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Jeffrey Len Main

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The effects of cover crops and tillage method on sweetpotato [*Ipomoea Batatas* (L.)
Lam.] in North Mississippi.

By
Jeffrey Len Main

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Horticulture
in the Department of Plant and Soil Science

Mississippi State, Mississippi

December 2017

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Jeffrey Len Main
2017

The effects of cover crops and tillage method on sweetpotato [*Ipomoea batatas* (L.)
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Pages in Study: 58

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Sweetpotato [*Ipomoea batatas* (L.) Lam] is a major food resource of much of the world. Sweetpotato production is damaging to the soils in which it is grown due to the nature of production and the condition the soil is left to overwinter. There is potential for future regulation on the production of sweetpotato as related to runoff and nonpoint source pollution as the sediment from runoff erosion is easy to pinpoint in nearby waterways. Two studies were carried out to determine the effect of a reduced tillage practice and cover crops on the accumulation of nutrients in cover crops and yield of sweetpotato. The use of stale seed beds will reduce the number of tillage operations in a field and will allow earlier access to the field. Cover crops will benefit the soil with cover during rains while accumulating and recycling nutrients that may otherwise be lost and improving soil structure with the addition of organic matter.

DEDICATION

This work is dedicated to my wife Sonya and children Jennifer and Jonathan for your love and support during this work. I would also like to thank the professors, staff, and students that I have worked with over my career at Mississippi State University. To the sweetpotato farmers and sweetpotato industry who have been gracious and understanding as they have taught me so many things about the sweetpotato.

ACKNOWLEDGEMENTS

I would like to acknowledge Trevor Garrett, Jerry Sartin and the rest of the crew at the Pontotoc Ridge-Flatwoods Branch Experiment Station for their support and hard work in harvesting and grading all these sweetpotatoes.

To Dr. Ramon Arancibia whom helped provided support and direction in the original development of this work.

To Dr. Stephen Meyers, thank you for pushing me through this journey of writing with friendship, wit, and when will this be done questions.

To Dr. Mark Shankle your friendship, knowledge, and persistence have taught me a great deal.

To Dr. Casey Barickman your knowledge of organic vegetables has been most valuable to me.

Dr. Gary Lawrence for all those hours sitting in your lab studying, counting nematodes or growing *Fusarium oxysporium* thank you for your patience with me and the great many things that you have passed on to me.

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CHAPTER I

INTRODUCTION

Nationally, sweetpotatoes [*Ipomoea batatas* (L.) Lam.] are produced primarily in the southeastern states and California with in excess of 52,609 hectares planted in 2012 (USDA 2013a). Sweetpotato is an economically and culturally important crop in Mississippi, which ranked second and third in the nation for planted sweetpotato hectares (9,712 hectares) and crop value (\$62.6 million), respectively, in 2012 (USDA 2013a, 2013b). Mississippi sweetpotato production has increased 155% since 2000 while North Carolina increased 185% over the same period. Of the major sweetpotato production states only Louisiana has decreased production (Johnson et al., 2015).

Total consumption of sweetpotato has increased over the past 15 years as a result of its nutritional attributes, low glycemic index, and the increased popularity of processed and value-added foods containing sweetpotato (Johnson et al., 2015). Sweetpotatoes contain more beta-carotene than many other vegetables, and serve as a source of potassium, fiber, and vitamins A and C (Gebhardt and Thomas, 2002; Johnson et al., 2015). Between 2000 and 2014, per capita sweetpotato consumption in the U.S. increased nearly 80 percent, from 1.9 kg to 3.4 kg (Naeve, 2015). The market price of sweetpotato has increased 50% between 2000 and 2014 (Johnson et al., 2015). While the price of sweetpotato has increased, production costs associated with fuel, fertilizer, pesticides, and labor have also increased. Since 2000 U.S. exports of sweetpotatoes have increased from

17,690 tons to the 140,160 tons projected for the 2014/15 marketing year (Johnson, 2015).

Sweetpotato production in North Mississippi is generally concentrated in the hill region often in bottom land and rolling hills with sloping grades of up to three percent. Traditionally sweetpotato production requires multiple tillage passes in the spring to prepare the soil, incorporate fertilizer and insecticide, and build rows prior to planting. Several cultivation events occur after planting for weed control and assumed gain in yield from root pruning or loosening the soil around the forming roots (Haley and Curtis, unpublished). At harvest a type of tillage occurs during the removal of the storage roots from the soil either by plow or chain digger. Multiple soil disturbances and field traffic from heavy equipment may cause hard pans across the field. Often after harvest a deep tillage tool, such as a chisel plow or an ox plow, is used to break any hard pans that may be present. Where hard pans form across the field, vertical water drainage will be reduced, increasing the amount of water available for surface erosion. Soil is generally smoothed with a final pass with a disk harrow. Unfortunately, the soil is generally left in this bare condition to weather the winter and spring wind and rain. Soil lost from sweetpotato production has been estimated to be up to 49 metric tons per hectare per year in places like Mississippi and Louisiana (Langdale et al., 1985).

Based on volume, sediment is the largest pollutant of surface water in the nation (Smith et al., 2012). The loss of soil as a result of erosion can lead to a decline in organic matter and nutrient content, the break-down of soil structure and a reduction in water-holding capacity (Bosco et al., 2015). Soil lost to erosion can never be used by the farmer again for production (Smith et al., 2012). As environmental regulations become more

focused on agricultural practices that lead to water pollution and other water quality issues such as sedimentation of streams and rivers, sweetpotato fields will become an easy target for erosion and other environmental laws.

Sweetpotato production can be limited by inadequate or excessive soil moisture and temperature. Villordon et al. (2012) emphasized that the growing environment during the early season (first 20 d) has a direct and significant impact on storage root initiation and thus final yield. Even though sweetpotato is a moderately drought tolerant crop (Ghuman and Lal, 1983; Hosokawa, 1908; Valenzuela, 2000), the plant is sensitive to water deficit, particularly during the establishment phase, including early vine development and storage root initiation (Gajanayake et al., 2013; Meyers et al., 2017; Pardales Jr and Esquibel, 1997). Most sweetpotato production in Mississippi is rain-fed. Some growers will use transplant water if a source is nearby and conditions become hot and dry during planting.

