error b	15	---	10	---

[z]Variables were square root transformed for homogeniety of variance.

[x]Data for 2002 and 2004 only.

[y]Values followed by different letters within column and year are different by Fisher's protected LSD, $P \leq 0.05$.

NS.*.**.***Nonsignificant or significant at P≤ 0.05, 0.01, or 0.0001, respectively.

Table 3.2. Gravimetric soil moisture (%) in management systems at six sample dates indicated here as days after planting (DAP) in 2001, 2002 and 2004.

Management	Soil moisture (%)											
	Date 1		Date 2		Date 3		Date 4		Date 5		Date 6	
2001	14 DAP		45 DAP		58 DAP		68 DAP		76 DAP		103 DAP	
Organic-NC	14.1	b[z]	17.7	b	15.7	a	18.3	a	16.6	a	15.6	a
Organic-CI	16.0	a	20.7	a	16.3	a	19.0	a	18.1	a	16.4	a
Organic-RT	13.6	b	16.9	b	13.6	a	15.1	b	14.7	a	14.8	a
Conventional	14.4	ab	18.4	ab	14.9	a	17.6	ab	15.7	a	14.5	a
2002	8 DAP		35 DAP		41 DAP		51 DAP		69 DAP		105 DAP	
Organic-NC	10.0	a	7.5	bc	4.4	a	6.2	ab	10.6	a	9.1	a
Organic-CI	10.9	a	8.8	b	5.0	a	6.6	ab	10.6	a	10.8	a
Organic-RT	9.9	a	11.3	a	5.8	a	7.2	a	11.3	a	10.9	a
Conventional	9.0	a	6.9	c	4.2	a	5.2	b	11.9	a	10.3	a
2004	18 DAP		31 DAP		44 DAP		56 DAP		74 DAP		93 DAP	
Organic-NC	9.7	a	11.4	b	9.8	a	14.8	a	14.1	a	15.0	a
Organic-CI	10.1	a	13.1	ab	10.5	a	16.3	a	15.9	a	15.9	a
Organic-RT	11.4	a	14.0	a	10.5	a	14.7	a	14.2	a	14.9	a
Conventional	10.4	a	12.6	ab	10.3	a	15.4	a	14.9	a	16.9	a

[z]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 3.3. Mean number of total wireworm larvae prior to sweetpotato planting in management systems in 2001, 2002 and 2004.

Management		All species[z] Mean no. $trap^{-1y}$
Organic-NC[x]		0.7 a[w]
Organic-CI		0.3 b
Organic-RT		0.5 ab
Conventional		1.8 a
Statistics		
Source of variation	df	Significance
Year (Y)	2	***
Error a	15	---
Management (M)	3	*
M*Y	6	NS
Error b	45	---

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

[z]All species = the mean number per trap of all species captured averaged over year including *M.communis*, *M. verbans*, *Conoderus vespertinus*, *C. ampicollis*, *C. lividus*, *C. falli*, *C. bellus*, *C. scissus*, *C. rudis*, *Glyphonyx* spp., *Aeolus* spp. and *Limonius* spp..

[y]All variables were log base 10 (n + 1) transformed prior to analysis, and backtransformed means presented here.

[x]Organic-NC = organically managed with tillage and no cover crop; Organic-CI = organically managed with tillage and cover crop; Organic-RT = organically managed with reduced tillage and cover crop; and Conventional = conventionally managed chemical and tilled control.

[w]Values within a column followed by the same letter are not different (Fisher's protected LSD test (P= 0.05).

Table 3.4. Analysis of variance combined over years (2001, 2002 and 2004) and sample dates for the mean number of insects per trap.

		All species[z]	*M. communis*	*Conoderus* spp.
Source of variation	df	Significance[y]		
Year (Y)	2	**	**	**
Error a	15	---	---	---
Management (M)	3	**	*	**
M*Y	6	**	*	NS
Error b	45	---	---	---
Date (D)	5	NS	NS	NS
Y*D	7	NS	NS	NS
Error c	60	---	---	---
M*D	15	NS	NS	NS
M*D*Y	21	NS	NS	NS
Error d	180	---	---	---

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

[z]All species = the mean number per trap of all species recovered including *M.communis*, *M. verbans*, *Conoderus vespertinus*, *C. ampicollis*, *C. lividus*, *C. falli*, *C. bellus*, *C. scissus*, *C. rudis*, *Glyphonyx* spp., *Aeolus* spp. and *Limonius* spp..
[y]All variables were base 10 log (n + 1) transformed prior to analysis.

Table 3.5. Mean +/- SEM of wireworm density per trap in management systems and year for combined species, *Melanotus communis*, and *Conoderus* species.

Management	All species[z]			*M. communis*			*Conoderus* spp.		
	Mean +/- SEM trap^{-1}[y]								
2001									
Organic-NC[x]	3.97	+/- 1.26	b[w]	3.51	+/- 1.24	ab	0.11	+/- 0.09	b
Organic-CI	21.74	+/- 1.14	a	13.44	+/- 1.35	a	0.82	+/- 0.37	a
Organic-RT	1.23	+/- 0.29	b	1.14	+/- 0.29	b	0.04	+/- 0.04	b
Conventional	3.86	+/- 0.35	b	3.78	+/- 0.35	ab		0.00	b
2002									
Organic-NC	1.57	+/- 0.38	ab	0.18	+/- 0.16	a	1.17	+/- 0.35	ab
Organic-CI	2.28	+/- 0.43	a	0.41	+/- 0.26	a	1.45	+/- 0.34	a
Organic-RT	0.94	+/- 0.32	ab	0.32	+/- 0.17	a	0.55	+/- 0.25	ab
Conventional	0.53	+/- 0.26	b	0.14	+/- 0.10	a	0.37	+/- 0.22	b
2004									
Organic-NC	0.60	+/- 0.17	a	0.40	+/- 0.13	a	0.17	+/- 0.10	a
Organic-CI	1.04	+/- 0.27	a	0.46	+/- 0.16	a	0.47	+/- 0.19	a
Organic-RT	1.04	+/- 0.29	a	0.51	+/- 0.18	a	0.50	+/- 0.18	a
Conventional	0.67	+/- 0.24	a	0.50	+/- 0.18	a	0.15	+/- 0.11	a
Contrasts[v]									
Conv vs. Org (3)		*			NS			**	
NCC (2) vs. CC (2)		NS			NS			NS	
Org-T (2) vs. Org-RT (1)		***			**			*	

[z]All species = *M.communis*, *M. verbans*, *Conoderus vespertinus*, *C. ampicollis*, *C. lividus*, *C. falli*, *C. bellus*, *C. scissus*, *C. rudis*, *Glyphonyx* spp., *Aeolus* spp. and *Limonius* spp..