Weed control options for sweetpotato production are fairly limited when compared to other major commodity crops (Haley and Curtis, unpublished data). Current weed control programs are focused on pre-emergence weed control. Clomazone is a chlorophyll inhibitor that is taken up by the roots of the target plants and moved upward to the leaf. Flumioxazin, a PPO (protoporphyrinogen oxidase enzyme) inhibitor, gives good residual control of weeds but must be applied pre-transplanting to prevent injury to the sweetpotato plant. *S*-metolachlor is a mitosis inhibitor which can result in decreased storage root yield and quality when applied near transplanting if followed by a moderate to heavy rainfall event (Abukari et al., 2015; Meyers et al., 2012; Meyers et al., 2013; Meyers et al., 2010). While napropamide and DCPA are labeled for use in sweetpotato

they are rarely used due to the need for mechanical incorporation and sporadic weed control (Meyers, Personal communication). Post-emergence grass control can be afforded with graminicide chemistries. Broadleaf and grass escapes may be controlled early in the season prior to vine lapping (layby) with cultivation. Broadleaf weed control after layby is accomplished by hand pulling or chopping the weeds.

A reduced-tillage system combined with the use of cover crops has the potential to increase profits for growers by decreasing inputs such as fertilizers and herbicides, fossil fuel, and labor. Sweetpotato, being a transplanted crop and not a small seeded crop, should perform well in a reduced-till system (Hoyt, 1999; Stone et al., 2005). The stale seedbed technique is based on the premise that weeds which germinate and emerge before the crop is planted are easier to manage. Ideally when using this technique, only the seeding or transplanting operation should be responsible for disturbing the soil. Some researchers have suggested that stale seedbed weed management is critical to maximize yields of crops that have limited herbicide options (Hooks et al., 2014). Winter annual cover crops such as hairy vetch (*Vicia villosa* Roth) and rye (*Secale cereal L*). reduce nitrate leaching and soil carbon losses (Drinkwater et al., 1998; Jackson et al., 2004; Ranells and Wagger, 1997), and increase soil water retention (Liebl et al., 1992). Winter cover crops provide the soil with protection from erosion by covering the soil surface and through a network of roots that help to hold soil in place. Research in North Carolina by Treadwell et al. (2008) found that there were no differences in yield between conventional and cover crop methods of sweetpotato production. Nutrient content of sweetpotato plants was greater in reduced tillage and cover crop systems than conventional production (Treadwell et al., 2008). Treadwell also found that nutrient

loading in the soil could take place after three years of cover crop system production suggesting a self-supporting system in sustainably managed sweetpotato.

Winter cover crops are also a valuable tool for managing weeds. By incorporating cover crops through tillage many weed seeds are stimulated to germinate and lower weed emergence can be expected when cover crop residue is left on the soil surface without tillage, because the weed seeds are not exposed to germination-inducing light (Teasdale and Rosecrance, 2003). Teasdale et al. (1991), reported that cover crops producing more than 300 g m⁻² and covering the ground more than 90% reduced weed density by 78% compared to treatments without cover crops. Pepper (*Capsicum annuum* L.) plants in cover crop plots produced 182% more marketable fruit than plants in bare ground plots (Hutchinson and McGiffen, 2000). The weed population in cover crop treatments was reduced by 80% and 90% compared to non-weeded plots in the first and second years of field experiments, respectively (Hutchinson and McGiffen, 2000).

The use of cover crops in sweetpotato has not been extensively studied and will differ from other row crops due to transplanting into tall, ridged rows. However, cover crops use may be more similar to some transplanted vegetable crops. In previous preliminary trials at the Pontotoc Branch Experiment Station, White (unpublished data) found that excessive cover crop residue reduced sweetpotato stand due to poor packing of the soil around the plant; therefore the project was discontinued. The use of cover crops in sweetpotato was examined again 2010 in which a modified transplanter was developed. The use of cover crops with the use of reduced tillage seed beds and reduced tillage transplanters were investigated for potential for commercial practice.

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CHAPTER II

EFFECTS OF COVER CROPS AND TILLAGE METHODS ON SWEETPOTATO AT
PONTOTOC RIDGE-FLATWOODS BRANCH EXPERIMENT STATION

Abstract

The effects of two tillage methods, conventional tillage and stale seed beds, a reduced tillage system, in combination with three cover crops and a fallow control were examined in the 2011 and 2012 at the Pontotoc Ridge-Flatwoods Branch Experiment Station. There were differences between years for both factors studied so treatments were compared by year. Nutrient uptake by the cover crops and weeds of the fallow treatment was also dependent upon year. Cover crop biomass yield was much higher in 2011 than 2012. Stale seed bed plots tended to produce more dry matter than the conventional plots, in 2011 and 2012. Fallow plots produced less dry matter than planted cover crop plots. Sweetpotato yield response varied by year, with 2011 tending to have a higher yield for stale seed bed plots than 2012. Sweetpotato yields among the cover crop treatments also tended to be higher than the fallow plots, in 2011. Whereas, in 2012, the fallow treatment tended to produce a higher sweetpotato yield than the cover crop treatments. While the results for sweetpotato yield were not as large as desired for reduced tillage and cover crops, they were not negative in comparison with conventional methods. In some years, conditions will lend themselves to one practice over another. This research shows that the benefits of soil protection do not deter yield of sweetpotato.

Introduction

Sweetpotatoes [*Ipomoea batatas* (L.) Lam.] are produced primarily in the southeastern states and California with in excess of 52,609 hectares planted in 2012 (USDA 2013a). Sweetpotato is an economically and culturally important crop in Mississippi, which ranked second and third in the nation for planted sweetpotato hectares (9,712 hectares) and crop value (\$62.6 million), respectively, in 2012 (USDA 2013a, 2013b). Mississippi sweetpotato production has increased 155% since 2000 while North Carolina increased 185% over the same period. Sweetpotato production has a rich history in Mississippi's hill region dating back to the 1900's. The production of sweetpotatoes generally uses multiple passes of tillage in the spring, and harvesting operations in the fall provide an additional tillage event. These tilled production fields are generally left bare, except for winter annual weeds, for up to six months between cropping seasons and are left exposed to heavy winter and spring rains due to time, expense, and lack of knowledge about cover crops.

The use of cover crops has been well established as promoting soil microbial activity, internal drainage, nutrient recycling, increasing soil tilth, and protecting the soil from wind and water erosion (Bloodworth and Lane 1994; Hoyt 1999; Jett 1998).