[y]All variables were base 10 log (n + 1) transformed for homogeniety of variance prior to analysis. Statistical conclusions derived from transformed data and backtransformed means are presented here. SEM obtained from backtransformed standard deviation / √ n. In 2001, n=24; 2002, n=30; 2004, n=36.

[x]Org-NC = organically managed with tillage and no cover crop; Org-CI = organically managed with tillage and cover crop; Org-RT = organically managed with reduced tillage and cover crop; and Conv = conventionally managed chemical and tilled control.

[w]Values within a column followed by the same letter are not different (Fisher's protected LSD test (α = 0.05).

[v]Contrasts: Conv vs. Org = Conventional control compared to Org-NC, Org-CI and Org-RT combined; NCC vs. CC = Organic-NC and Conventional compared to Organic-CI and Organic-RT; and Org-T vs. Org-RT = Organic systems with tillage (Org-NC and Org-CI) compared to Org-RT.

Table 3.6. Wireworm species composition within management systems and year (2001, 2002, and 2004). Mean number of wireworms per trap for each system and year are expressed as a percentage of the grand mean (GM) per trap for each management system and year.

	2001				2002				2004			
	Org-NC[z]	Org-CI	Org-RT	Conv	Org-NC	Org-CI	Org-RT	Conv	Org-NC	Org-CI	Org-RT	Conv
Wireworm species	Percent (%)											
Melanotus communis	90.8	83.6	96.0	98.1	18.6	32.7	33.3	23.8	70.0	47.2	50.0	79.2
Melanotus verbans	6.4	5.1	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conoderus vespertinus	2.8	7.9	4.0	0.0	39.5	51.9	9.1	38.1	10.0	13.9	13.2	0.0
Conoderus ampicollis	0.0	1.4	0.0	0.0	16.3	11.5	15.2	4.7	0.0	13.9	13.2	4.2
Conoderus lividus	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conoderus falli	0.0	0.9	0.0	0.0	4.7	0.0	0.0	4.7	10.0	25.0	7.9	0.0
Conoderus bellus	0.0	0.0	0.0	0.0	7.0	0.0	24.2	0.0	0.0	0.0	5.3	0.0
Conoderus. rudis	0.0	0.0	0.0	0.0	4.7	1.9	9.1	19.0	0.0	0.0	5.3	16.7
Glyphonyx spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0
Aeolus spp.	0.0	0.9	0.0	0.0	4.7	1.9	9.1	9.5	5.0	0.0	0.0	0.0
Limonius spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0
Melanotus spp.	97.2	88.8	96.0	100.0	18.6	32.7	33.3	23.8	70.0	47.2	50.0	79.2
Conoderus spp.	2.8	10.3	4.0	0.0	76.7	65.4	57.6	66.5	20.0	52.8	44.7	20.8
Other spp.[y]	0.0	0.9	0.0	0.0	4.7	1.9	9.1	9.5	10.0	0.0	5.3	0.0
	No. trap^{-1} season^{-1}											
GM[x]	2.3	4.5	0.5	1.2	0.7	0.9	0.6	0.4	0.3	0.5	0.5	0.3

[z]Org-NC = organically managed with tillage and no cover crop; Org-CI = organically managed with tillage and cover crop; Org-RT = organically managed with reduced tillage and cover crop; and Conv = conventionally managed chemical and tilled control.

[y]Other spp. = the sum of *Glyphonyx* spp. , *Aeolus* spp. and *Limonius* spp..

[x]The mean number per trap of all species captured averaged over sample dates within management system and growing season. 2001 = 4 sample dates; 2002 = 5 sample dates; 2004 = 6 sample dates.

Table 3.7. Analysis of variance and protected LSDs of sweetpotato yield by market grade, percent damage to No. 1 roots and adjusted No.1 yield due to WDS damage only in management systems in 2001, 2002 and 2004.

	Total[z]	Jumbos	Canners	No. 1s	No. 1s	No. 1 Damage	Mrkt No. 1
Management	kg ha^{-1}					%	kg ha^{-1}
2001							
Organic-NC	15447 a[x]	40 a	5693 ab	9457 a	61.5 ab	57.0 b	4194 a
Organic-CI	15405 a	67 a	4944 b	10008 a	64.5 ab	81.0 a	2287 a
Organic-RT	14285 a	12 a	7601 a	6405 a	44.5 c	31.8 c	4654 a
Conventional	15468 a	16 a	7574 a	7679 a	50.0 bc	58.4 b	3553 a
2002							
Organic-NC	21774 a	665 a	8139 a	30944 a	70.8 a	50.4 b	10639 a
Organic-CI	19216 a	620 a	7678 a	26680 a	73.6 a	72.7 a	6251 a
Organic-RT	4948 b	85 a	4332 a	9862 b	47.9 b	78.9 a	1274 b
Conventional	16718 a	174 a	7546 a	24831 a	67.2 a	59.8 ab	6466 a
2004							
Organic-NC	31036 a	1830 a	7796 a	20976 a	67.3 a	77.0 a	5183 a
Organic-CI	29577 a	3303 a	7239 a	18898 a	64.0 a	71.7 a	5658 a
Organic-RT	28822 a	1350 a	8082 a	18876 a	65.6 a	74.9 a	4724 a
Conventional	28362 a	769 a	9765 a	17085 a	60.8 a	79.4 a	3738 a

Statistics		Total	Jumbos	Canners	No. 1s	No.1s	No. 1 Damage	Mrkt No. 1
		kg ha^{-1}					%	kg ha^{-1}
Source of variation	df				Significance			
Year (Y)	2	**	***	NS	**	**	**	NS
Error a	15	---	---	---	---	---	---	---
Management (M)	3	**	*	NS	***	**	***	*
M*Y	6	**	NS	**	**	*	***	**
Error b	45	---	---	---	---	---	---	---

[z]Yield variables were square root transformed for homogeniety of variance prior to analysis.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 3.8. Frequency (%) of harvested roots assigned to three damage categories according to the source of insect damage in management systems by year in 2001, 2002 and 2004.

	WDS[z]			Grub			Flea beetle			Total		
Management	M[y]	D	NM	M	D	NM	M	D	NM	M	D	NM
2001	Frequency (%)											
Organic-NC[x]	45.6	23.3	31.1	96.5	---	3.5	100.0	0	0.0	44.3	23.5	32.3
Organic-CI	20.6	24.3	55.2	99.3	---	0.8	100.0	0	0.0	20.3	24.4	55.4
Organic-RT	69.2	15.1	15.7	97.8	---	2.2	100.0	0	0.0	68.5	14.7	16.9
Conventional	44.3	27.8	27.8	99.5	---	0.5	100.0	0	0.0	43.8	27.8	28.4
2002												
Organic-NC	74.1	16.6	9.3	65.86	---	34.14	95.2	3.5	0.4	40.2	14.3	45.5
Organic-CI	55.2	22.8	22.1	47.93	---	52.07	96.6	3.5	1.4	49.8	10.7	39.5
Organic-RT	35.0	21.4	43.6	50.71	---	49.29	98.6	1.4	0.0	27.2	11.7	61.0
Conventional	67.1	22.7	10.1	58.04	---	41.96	92.3	7.3	0.0	20.0	7.9	72.1
2004												
Organic-NC	27.3	16.8	55.9	89.5	---	10.5	94.1	1.8	4.2	23.4	15.4	61.2
Organic-CI	29.5	15.4	55.1	92.8	---	7.2	98.6	0.7	0.7	28.1	14.7	57.2
Organic-RT	28.7	9.2	62.1	81.6	---	18.4	98.0	0.3	1.7	25.3	7.2	67.6
Conventional	27.5	11.5	61.0	84.3	---	15.7	86.4	2.8	10.8	20.6	9.4	70.0

[z]WDS = WDS = damage incurred by wireworm larvae, *Diabrotica* spp., and *Systena* spp.

[y]Damage categories as follows: M = marketable, with no to negligible damage, D = some damage but suitable for processing, and NM = not marketable with extensive damage.

[x]Org-NC = organically managed with tillage and no cover crop; Org-CI = organically managed with tillage and cover crop; Org-RT = organically managed with reduced tillage and cover crop; and Conv = conventionally managed chemical and tilled control.

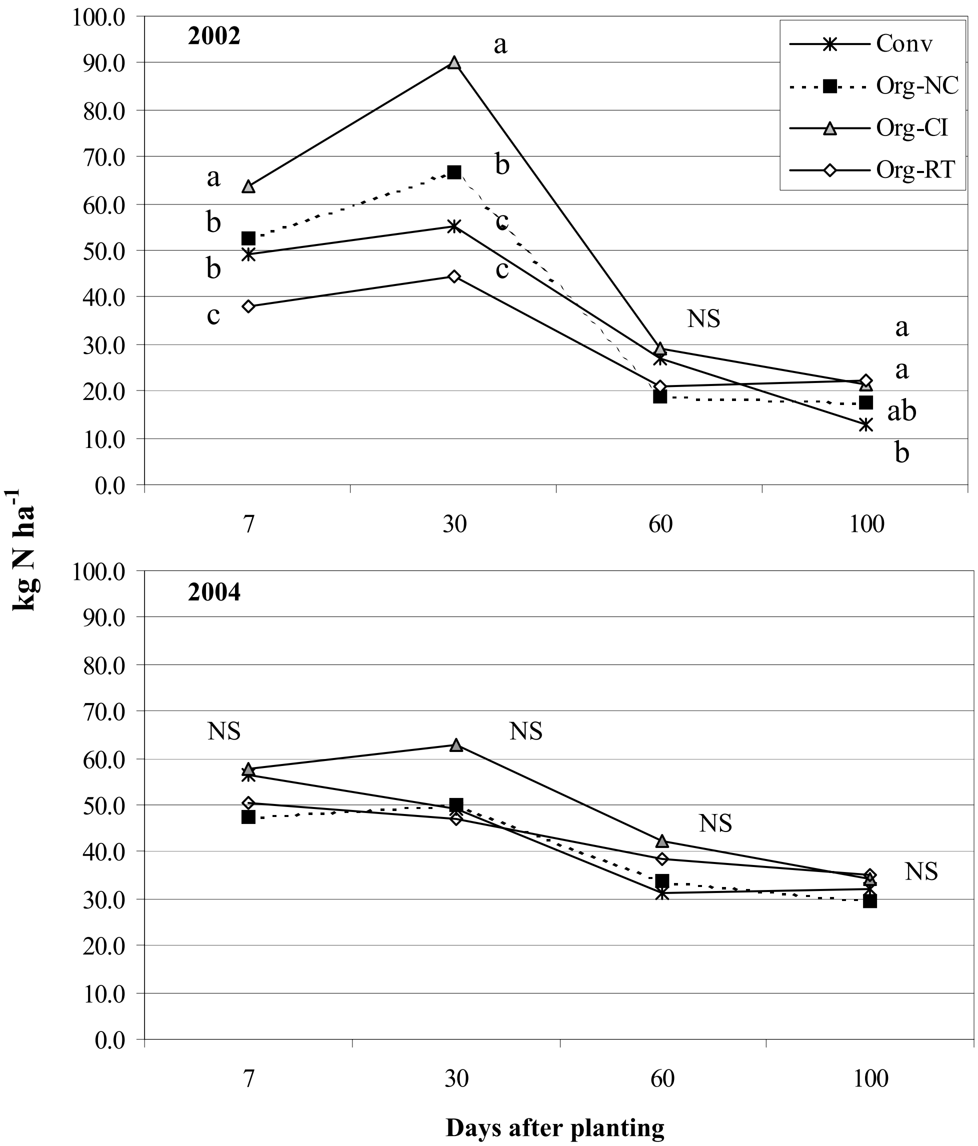

Figure 1.1. Soil total inorganic nitrogen (NO_3 + NH_4) sampled to a depth of 20 cm in management systems at 7, 30 and 60 days after planting and sweetpotato harvest averaged over 2002 and 2004. Mean separation within year and sample date by Fisher's protected $_{LSD}$ at $P \leq 0.05$.