Stale seed beds, a method of reduced tillage, can be of several types either made weeks before planting to initiate germination of weed seed as part of a weed control system or months in advance to promote field drainage, soil warming, or eliminating spring tillage (Alliaume et al., 2014; Coleman et al., 2016; Hooks et al., 2014). This work looks at stale seed beds as fall made beds which may improve overall moisture and temperature conditions while reducing tillage for earlier spring planting.

Sweetpotato planting may start as early as the last week of April and continue into July. Historically, planting should be completed by June 15th to ensure maximized yields and reduce potential weather hazards such as summer drought or fall rains at harvest. The use of a combination of cover crops and stale seed beds will be addressed to examine the potential of these systems in combination and individually to affect sweetpotato yield. The yield of biomass from the cover crops will be examined for nutrient recycling potential. The resulting yield of the sweetpotato crop from those treated plots will be analyzed to determine if stale seed beds and cover crops can be used successfully in sweetpotato production systems.

Materials and Methods

The effect of cover crops and sweetpotato tillage methods on sweetpotato yield were examined in 2010-2011 and 2011-2012 growing seasons at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc, MS, near the center of Mississippi's predominate sweetpotato growing area. The field selected for the study was of similar soil texture to that of the main sweetpotato growing area, however, the field had a four year history of minimum tillage corn-soybean rotation with fairly high 2.5%-3.0% organic matter in the soil. Treatments consisted of a factorial using four cover crops with two tillage methods. 'Terral 8861' wheat (*Triticum aestivum* L.) (168 kg·ha⁻¹), 'Dixie' crimson clover (*Trifolium incarnatum* L.) (24 kg·ha⁻¹) plus 'Marshall' ryegrass (*Lolium multiflorum* L.) (17 kg·ha⁻¹), and unknown varieties of hairy vetch (*Vicia villosa* L.) (44.8 kg·ha⁻¹) were planted on 1 Nov. 2010 and 11 Oct. 2011 with an ATV-mounted broadcast spreader (Earthway Ev-N-Spred, model M20, Earthway Products, Inc., Bristol, IN 46507)

on either fall-made, ridged beds (stale seed bed) or conventional tilled, level ground (Figure 2.1) (Bloodworth and Lane.,1995; Coleman et al.,2016; Hooks et al., 2014). Additionally, a fallow treatment was included for comparison. The fallow plot was not intentionally planted and biomass was comprised of native winter weeds including annual bluegrass (*Poa Annua* L.), Carolina geranium (*Geranium carolinianum* L.), and cutleaf evening primrose (*Oenothera laciniata* Hill). The experiment design was a randomized complete block with four replications each treatment was placed in the same plot each year. Based on soil test recommendations, 112 kg·ha⁻¹ P₂O₅ and 336 kg·ha⁻¹ K₂O fertilizer were incorporated into the beds prior to planting cover crops. Plots were 18 m long by 18 m wide. One 1 m² sample of above ground biomass was harvested on 1 April 2011 and 2 May 2012 by cutting stems at the soil surface (Figure 2.2). Weed and crop portions were separated, weighed, and dried at 43° C until weight changes stabilized. In most cases weeds did not comprise a significant amount of biomass. Samples were ground and homogenized in a food processor (Magic Bullet, Homeland Housewares, Pacoima, CA 91333), then analyzed for nitrogen, phosphorous, potassium, and sulfur content by Waypoint Analytical, Memphis, TN 38133. The weed portion of the harvested biomass was not analyzed. Nitrogen was extracted using the LECO method while elements were extracted using wet digestion HNO₃ and H₂O₂ (Westerman, 1990). Tissue nutrients were analyzed for only the first replication of each treatment both years due to expense. Due to a lack of replication, cover crop tissue content data were not subjected to statistical analysis.

Cover crops were terminated with an application of glyphosate (Roundup WeatherMax, Monsanto Company, 800 N. Lindbergh Blvd. St. Louis, Missouri 63167) at

1.26 kg acid equivalent·ha⁻¹ on 28 March 2011 and 3 May 2012 then were flail mowed with either a contoured blade mower (United Farm Tools, model FB-80, South Charleston, WV 25309) on the stale seed bed plots or a standard flail mower (unknown manufacture) for conventional tillage plots on 4 April 2011 and 10 May 2012. Conventional tillage plots were then immediately disced with three passes to incorporate cover crop residue into soil. Six rows, each 1 m wide and 10.6 m long, were established in the middle of the cover crop plot of the conventional tillage plots. Rows were hipped up, knocked half way down using a doall harrow, and fertilizer was applied according to field-wide soil test recommendations each year (56 kg·ha⁻¹ N, 112 kg·ha⁻¹ P₂O₅, and 336 kg·ha⁻¹ K₂O) using a Gandy® 10T drop type fertilizer distributor (Gandy Company, Owatonna, MN 55060). Fertilizer was then incorporated with a disk and rows rehipped. Nitrogen was applied to the stale seedbed plots using a four row KBH UAN knife injector (KBH Co., Clarksdale, MS 38614) using a 32% urea nitrogen solution set off center of the row on 17 May 2011 and 20 May 2012. A two-row mechanical transplanter (Mechanical Transplanter Company, Model 22C, Holland, MI 49423) was used to transplant ‘Beauregard B14’ sweetpotato slips into rows with an in-row spacing of 30.5 cm in the conventional till plots on 16 June 2011 and 29 May 2012. On the same dates, a modified two-row mechanical transplanter (modified No-Till Attachment OE35, Mechanical Transplanter Company, Model 22C, Holland, MI 49423) was used to plant into the stale beds. Modification included a coulter to slice an opening in the row followed by a ripper shank set for a depth of 10 inches to loosen soil for the transplanter’s packing wheels (Figure 2.3 and 2.4).

In 2011, weeds were managed with a tank-mix of clomazone at 1.4 kg ai·ha⁻¹ plus pyroxasulfone at 60 g ai·ha⁻¹ applied immediately after transplanting. In 2012, a tank-mix of clomazone at 1.4 kg ai·ha⁻¹ plus *S*-metolachlor at 0.85 kg ai·ha⁻¹ was applied 18 h after transplanting. Additional weeding was carried out throughout each season by hand-hoeing as necessary. Sweetpotato plants were devined with a contoured flail mower immediately prior to harvest on 26 Sept. 2011 and 1 Oct. 2012. Storage roots were harvested using a one-row chain digger. All roots were hand-graded based on modified USDA (2005) standards for grades of fresh market sweetpotato into No.1 (5.08 to 8.89 cm diameter, 7.62 to 22.86 cm in length, and free of defects), canner (3.81 to 5.08 cm diameter, 7.62 to 17.78 cm in length), and jumbo (roots that exceeded the diameter, length or weight requirements of the No.1 grade), and cull (roots of the No.1 and jumbo sized, but misshapen and not suitable for the fresh market. Marketable yield was calculated as the sum of No. 1, jumbo, and canner. In addition, percent No.1 was calculated by dividing No. 1 yield by the total marketable yield. All yields are reported as 18 kg boxes·ha⁻¹, the standard carton size sold in the U.S.