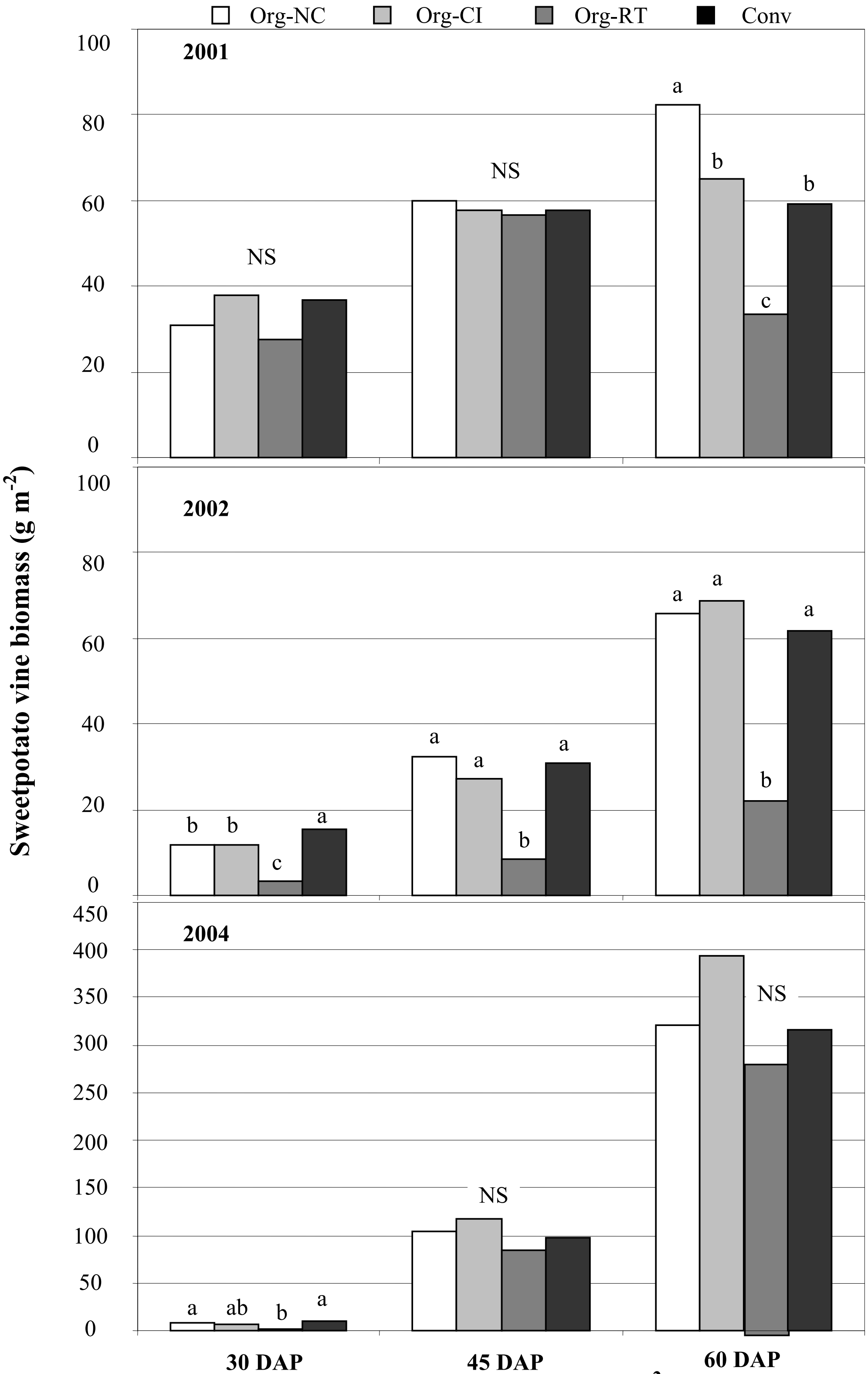

Figure 1.2 Seasonal sweetpotato vine biomass (g m^{-2}) at 30, 45 and 60 days after planting (DAP) in 2001, 2002 and 2004.

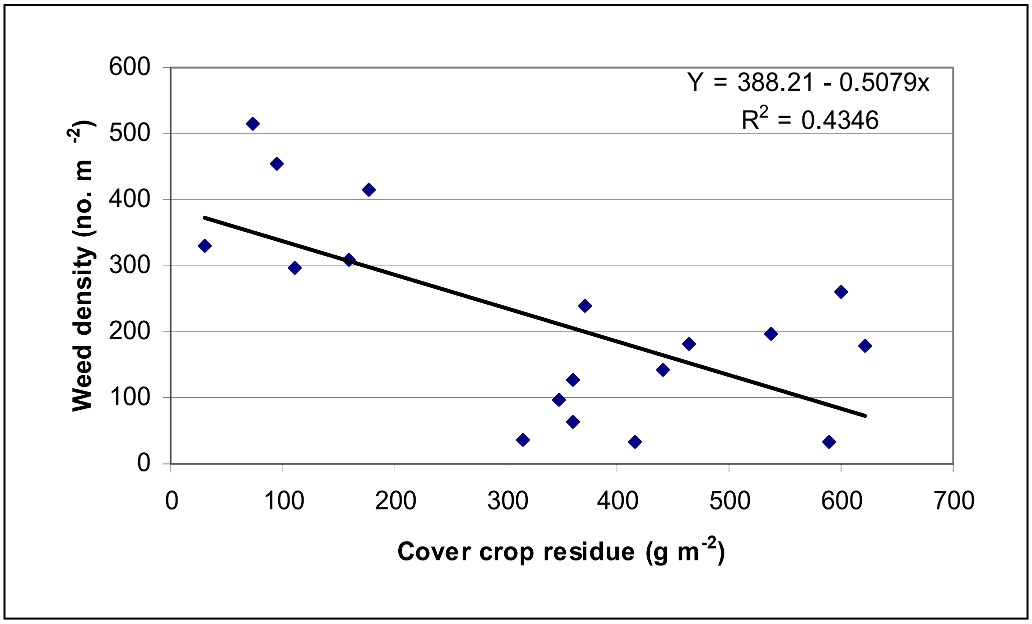

Figure 2.1 Cover crop residue and weed density in Org-RT in all years (2001, 2002 and 2004)