Data were subjected to ANOVA by SAS (SAS Enterprise Guide version 7.1, 2014, SAS Institute Inc., Cary, NC, 27513) Proc GLMMIX with the fixed effects of cover crop and tillage method and random effects of year and replication with year. LS-means were separated by pairwise differences (Bolker et al., 2009; High; Schabenberger, 2005).

Results and Discussion

Due to a year by cover crop and/or tillage method interaction, all data were analyzed separately by year. There were no cover crop by tillage method interactions;

therefore, data are shown by year with the effect of cover crop averaged over tillage method and the effect of tillage method averaged over cover crop.

Cover Crop Biomass.

In 2011 and 2012, biomass production was significantly related to cover crop but not tillage method. Production of dry biomass was greatest for wheat in 2011 with 2,350 kg·ha⁻¹ which was greater than hairy vetch and the fallow treatment (1,440 and 510 kg·ha⁻¹, respectively) (Table 2.1). Crimson clover+ryegrass was not different from wheat or hairy vetch producing 1,930 kg·ha⁻¹. Dry biomass production overall was much lower in 2012, ranging from 700 to 270 kg·ha⁻¹ for crimson clover+ryegrass and the fallow treatment, respectively. Wheat, which produced 600 kg·ha⁻¹ of dry biomass, was similar to crimson clover+ ryegrass. Although not statistically significant, dry biomass was higher in stale seedbeds (1,650 and 520 kg·ha⁻¹) than in conventional tillage (1,470 and 430 kg·ha⁻¹) in both 2011 and 2012 (Table 2.2).

Cover Crop Nutrients.

Above ground cover crop nutrient analysis was conducted for only the first replication each year. Data are reported by year for the main effect of cover crop averaged over tillage method and tillage method averaged over cover crop. Differences in nitrogen concentration were observed between cover crop treatments in 2011 and 2012. Nitrogen concentration was highest with hairy vetch in both years (3.4% and 3.6%, respectively in 2011 and 2012) (Figure 2.5). Weeds in the fallow treatment contained a higher percentage of nitrogen (2.5% and 2.8%) than wheat (1.9% and 1.8%) in both years. Nitrogen concentration was higher in cover crop tissue from the

conventional tillage method than the stale seedbed in both years (0.66% and 0.18%) (Figure 2.6). Phosphorus concentration in the cover crop tissue were slightly higher in the fallow (0.37% and 0.40%) and hairy vetch (0.38% and 0.43%) treatments across tillage methods than crimson clover+ryegrass (0.32% and 0.35%) or wheat (0.28% and 0.32%) in each year (Figure 2.7). In 2011, phosphorus concentration in biomass from conventional and stale seedbed tillage were 0.35% and 0.32%, respectively (Figure 2.8). In 2012, biomass from conventional tillage plots had an average of 0.33% P while the stale seed bed plots were 0.39%. Potassium in the cover crop tissue across tillage types was lowest for wheat in each year with 2.3% and 2.0% in 2011 and 2012, respectively (Figure 2.9). Crimson clover + ryegrass had the highest potassium concentration each year with 3.7% and 3.3%, in 2011 and 2012, respectively. Potassium concentration was higher in the stale seed bed plots in 2011 and 2012 (3.6% and 3.0%, respectively) than in conventional tillage plots (2.7% and 2.3%, respectively) (Figure 2.10). Sulfur concentration in the cover crop tissue ranged from 0.25% to 0.22% for conventional tillage in 2011 and stale seedbed plots in 2012, respectively (Figure 2.11). Sulfur was more concentrated in the conventional tillage plots than the stale seedbed plots in both years. Sulfur was also more concentrated in the fallow and hairy vetch treatments than in the crimson clover+ryegrass or wheat treatments in each year (Figure 2.12). Fallow plots averaged 0.31% and 0.28% sulfur in 2011 and 2012, respectively. While wheat plots averaged 0.16% and 0.15% in 2011 and 2012, respectively.

Sweetpotato Yield.

2011. There were no differences between No. 1, canner, cull, total marketable grades or percent No. 1 among cover crops, in 2011 (Table 2.3). No. 1 yield ranged from 405 to

355 boxes·ha⁻¹ with hairy vetch and fallow treatments, respectively. Canner yield ranged from 281 to 158 boxes·ha⁻¹ with hairy vetch and fallow treatment, respectively. Cull yield was high, in 2011, ranging from 271 to 220 boxes·ha⁻¹ with hairy vetch. Jumbo yield ranged from 168 to 42 boxes·ha⁻¹ with fallow and hairy vetch treatments, respectively.

Most grades of sweetpotato yield did not differ by tillage method in 2011 (Table 2.4). No. 1 yield was 404 boxes·ha⁻¹ with conventional tillage and 373 boxes·ha⁻¹ with stale seed bed tillage. Jumbo yield was significantly greater in stale seed beds (161 boxes·ha⁻¹) compared to conventional tillage (79 boxes·ha⁻¹). Total yield, while not statistically different, was higher with the stale seed bed tillage (807 boxes·ha⁻¹) compared to conventional tillage (675 boxes·ha⁻¹). The percentage of No. 1 roots was higher with conventional tillage (60.2%) compared to the stale seed bed (43.1%).

2012. Total sweetpotato yield from fallow plots in 2012 was 536 boxes·ha⁻¹. Yield from wheat plots (432 boxes·ha⁻¹) was similar to fallow plots (Table 2.5). Jumbo yield of crimson clover+ryegrass (45 boxes·ha⁻¹) was significantly greater than hairy vetch (18 boxes·ha⁻¹) and wheat (28 boxes·ha⁻¹). Total marketable yield in 2012 ranged from 765 boxes·ha⁻¹ with fallow to 611 boxes·ha⁻¹ with wheat.

No. 1 yield did not differ between conventional tillage (506 boxes·ha⁻¹) and stale seed bed plots (453 boxes·ha⁻¹) (Table 2.6). Cull yield was greater in stale seed bed plots (58 boxes·ha⁻¹) than conventional tillage plots (24 boxes·ha⁻¹). Total marketable yield was 720 and 675 boxes·ha⁻¹ with conventional and stale seed bed plots, respectively.

Conclusion.

Biomass production from stale seed bed plots tended to be higher than the conventional tillage plots in both years. Wheat produced the highest amount of biomass followed by crimson clover+ryegrass in each year.

Sweetpotato yields were generally improved by inclusion of cover crops, in 2011. However, in 2012, sweetpotato yield was generally lower with cover crop treatments, but not different than the fallow treatment. Total yield was also improved by the use of stale seed beds in 2011, however, sweetpotato yield tended to be higher with conventional tillage, in 2012. While the benefits of reduced tillage and cover crops were not seen with an increase in sweetpotato yield each year of the study, other benefits that are well equated with these practices such as organic matter, soil tilth, bulk density, and runoff were not measured with this trial (Arnhold et al. 2014; Bloodworth, and Lane.,1995; Fageria et al., 2005; Jackson et al., 2004; Smith et al. 2012; Stone and Kemble 2005;). Better management of the cover crops, fertility, and harvest timing for each tillage and cover crop type, may have made a difference in the final outcome (Hubbard et al., 2013; Monday et al., 2013; Treadwell et al. 2007a; 2007b; 2008). These results indicate that cover crops and stale seed bed reduced tillage can be used to improve soil health, while maintaining sweetpotato yield comparable to a conventional tillage system.

Figure 2.1 Conventional tillage (left) and fall-made beds (right) at Pontotoc, MS in 2011.

Figure 2.2 At harvest a 1 m² above ground biomass sample was divided into crop and weed portions.

Figure 2.3 A coultter and ripper shank were added to a conventional transplanter to loosen the bed ahead of planting into stale seedbed plots at Pontotoc, MS in 2011.

Figure 2.4 Sweetpotato slips were transplanted into a killed hairy vetch stale bed treatment with a modified sweetpotato transplanter at Pontotoc, MS in 2011.

Table 2.1 Effect of cover crop on dry biomass production across tillage methods at Pontotoc, MS in 2011 and 2012.

	2011	2012
Cover crop	kg·ha ⁻¹	
Crimson clover + ryegrass	1,930 ab ^z	700 a
Fallow	510 c	270 b
Hairy vetch	1,440 b	320 b
Wheat	2,350 a	600 a
Cover crop	0.0001	0.0002
Cover crop x tillage method	NS	NS

^z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

Table 2.2 Effect of tillage method on cover crop above ground dry biomass production across cover crops at Pontotoc, MS in 2011 and 2012.

		2011	2012
Tillage method		kg·ha ⁻¹	
Stale seedbed		1650	520
Conventional		1470	132
Tillage method		NS	NS
Cover crop x tillage method		NS	NS

LS means pairwise separation $P \leq 0.05$.

Figure 2.5 Nitrogen concentration in above ground cover crop tissue across tillage methods at Pontotoc, MS in 2011 and 2012.

Figure 2.6 Percent nitrogen in cover crop tissue with tillage methods across cover crop treatments, in Pontotoc, MS, in 2011 and 2012.

Figure 2.7 Phosphorus content in the cover crop averaged over tillage method, in Pontotoc, MS, in 2011 and 2012.

Figure 2.8 Phosphorus content in the cover crop tissue with tillage method averaged over the cover crop treatment, in Pontotoc, MS, in 2011 and 2012.

Figure 2.9 Potassium content in the cover crop averaged over tillage method, in Pontotoc, MS, in 2011 and 2012.

Figure 2.10 Potassium content in the cover crop tissue with tillage method averaged over the cover crop treatment, in Pontotoc, MS, in 2011 and 2012.

Figure 2.11 Sulfur content in the cover crop averaged over tillage method, in Pontotoc, MS, in 2011 and 2012.

Figure 2.12 Sulfur content in the cover crop tissue with tillage method averaged over the cover crop treatment, in Pontotoc, MS, in 2011 and 2012.

Table 2.3 Effect of cover crop on sweetpotato yield across tillage methods at Pontotoc, MS in 2011.

	No. 1	Canner	Jumbo	Cull	Total	No. 1
Cover crop						
treatment		18 kg boxes·ha ⁻¹				%
Crimson						
Clover +						
Ryegrass	397	222	138 a ^Z	271	757	55
Fallow	355	159	168 a	246	682	49
Hairy vetch	405	281	42 b	220	727	51
Wheat	397	271	131 ab	232	798	51
Cover crop	NS	NS	0.0586	NS	NS	NS
Cover crop						
X Tillage	NS	NS	NS	NS	NS	NS

^Z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

Table 2.4 Effect of tillage method on sweetpotato yield across cover crops at Pontotoc, MS in 2011.

	No. 1	Canner	Jumbo	Cull	Total	No. 1
Tillage						
treatment			18 kg boxes·ha ⁻¹			%
Stale						
Seedbed	373	273	161 a ^Z	246	807	43 b
Conventional	404	193	79 b	238	675	60 a
Tillage	NS	NS	0.0177	NS	NS	0.0087
Cover crop						
X Tillage	NS	NS	NS	NS	NS	NS

^Z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

Table 2.5 Effect of cover crop on sweetpotato yield across tillage methods at Pontotoc, MS in 2012.

	No. 1	Canner	Jumbo	Cull	Total	No. 1
Cover crop						
treatment		18 kg boxes·ha ⁻¹				%
Crimson						
Clover +						
Ryegrass	501	164	75 a ^Z	54	740	66
Fallow	536	171	59 ab	25	765	66
Hairy vetch	459	197	18 b	43	675	68
Wheat	423	160	28 b	41	611	67
Cover crop	NS	NS	0.0383	NS	NS	NS
Cover crop						
X Tillage	NS	NS	NS	NS	NS	NS

^Z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

Table 2.6 Effect of tillage method on sweetpotato yield across cover crops at Pontotoc, MS in 2012.