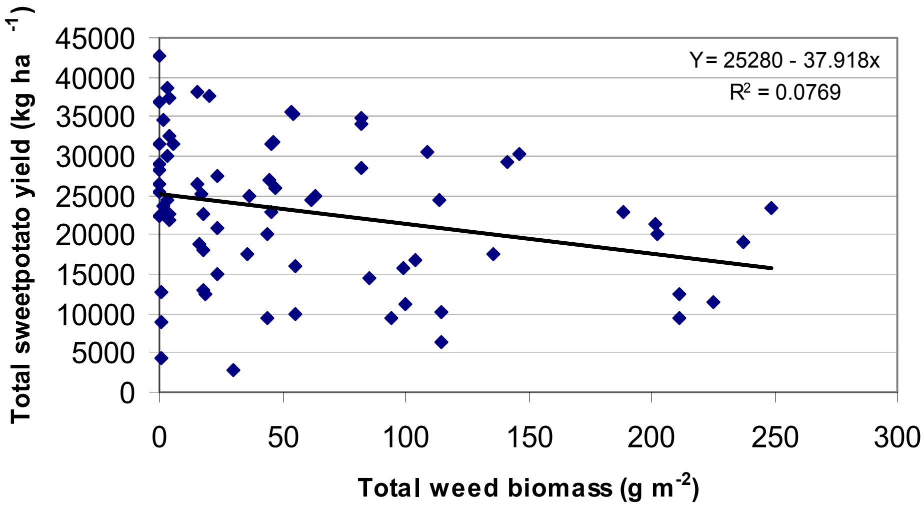

Figure 2.2 Total sweetpotato yield as a function of total weed biomass in all years (2001, 2002 and 2004).

APPENDIX A1

Table A1.1. Average monthly precipitation, temperature and growing degree days[z] for 2000-2004 and the 30-yr average for Goldsboro, NC.

	Average Monthly Precipitation					
	2000	2001	2002	2003	2004	30-yr Av.
Month	mm					
January	110.2	27.7	148.3	25.4	33.3	115.3
February	66.0	61.7	35.3	112.8	86.6	91.7
March	85.6	175.8	63.0	114.3	12.4	113.8
April	90.4	34.0	90.2	130.0	70.4	86.1
May	34.0	106.4	70.4	143.3	89.9	96.5
June	145.3	124.2	36.8	63.5	124.5	100.8
July	94.5	111.5	144.3	260.9	126.2	136.9
August	186.9	123.2	98.0	141.5	179.3	144.8
September	124.2	86.1	65.8	108.0	154.9	135.6
October	0.3	23.9	29.7	107.2	24.9	78.0
November	38.9	39.6	124.0	34.3	121.7	81.0
December	24.1	21.6	98.6	69.6	49.0	85.3
	Average Monthly Temperature					
	2000	2001	2002	2003	2004	30-yr Av.
Month	°C					
January	3.9	5.1	6.5	3.3	3.4	6.3
February	7.8	7.5	7.6	5.4	5.0	8.1
March	12.2	9.2	10.9	11.7	11.2	12.0
April	14.6	15.5	17.4	14.1	15.8	16.9
May	21.2	20.0	19.1	20.0	22.5	21.3
June	24.4	24.7	24.9	24.0	24.2	25.2
July	24.4	24.1	26.7	25.7	26.3	27.3
August	24.3	25.0	25.6	26.2	24.0	26.4
September	20.5	20.7	22.8	21.8	22.1	23.3
October	15.5	15.4	17.3	15.3	16.7	17.1
November	8.5	13.7	9.6	15.1	12.2	12.5
December	2.1	9.5	5.0	4.3	5.7	7.9
	Average Monthly Growing Degree Days					
Month	2000	2001	2002	2003	2004	30-yr Av.
January	0.0	0.0	0.0	0.0	0.0	0.0
February	38.1	0.0	0.0	0.0	0.0	0.0
March	110.4	0.0	0.0	0.0	0.0	0.0
April	137.6	0.0	24.2	0.0	5.8	0.0
May	436.2	20.1	31.2	27.4	65.0	4.2
June	547.8	109.8	119.5	87.2	96.9	127.6
July	557.1	102.4	172.6	144.8	163.0	199.6
August	536.7	124.3	140.4	157.0	98.1	168.7
September	201.0	36.7	58.2	41.2	50.2	68.1
October	202.3	0.0	17.6	1.0	6.6	0.0
November	33.5	0.0	0.0	0.0	0.0	0.0
December	0.0	0.0	0.0	0.0	0.0	0.0
Annual total	2800.7	393.3	563.6	458.6	485.5	568.2

[z]Growing degree days were calculated using a base temperature of 21.1 °C.

Table A1.2. Hairy vetch and rye dry matter production (biomass), C:N ratio, N concentration and N content in Org-CI and Org-RT in 2001, 2002 and 2004.

Year	Cover crop biomass[z] Mg ha^{-1}		C:N ratio		N concentration (%)		N content (kg ha^{-1})	
2001	13.6	a[x]	32.1	a	1.37	a	186.4	a
2002	9.8	b	30.2	a	1.49	a	142.4	b
2004	8.0	c	28.1	a	1.64	a	127.9	b

Statistics Source of variation	df	Cover crop biomass	C:N ratio	N concentration	N content
		Significance			
Year	2	**	NS	NS	**
Error a	15	---	---	---	---
Management	1	NS	NS	NS	NS
Management*year	2	NS	NS	NS	NS
Error b	15	---	---	---	---

[z]Cover crop biomass and N content were square root transformed for homogeniety of variance.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table A1.3. Weed C:N ratio and N concentration in management systems at cover crop and weed kill in 2002 and 2004.

	C:N ratio				N concentration				N content			
Treatment	2002		2004		2002		2004		2002		2004	
					g kg^{-1}				kg ha^{-1}			
Organic-NC	20.5	a	40.7	a	16.3	a	20.5	a	37.5	a	88.2	a
Organic-CI	---		---		---		---		---		---	
Organic-RT	---		---		---		---		---		---	
Conventional	20.9	a	20.9	b	15.3	a	10.6	b	32.1	a	37.1	a

Statistics		C to N ratio	N concentration	N content
Source of variation	df			
Year	1	NS	NS	NS
Error a	10	---	---	---
Management	1	**	*	**
Management*year	1	*	*	NS
Error b	10	---	---	---

[z]Weed N content was square root transformed for homogeniety of variance.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table A1.4. Soil nutrient content (kg ha^{-1}), pH and base saturation (Basesat) averaged over management systems in 2001, 2002 and 2004.