	No. 1	Canner	Jumbo	Cull	Total	No. 1
Tillage						
treatment		18 kg boxes·ha ⁻¹				%
Stale						
Seedbed	453	178	44	58 a ^z	675	65
Conventional	506	168	46	24 b	720	70
Tillage	NS	NS	NS	0.0002	NS	NS
Cover crop						
X Tillage	NS	NS	NS	NS	NS	NS

^z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

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CHAPTER III
EFFECT OF COVER CROPS ON SWEETPOTATO YIELD IN
HOULKA, MISSISSIPPI

Abstract

Studies were conducted in the 2011 and 2012 growing seasons on a producer farm located in Houlika, MS to determine the effects of five cover crops ('Dixie' crimson clover, 'Daikon' radish, unknown variety of hairy vetch, 'Terral 8861' wheat, 'Marshall' ryegrass on sweetpotato yield. A fallow treatment (non planted native weeds) was included to compare against the producer standard. All planted cover crops provided acceptable ground cover and biomass in both years. In 2011, biomass production was not significantly different among cover crops. Production of dry matter was highest for radish in 2011 with $2,500 \text{ kg}\cdot\text{ha}^{-1}$, hairy vetch and crimson clover each produced more than $2,000 \text{ kg}\cdot\text{ha}^{-1}$. Dry matter production overall was generally higher in 2012, ranging from 5,270 to $1,250 \text{ kg}\cdot\text{ha}^{-1}$ for daikon radish and the fallow treatment, respectively. Crimson clover, which produced $4,770 \text{ kg}\cdot\text{ha}^{-1}$ of dry matter, was similar to daikon radish and both were greater than hairy vetch ($3,440 \text{ kg}\cdot\text{ha}^{-1}$), wheat ($2,780 \text{ kg}\cdot\text{ha}^{-1}$), ryegrass ($2,180 \text{ kg}\cdot\text{ha}^{-1}$), and fallow ($1,250 \text{ kg}\cdot\text{ha}^{-1}$). Cover crops were effective at accumulating and recycling N, P, K, and S. Hairy vetch and crimson clover were best at recycling nutrients with the exception of sulfur. Sweetpotato yield was influenced differently each year by cover crops. In 2011, total yield was greatest for the fallow treatment ($1,504 \text{ boxes}\cdot\text{ha}^{-1}$)

but not different from wheat (1,333 boxes·ha⁻¹), and hairy vetch (1,182 boxes·ha⁻¹). Sweetpotato total yield was higher with the fallow treatment than crimson clover (1,064 boxes·ha⁻¹), daikon radish (1,062 boxes·ha⁻¹), and ryegrass (837 boxes·ha⁻¹) in 2011. There were no differences in percentage of No. 1 yield for 2011, which ranged from 57% (fallow and daikon radish) to 61% (hairy vetch). Fallow plots (1,042 boxes·ha⁻¹) did not produce more or less than any other treatment for total yield among treatments in 2012. Percentage of No. 1 roots was highest 66% (wheat and ryegrass) and lowest for 46% (fallow) treatments in 2012.

Introduction

Controlled studies are generally considered important by agricultural producers, but until they see it for themselves they will be of little real interest. Results that are representative of typical ecological responses by the organisms within the actual ecosystem are favored; as compared to research station experiments that often cannot replicate the abiotic and biotic environment of commercial farms (Jackson et al. 2004). The production of sweetpotatoes generally uses multiple passes of tillage or tillage like harvesting equipment in the spring and fall when much of the heavy seasonal rains occur. These tilled production fields are generally left bare, except for winter annual weeds, for up to six months between cropping seasons due to time, expense, and lack of knowledge about cover crops.

In 2011 and 2012, cover crops were introduced to a producer, on farm, in Houlka, Mississippi. The producer farms approximately 100 ha of sweetpotato each year near the center of sweetpotato production in Mississippi. This producer was chosen for his willingness to try new technology and systems.

The use of cover crops has been well established as promoting soil microbial activity, internal drainage, nutrient recycling, increasing soil tilth, and protecting the soil from wind and water erosion (Bloodworth and Lane, 1994; Hoyt, 1999; Jett, 1998). Problems often encountered in this area include high erosion potential due to terrain, poor soil health and low organic matter in the soils due to continued cultivation of sweetpotato and peanut production. The potential for run off and nonpoint source pollution is high. Risks associated with cover crop use can include nutrient imbalances, non-termination of the cover crop, the cover crop becoming a weed to the cash crop, introduction of insect pests, and inadequate weed control due to herbicide immobilization (Jackson et al., 2004; Jackson and Harrison, 2008; Smith et al., 2012).

Materials and Methods

Studies were conducted in 2010-2011 and 2011-2012 growing seasons on a grower location near Houlka, MS to determine the effect of fall-planted cover crops on sweetpotato yield. The location had a history of continuous cropping with greater than four years of sweetpotato or peanut production leading to very low organic matter levels near 0.5%. Treatments consisted of five cover crops: ‘Terral 8861’ wheat (*Triticum aestivum* L.) (112 kg·ha⁻¹), ‘Dixie’ crimson clover (*Trifolium incarnatum* L.) (33 kg·ha⁻¹), ‘Marshall’ ryegrass (*Lolium multiflorum* L.) (33 kg·ha⁻¹), an unknown variety hairy vetch (*Vicia villosa* L.) (45 kg·ha⁻¹), and ‘Daikon’ radish (*Raphanus sativus* L.) (22 kg·ha⁻¹) were planted on 20 Sept. 2010 and 22 Sept. 2011. Five cover crop treatment and an unplanted weedy fallow treatment was used to compare cover crops to the production standard. Cover crop seed were sown on disc tilled soil, with an ATV-mounted broadcast

spreader (Earthway Ev-N-Spred, model M20, Earthway Products, Inc., Bristol, IN 46507) then culti-packed. Additionally, a fallow treatment was included for comparison. The experiment was a randomized complete block design with three replications. Plots were 30.5 m long by 30.5 m wide.

A 1 m² sample of above ground biomass was harvested from each plot by cutting stems at the soil surface on 1 April 2011 and 3 April 2012 with the exception of radish in 2012. In 2012, radish bolted and was sampled on 15 March to prevent seed set (Figure 3.1). Above ground portions of the radish taproot were included in the above ground biomass giving the crop an advantage for crop yield. Weed and crop portions were separated, weighed, and dried at 43°C until weight changes stabilized. Samples were ground and homogenized in a food processor (Magic Bullet, Homeland Housewares, Pacoima, CA 91333), then analyzed for nitrogen, phosphorous, potassium, and sulfur content (Waypoint Analytical, Memphis, TN 38133). Nitrogen was extracted using the LECO method while other elements were extracted using wet digestion HNO₃ and H₂O₂ (Westerman, 1990). Tissue nutrients were analyzed for the first replication of each treatment in 2011 due to expense and were therefore, not subjected to statistical analysis. All replications were analyzed for tissue nutrient content in 2012. Mean comparisons were conducted for all plots in 2012.

Cover crops were terminated as a green manure crop on 3 April 2011 for all treatments in the 2010-2011 growing season and 21 March 2012 for radish and 4 April 2012 for other treatments in the 2011-2012 growing season by flail mowing to speed the breakdown of biomass then immediately disced with three passes to incorporate residue into the soil. Radish was terminated early in 2012 to minimize the potential for

germinating radish seed to become a weed in following crops. Fertilizer was applied commercially by variable rate application to meet soil test recommendations of 56-112-224 kg·ha⁻¹ N-P₂O₅-K₂O. Rows were hipped-up 1 m apart on center and ‘Beauregard B14’ sweetpotato slips were mechanically transplanted (Mechanical Transplanter Company, Model 22C, Holland, MI 49423) with an in-row spacing of 30.5 cm on 20 May 2011 and 20 May 2012. Six rows, each 1 m wide and 10.6 m long, were established in the middle of the cover crop plot for observation and data collection.

In 2011 and 2012, weeds were managed with a tank-mix of clomazone at 1.4 kg ai·ha⁻¹ plus *S*-metolochor at 0.85 kg ai·ha⁻¹ applied immediately post-transplanting. Additional weeding was carried out throughout each season by hand-hoeing as necessary. Plants were devined with a contoured flail mower immediately prior to harvest on 29 Aug. 2011 and 24 Aug. 2012. Storage roots were dug using a one row chain digger. All roots were hand-graded based on modified USDA (2005) standards for grades of fresh market sweetpotato No. 1 (5.08 to 8.89 cm diameter, 7.62 to 22.86 cm in length) and free of defects; canner (3.81 to 5.08 cm diameter, 7.62 to 17.78 cm in length) and jumbo (roots that exceeded the diameter, length or weight requirements of the No. 1 grade). Culls were roots of the No. 1 and jumbo grades so misshapen or unattractive that they could not be marketed in any of the above grades for fresh market. Culls were included in the canner class in 2012. Marketable yield was calculated as the sum of No. 1, jumbo, and canner. In addition, percent No. 1 was calculated by dividing No. 1 yield by the total marketable yield. All yields are reported as 18 kg boxes·ha⁻¹.

Data were subjected to ANOVA by SAS (SAS Enterprise Guide version 7.1, 2014, SAS Institute Inc., Cary, NC, 27513) Proc GLMMIX by year with the fixed effect

of cover crop and random effect of replication. LS-means were separated by pairwise differences (Bolker et al., 2009; High; Schabenberger, 2005).

Results and Discussion

Due to a year by cover crop interaction, all data were analyzed separately by year. Therefore, data are shown by year with cover crop treatment.

Cover Crop Biomass.

Ground coverage in both years for the planted cover crops by time of cutting was 100 percent by visual observation. In 2011, above ground biomass production was not significantly different among the cover crops. Production of dry biomass was highest for radish in 2011 with 2,500 kg·ha⁻¹; hairy vetch and crimson clover each produced more than 2,000 kg·ha⁻¹. Ryegrass, wheat, and fallow treatments yielded 1,570, 1,260, and 1,230 kg·ha⁻¹, respectively (Table 3.1). Dry biomass production overall was generally higher in 2012, ranging from 5,270 to 1,250 kg·ha⁻¹ for daikon radish and the fallow treatment, respectively (Table 3.1). Crimson clover, which produced 4,770 kg·ha⁻¹ of dry biomass, was similar to daikon radish and both were greater than hairy vetch (3,440 kg·ha⁻¹), wheat (2,780 kg·ha⁻¹), ryegrass (2,180 kg·ha⁻¹), and fallow. Wheat was only greater than the fallow treatment.

Cover Crop Nutrients.

Differences in tissue nitrogen levels were observed with among cover crop treatments in 2012. Hairy vetch contained the most nitrogen in the cover crop tissue in both years (3.6% and 4.1%), respectively in 2011 and 2012 (Figure 3.2). Crimson Clover (2.7% and 3.0%) contained more nitrogen than all other cover crops except for hairy

vetch in 2011 and 2012. Weeds in the fallow treatment, (1.0% and 1.7%) appeared to have volunteer hairy vetch from seed distributed from the previous year's crop in 2012. The fallow plots contained as much nitrogen in the weed tissue as the ryegrass, wheat, and radish in 2012. Phosphorus levels were higher with hairy vetch treatments (0.46% and 0.75%) than all other treatments in 2011 and 2012 (Figure 3.3). Fallow and ryegrass both contained less than 0.30% in 2011 while all cover crops contained at least 0.32% in 2012. Crimson clover (0.45%) contained significantly more phosphorus than ryegrass (0.32%), but similar to daikon radish (0.39%), fallow (0.35%) and wheat (0.35%) in 2012. Potassium in the cover crop tissue was greatest with hairy vetch treatments (7.8% and 4.7% in 2011 and 2012, respectively) (Figure 3.4). Crimson clover followed in each year (4.3% and 3.9% in 2011 and 2012, respectively). Fallow and wheat contained 1.8% and 1.5%, potassium respectively, in 2012. Sulfur concentration in the cover crop tissue ranged from 0.54% to 0.14% in 2011 and 0.49% to 0.14% in 2012 (Figure 3.5). Sulfur was more concentrated in daikon radish (0.54% and 0.49%, in 2011 and 2012 respectively). Sulfur accumulation in hairy vetch (0.34%) was also higher than fallow (0.23%), crimson clover (0.21%), ryegrass (0.18%) and wheat (0.14%) in 2012. The pattern was similar in 2011.

Sweetpotato Yield.