	P		K		Ca		Mg		pH		Basesat	
Sampling date	Nutrient content (kg ha^{-1})										(%)	
2001												
7 DAP	712	b[z]	477	a	21767	a	5107	a	5.6	b	85.3	a
30 DAP	732	b	449	a	21833	a	4925	a	6.0	a	83.9	ab
60 DAP	789	a	458	a	21767	a	4894	b	6.0	a	83.1	bc
Harvest	649	c	355	b	21250	b	5188	a	6.0	a	82.0	c
2002												
7 DAP	1324	ab	387	b	1269	c	293	b	5.9	c	79.3	d
30 DAP	1356	b	451	a	1464	a	352	a	6.1	b	85.7	b
60 DAP	1296	b	305	c	1355	b	305	b	6.1	b	80.5	c
Harvest	1261	c	263	d	1495	a	359	a	6.3	a	87.4	a
2004												
7 DAP	641	a	424	a	1320	b	209	b	5.8	a	83.3	a
30 DAP	668	a	430	a	1401	a	231	a	5.4	c	80.7	bc
60 DAP	661	a	312	b	1193	a	187	c	5.3	d	77.8	c
Harvest	671	a	282	b	1439	c	209	b	5.5	b	81.2	b

[z]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

TableA1.5. Analysis of variance combined over 3 years (2001, 2002, and 2004) for concentration of nutrients in sweetpotato leaf and petiole tissue.

		Concentration (%)			Concentration (ppm)			
Source of variation	df	S	Na	Fe	Mn	Zn	Cu	B
Year	2	***	***	***	NS	NS	***	***
Error a	15	---	---	---	---	---	---	---
Date	1	***	**	***	NS	**	**	***
Date*year	2	***	***	**	NS	NS	***	***
Error b	15	---	---	---	---	---	---	---
Management	3	NS	NS	NS	***	NS	NS	NS
Management*date	3	NS	NS	*	NS	NS	NS	NS
Management*year	6	NS	NS	*	*	NS	NS	NS
Management*date*year	6	NS	NS	NS	NS	NS	NS	NS
Error c	90	---	---	---	---	---	---	---

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table A1.6. Concentration of nutrients in sweetpotato leaf and petiole tissue at 30 and 60 days after planting in 2001, 2002 and 2004.

	Fe				Mn				Zn			
	30 DAP		60 DAP		30 DAP		60 DAP		30 DAP		60 DAP	
Management	Concentration (ppm)											
2001												
Organic-NC	293.3	a	108.5	a	60.1	a	59.4	ab	62.2	a	33.4	a
Organic-CI	249.5	a	103.5	a	54.5	a	51.6	b	49.8	a	35.1	a
Organic-RT	270.2	a	161.0	a	43.6	a	41.3	b	46.4	a	32.7	a
Conventional	231.7	a	103.7	a	65.8	a	72.2	a	68.5	a	31.6	a
2002												
Organic-NC	140.2	a	65.5	a	41.3	b	49.0	a	37.7	a	27.7	b
Organic-CI	77.5	bc	67.8	a	45.3	b	65.8	a	37.7	a	28.6	ab
Organic-RT	63.0	c	69.2	a	43.6	b	65.6	a	40.8	a	28.0	b
Conventional	117.5	ab	69.3	a	74.2	a	83.2	a	40.7	a	31.5	a
2004												
Organic-NC	63.8	b	47.5	a	49.6	b	43.0	ab	37.8	a	28.4	b
Organic-CI	61.7	b	47.0	a	45.7	b	37.9	b	40.8	a	31.8	a
Organic-RT	63.1	b	45.8	a	52.2	b	45.3	a	36.9	a	28.1	b
Conventional	173.5	a	44.3	a	69.5	a	49.8	a	40.4	a	29.9	ab

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table A1.7. Concentration of S and Na in sweetpotato leaf and petiole tissue at 30 and 60 days after planting in 2001, 2002 and 2004.

	S				Na			
	30 DAP		60 DAP		30 DAP		60 DAP	
Management	Concentration (%)							
2001								
Organic-NC	0.24	a	0.28	a	0.04	a	0.02	a
Organic-CI	0.25	a	0.27	a	0.03	a	0.01	a
Organic-RT	0.25	a	0.27	a	0.04	a	0.02	a
Conventional	0.25	a	0.27	a	0.03	a	0.01	a
2002								
Organic-NC	0.30	ab	0.23	a	0.01	a	0.02	a
Organic-CI	0.29	ab	0.23	a	0.01	a	0.02	a
Organic-RT	0.31	a	0.24	a	0.01	a	0.01	a
Conventional	0.29	b	0.23	a	0.01	a	0.01	a
2004								
Organic-NC	0.33	ab	0.26	a	0.02	a	0.02	a
Organic-CI	0.34	ab	0.28	a	0.02	a	0.02	a
Organic-RT	0.35	a	0.28	a	0.02	a	0.02	a
Conventional	0.32	b	0.27	a	0.02	a	0.02	a

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

Table A1.8. Analysis of variance of number of sweetpotato roots within market grade in management systems in 2001, 2002 and 2004.

Management		Total		No. 1s		Canner		Jumbos	
		no. ha^{-1}							
2001									
	Organic-NC	98715	a	34507	a	63585	ab	48	a
	Organic-CI	91870	a	37129	a	53504	b	90	a
	Organic-RT	109230	a	24025	a	83909	a	22	a
	Conventional	112292	a	30790	a	80770	a	60	a
2002									
	Organic-NC	132147	a	68461	a	61966	a	762	a
	Organic-CI	123524	a	63162	a	72442	a	799	a
	Organic-RT	64887	b	19265	b	44256	a	112	a
	Conventional	111449	a	52016	a	58366	a	202	a
2004									
	Organic-NC	134660	a	57102	a	74245	a	2278	a
	Organic-CI	130119	a	55489	a	70602	a	3600	a
	Organic-RT	146016	a	61271	a	81996	a	1640	a
	Conventional	141090	a	53861	a	84978	a	1105	a

Statistics		Total	No. 1s	Canners	Jumbos
Source of variation	df	Significance			
Year	2	*	**	NS	***
Error a	15	---	---	---	---
Management	3	NS	**	NS	NS
Management*year	6	**	**	*	NS
Error b	45	---	---	---	---

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table A1.9. Soil inorganic nitrogen ($NO_3 + NH_4$) content (kg N ha^{-1}) at crop establishment, 30 and 60 days after planting and sweetpotato harvest in 2002 and 2004.

	Establishment		30 DAP		60 DAP		Harvest	
Management	Inorganic nitrogen content (kg ha^{-1})							
2002								
Organic-NC	52.73	b	66.60	b	18.77	a	17.73	ab
Organic-CI	63.57	a	90.13	a	28.93	a	21.17	a
Organic-RT	37.90	c	44.63	c	20.93	a	22.33	a
Conventional	48.97	b	55.03	c	26.97	a	12.73	b
2004								
Organic-NC	47.63	a	49.90	a	33.77	a	29.47	a
Organic-CI	57.83	a	62.90	a	42.13	a	34.10	a
Organic-RT	50.33	a	47.07	a	38.53	a	34.90	a
Conventional	56.60	a	49.03	a	31.27	a	31.93	a

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.

[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

APPENDIX A2

Table A2.1. Scientific name, BAYER code[z], and common name of weed species grouped according to similar characteristics and present in at least one treatment at locations in 2001, 2002, and 2004.

Scientific name	BAYER Code	Common name	Presence of species 2001	2002	2004
Annual monocots					
Urochloa platyphylla (Nash) R.D. Webster	BRAPP	Broadleaf signalgrass	x	x	x
Digitaria sanguinalis (L.) Scop.	DIGSA	Large crabgrass	x	x	x
Eleusine indica (L.) Gaertner	ELEIN	Goose grass	x	x	x
Sorghum halepense (L.) Pers.	SORHA	Johnsongrass		x	
Summer annual dicots					
Amaranthus spp.[y]	AMAZZ	Pigweed species	x	x	x
Senna obtusifolia (L.) H.S. Irwin & Barneby	CASOB	Sicklepod	x	x	
Chenopodium album L.	CHEAL	Common lambsquarters	x		
Gamochaeta purpurea (L.) Cabrera	GNAPU	Purple cudweed			x
Ipomoea spp.[x]	IPOZZ	Morning glory species	x	x	x
Mollugo verticillata L.	MOLVE	Carpetweed	x	x	x
Oxalis stricta L.	OXAST	Yellow woodsorrel	x		x
Phytolacca americana L.	PHTAM	Pokeweed			x
Plantago lanceolata L.	PLALA	Buckhorn plantain			x
Polygonum pensylvanicum L.	POLPY	Pennsylvania smart weed	x		
Portulaca oleraceae L.	POROL	Common purslane			x
Rumex cripus L.	RUMCR	Curly dock	x		
Sida rhombifolia L.	SIDRH	Arrowleaf sida	x		x
Sida spinosa L.	SIDSP	Prickly sida	x	x	x
Solanum nigrum L.	SOLNI	Eastern black nightshade	x		x
Solidago fistulosa Mill.	SOOFI	Hollow goldenrod		x	
Winter annual dicots					
Capsella bursa-pastoris (L.) Medik.	CAPBP	Shepard's-purse			x
Coronopus didymus (L.) Sm.	COPDI	Lesser swinecress			x
Lamium amplexicaule L.	LAMAM	Henbit			x
Lepidium virginicum L.	LEPVI	Virgina pepperweed			x
Raphanus raphanistrum L.	RAPRA	Wild raddish		x	
Vicia angustifolia L.	VICAN	Narrow leaf vetch			x
Perennials (monocots and dicots)					
Cynodon dactylon (L.) Pers.	CYNDA	Bermudagrass			x
Cyperus esculentus L.	CYPES	Yellow nutsedge	x	x	x
Solanum carolinense L.	SOLCA	Horsenettle	x		
Volunteer crops					
Vicia villosia L.	---	Hairy vetch	x	x	x
Secale cereale L.	---	Rye	x	x	x
Sorghum bicolor (L.) Moench	SORVU	Sorghum sudangrass			x

[z]WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available on computer disk from WSSA, Lawrence, KS.

[y]*Amaranthus spp. = Amaranthus hybridus* L. (AMACH) smooth pigweed, *Amaranthus palmeri* S. Wats. (AMAPA) palmer amaranth, *Amaranthus retroflexus* L. (AMARE) redroot pigweed and *Amaranthus spinosus* L. (AMASP) spiny pigweed.

Table A2.2. Presence of weed species in at least one management system within year, and presence in management system in at least one year.

	Presence of weed species						
	Year			Management system			
BAYER Code[z]	2001	2002	2004	Org-NC	Org-CI	Org-RT	Conv
BRAPP	x	x	x	x	x	x	x
DIGSA	x	x	x	x	x	x	x
ELEIN	x	x	x	x	x	x	x
SORHA		x		x	x		
AMAZZ	x	x	x	x	x	x	x
CASOB	x	x		x	x	x	x
CHEAL	x				x	x	
GNAPU			x	x	x	x	x
IPOZZ	x	x	x	x	x	x	x
MOLVE	x	x	x	x	x	x	x
OXAST	x		x	x	x	x	x
PHTAM			x			x	
PLALA			x	x		x	
POLPY	x					x	
POROL			x			x	
RUMCR	x					x	
SIDRH	x		x	x	x	x	x
SIDSP	x	x	x	x	x	x	x
SOLNI	x		x	x	x	x	x
SOOFI		x				x	
CAPBP			x	x	x	x	x
COPDI			x			x	
LAMAM			x	x	x		x
LEPVI			x	x	x	x	x
RAPRA		x		x	x	x	x
VICAN			x	x	x	x	x
CYNDA			x		x		
CYPES	x	x	x	x	x	x	x
SOLCA	x			x	x	x	x
Vicia villosia L.	x	x	x			x	
Secale cereale L.	x	x	x		x	x	
SORVU			x	x	x	x	x

[z]WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available on computer disk from WSSA, Lawrence, KS.

[y]*Amaranthus spp.* = *Amaranthus hybridus* L. (AMACH) smooth pigweed, *Amaranthus palmeri* S. Wats. (AMAPA) palmer amaranth, *Amaranthus retroflexus* L. (AMARE) redroot pigweed and *Amaranthus spinosus* L. (AMASP) spiny pigweed.