No. 1 sweetpotato yield ranged from 521 to 859 boxes ha⁻¹ in 2011 (Table 3.2), however, there were no significant differences. Significant differences were seen in the canner grade with fallow plots producing 645 boxes ha⁻¹ which was greater than crimson clover (412 boxes·ha⁻¹) and ryegrass (305 boxes·ha⁻¹) treatments. Jumbo roots were only produced with ryegrass in 2011 (10 boxes·ha⁻¹). Cull yield ranged from 52 to 195

boxes·ha⁻¹ for hairy vetch and crimson clover, respectively. Total yield with the fallow treatment (1,504 boxes·ha⁻¹) was not different from wheat (1,333 boxes·ha⁻¹), and hairy vetch (1,182 boxes·ha⁻¹). Sweetpotato yield with the fallow treatment was higher than crimson clover (1,064 boxes·ha⁻¹), daikon radish (1,062 boxes·ha⁻¹), and ryegrass (837 boxes·ha⁻¹). There were no differences in percentage of No. 1 yield, which ranged from 57% (fallow and daikon radish) to 61% (hairy vetch).

In 2012, No. 1 yield ranged from 374 boxes·ha⁻¹ (crimson clover) to a high of 960 boxes·ha⁻¹ (wheat) (Table 3.3). No. 1 yield with wheat was not different than ryegrass (944 boxes·ha⁻¹), or daikon radish (791 boxes·ha⁻¹). Crimson clover plots were not different than fallow (501 boxes·ha⁻¹) or hairy vetch (475 boxes·ha⁻¹) in production of sweetpotato No. 1 yield. There were no differences in canner yield among the cover crop treatments. Canner yields ranged from 280 to 458 boxes·ha⁻¹ for hairy vetch and ryegrass, respectively. While more jumbos were produced in 2012 than in 2011, there were no differences among the cover crop treatments. Jumbo yield ranged from 0 boxes·ha⁻¹ (hairy vetch) to 94 boxes·ha⁻¹ (fallow). The highest total yield was produced with wheat (1,052 boxes·ha⁻¹), which was higher than hairy vetch (756 boxes·ha⁻¹) and crimson clover (702 boxes·ha⁻¹). Fallow plots (1,042 boxes·ha⁻¹) did not produce more or less than any other treatment for total yield in 2012. Percentage of No. 1 roots was highest in wheat and ryegrass (66%) and lowest in fallow (46%) treatments in 2012. Daikon radish and hairy vetch both 62% No. 1 were not different from the wheat, ryegrass, or crimson clover (54%).

Conclusion

All planted cover crops produced large amounts of dry biomass which could protect the soil from erosion and cycle nutrients to the following crop. Escapes of hairy vetch and daikon radish seed in 2011 may have contributed to the plant population in fallow treatments in 2012. Extra care was taken in 2012 to terminate the daikon radish treatment before seed formation ending its growing season prior to the other crops that still needed growing time to maximize their potential biomass. While all cover crops including weeds in the fallow treatment did recycle nutrients, hairy vetch had higher concentrations of most nutrients presented with the exception of sulfur, which was higher with daikon radish in both years. No till research in Maryland found that weeds recycled about $50 \text{ kg} \cdot \text{ha}^{-1}$ of N, while radish shoots contained $300 \text{ kg} \cdot \text{ha}^{-1}$ N and $48 \text{ kg} \cdot \text{ha}^{-1}$ S (Lounsbury 2014a) (Lounsbury 2014b). In 2011, yield was higher with the fallow treatment than some of the cover crop treatments possibly due to the lack of microbial flora to break down the biomass or an imbalance of the C:N ratio in the first year. The increase in carbon input by the cover crop can increase the optimum N requirement in the soil (Dabney, Delgado, and Reeves 2001). The production of nitrogen by crimson clover and hairy vetch along with the standard $56 \text{ kg} \cdot \text{ha}^{-1}$ N application may have impeded yield, in 2012. Sweetpotato plants in those plots produced excessive vines instead of storage roots.

The grower was impressed with the results of this trial in his observation of improvement in soil tilth and the ability to work the soil earlier. Because of this trial he has incorporated cover crop mixtures into production plans especially in soils that are generally hard to work.

Figure 3.1 'Daikon' radish, at Houlka, MS 2012
'Daikon' radish in flowering (background) and flail mowed (foreground).

Table 3.1 Effect of cover crop treatment on above ground dry biomass production, in Houlka, MS, in 2011 and 2012.

Cover crop	2011	2012
Crimson clover	2,300	4,770 a ^z
Daikon radish	2,500	5,270 a
Fallow	1,230	1,250 d
Hairy vetch	2,440	3,430 b
Ryegrass	1,570	2,180 cd
Wheat	1,260	2,780 bc
P≤0.05	0.1858	0.0001

^z Means followed by the same letter within a column are not different by LS means pairwise separation P≤0.05.

Figure 3.2 Nitrogen content in the cover crop tissue, in Houlka, MS, in 2011 and 2012. Averaged over the cover crop treatment at termination in Houlka, MS, in 2011 and 2012. LS means separation conducted in 2012 means columns with the same letter are not different by LS means pairwise separation $P \leq 0.05$.

Figure 3.3 Phosphorus content in the cover crop tissue, in Houlika, MS, in 2011 and 2012. Averaged over the cover crop treatment at termination in Houlika, MS, in 2011 and 2012. LS means separation conducted in 2012 means columns with the same letter are not different by LS means pairwise separation $P \leq 0.05$.

Figure 3.4 Potassium content in the cover crop tissue, , in Houlka, MS, in 2011 and 2012.

Averaged over the cover crop treatment at termination in Houlka, MS, in 2011 and 2012.

LS means separation conducted in 2012 means columns with the same letter are not different by LS means pairwise separation $P \leq 0.05$.

Figure 3.5 Sulfur content in the cover crop tissue, , in Houlka, MS, in 2011 and 2012.

Averaged over the cover crop treatment at termination in Houlka, MS, in 2011 and 2012. LS means separation conducted in 2012 means columns with the same letter are not different by LS means pairwise separation $P \leq 0.05$.

Table 3.2 Effect of cover crop on sweetpotato yield, in Houlika, MS, in 2011.

	No. 1	Canner	Jumbo	Cull	Total	No 1
Cover crop						
treatment			18 kg boxes·ha ⁻¹			%
Crimson clover	652	412 bc ^Z	0	195	1,064 bc	60
Daikon radish	613	449 abc	0	170	1,062 bc	57
Fallow	859	645 a	0	151	1,504 a	57
Hairy vetch	725	457 abc	0	52	1,182 ab	61
Ryegrass	521	305 c	10	123	837 c	60
Wheat	789	544 ab	0	73	1,333 ab	59
P≤0.05	NS	0.0497	NS	NS	0.0163	NS

^Z Means followed by the same letter within a column are not different by LS means pairwise separation $P \leq 0.05$.

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