[x]*Ipomoea* spp. = *Ipomoea coccinea* L. (IPOCC) red morningglory, *Ipomoea hederacea* Jacq. (IPOHE) ivyleaf morningglory, *Ipomoea lacunosa* L. (IPOLA) pitted morningglory, *Ipomoea purpurea* (L.) Roth (PHBPU) tall morningglory.

APPENDIX A3

Table A3.1. The mean number of entire wireworms (all species) and entire plus partial wireworms (all *Melanotus* spp.) per trap averaged over 4 sample dates, and the percent contribution of partial wireworms to the sum of entire plus partial wireworms in 2001.

Management	Entire	Entire + partial	Difference (%)
2001			
Organic-NC	1.02	1.18	13.61
Organic-CI	1.72	2.07	16.94
Organic-RT	0.58	0.62	3.92
Conventional	0.57	0.62	8.04

Table A3.2. Analysis of variance of nematode density among management systems at sweetpotato harvest in 2001, 2002 and 2004.

		All species[z]	Dagger	Lance	Ring	Rootknot	Stubby	Stunt	Spiral
Source of variation	df	Significance[y]							
Year (Y)	2	**	*	**	NS	NS	NS	***	NS
Error a	15	---	---	---	---	---	---	---	---
Management (M)	3	***	**	**	***	NS	NS	NS	**
M*Y	6	NS	NS	NS	NS	NS	NS	NS	NS
Contrasts[x]									
Conv (1) vs. Org (3)		***	**	***	**	NS	NS	*	**
NCC (2) vs. CC (2)		NS	NS	NS	*	NS	NS	NS	NS
Org-T (2) vs. Org-RT (1)		NS	**	NS	***	*	NS	NS	NS

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table A3.3. Means +/- SEM and least significant differences of nematode density among management systems at sweetpotato harvest combined over year in 2001, 2002 and 2004.

	Management							
	Organic - NC[z]		Organic - CI		Organic - RT		Conventional	
Nematodes	No. 500 cc soil-1[y]							
All species[x]	$1.1*10^7$ +/- 1.8	ab[w]	$5.2*10^6$ +/- 2.7	b	$2.6*10^7$ +/- 1.8	a	$5.1*10^5$ +/- 21.3	c
Dagger	8.5 +/- 5.3	cb	13.6 +/- 6.9	b	117.3 +/- 16.1	a	2.2 +/- 2.0	c
Lance	363.2 +/- 24.3	a	884.9 +/- 13.9	a	$3.3*10^3$ +/- 32.1	a	13.9 +/- 12.0	b
Ring	12.2 +/- 11.2	b	8.9 +/- 5.8	b	$1.2*10^{3}$ +/- 87.5	a	1.7 +/- 1.9	b
Rootknot	177.7 +/- 111.5	a	204.5 +/- 153.5	a	$7.7*10^3$ +/- 92.3	a	114.8 +/- 165.5	a
Stubby	91.2 +/- 10.3	a	45.9 +/- 14.9	a	254.5 +/- 24.9	a	108.6 +/- 8.9	a
Stunt	$1.2*10^4$ +/- 60.2	a	$3.5*10^3$ +/- 112.6	a	$2.4*10^4$ +/- 36.4	a	$8.3*10^2$ +/- 136.9	a
Spiral	$1.9*10^6$ +/- 16.9	a	$5.7*10^5$ +/- 13.4	a	$1.4*10^6$ +/- 28.8	a	$2.5*10^4$ +/- 49.5	b

[z]Organic-NC = organically managed with tillage and no cover crop; Organic-CI = organically managed with tillage and cover crop; Organic-RT = organically managed with reduced tillage and cover crop; and Conventional = conventionally managed chemical and tilled control.

[y]All variables were base 10 log (n + 1) transformed prior to analysis, and backtransformed means presented here.

[x]All species = the number of all nematode species observed per 500 cc soil including: *Meloidogyne incognita, M. arenaria, and M. javanica* (Root knot nematode).

[w]Mean separation within nematode species (row) by Fisher's protected LSD, $P \leq 0.05$.

Table A3.4. Analysis of variance combined over years and management systems of Lesion nematode density at sweetpotato harvest in 2001, 2002 and 2004.

Source of variation	df	Significance[z]
Year (Y)	2	**
Error a	15	NS
Management (M)	3	*
M*Y	6	*
Contrasts[y]		
Conv vs. Org (3)		NS
NCC (2) vs. CC (2)		NS
Org-T (2) vs. Org-RT (1)		*

NS.*.**.***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

[z]Density was base 10 log (n + 1) transformed prior to analysis, and backtransformed means presented here.

[y]Contrasts: Conv vs. Org = Conventional (Conv) control compared to Organic-No Cover (Org-NC), Org-Cover Incorporated (Org-CI) and Organic-Reduced Tillage (Org-RT) combined; NCC vs. CC = Org-NC and Conv compared to Org-CI and Org-RT; and Org-T vs. Org-RT = Organic systems with tillage (Org-NC and Org-CI) compared to Org-RT.

Table A3.5. Means +/- SEM and least significant differences of Lesion nematode density by management systems and year at sweetpotato harvest.

	Lesion		
Management	No. 500 cc soil-1[z]		
2001			
Organic-NC[y]	27.9	+/- 11.4	a[x]
Organic-CI		0.0	a
Organic-RT		0.0	a
Conventional		0.0	a
2002			
Organic-NC	47.4	+/- 19.4	ab
Organic-CI	28.2	+/- 11.5	b
Organic-RT	189.7	+/- 77.5	a
Conventional	26.3	+/- 10.7	b
2004			
Organic-NC	17.5	+/- 7.1	a
Organic-CI		0.0	a
Organic-RT	47.5	+/- 19.4	a
Conventional	9.5	+/- 3.9	a

[z]Density was base 10 log (n + 1) transformed prior to analysis, and backtransformed means presented here.

[y]Org-NC = organically managed with tillage and no cover crop; Org-CI = organically managed with tillage and cover crop; Org-RT = organically managed with reduced tillage and cover crop; and Conv = conventionally managed chemical and tilled control.

[x]Mean separation within column and year by Fisher's protected LSD, $P \leq 0.05$.