Assessment of leguminous cover crops for use in Saccharum

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Assessment of leguminous cover crops for use in *Saccharum*

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Cover crops play a part in improving sustainability by reducing negative environmental impacts such as soil erosion and nutrient runoff. Energycane could benefit from cover crops due to its row spacing. This study was conducted at the Bearden Dairy Research Center to determine differences in nitrogen accumulation, weed suppression, and energycane yield among treatments.

Four cool-season species (planted in the fall of 2020 and 2021) [balansa clover (*Trifolium michelianum*), hairy vetch (*Vicia villosa*), white clover (*T. repens*) and winter pea (*Pisum sativum* subsp. *arvense*)], and four warm-season species (planted in the spring of 2021 and 2022 [alfalfa (*Medicago sativa*), alyceclover (*Alysicarpus vaginalis*), soybean (*Glycine max*), and sunnhemp (*Crotalaria juncea*)] plus negative and positive controls (0 and 168 kg N ha\(^{-1}\)) were used. Regarding cool-season cover crops, significant differences were seen in all previously mentioned metrics. Warm-season cover crops only showed differences regarding nitrogen accumulation and weed suppression abilities.
DEDICATION

I would like to dedicate this thesis to a few people who have had the most influence on me, throughout the completion of this work and my entire life. First, my father, Jeff, for setting the example of how to carry myself daily while inspiring and encouraging my passion for agriculture to this day. Next, my major professor, Dr. Baldwin, for mentoring me daily throughout my degree and treating me as your own. Lastly, my best friend and wife, Anna, for unending support and love every day. Thank you all.
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CHAPTER I
INTRODUCTION

Cover crops provide numerous benefits including slowing erosion, weed suppression, and enhancing nutrient and water availability (Clark, 2007). Leguminous species have the added benefit of increasing soil nitrogen through nitrogen fixation. These species are set to play a crucial role in agriculture moving forward given the increasing push for more sustainable farming practices, including reducing the reliance on synthetic fertilizers, herbicides, and limiting soil erosion. Conventional row spacing in sugarcane is 1.5m (Baucum and Rice, 2009). This leaves a significant amount of bare ground between rows that is susceptible to erosion.

For this study, we propose to use for cool-season leguminous species [balansa clover (Trifolium michelianum), hairy vetch (Vicia villosa), and white clover (T. repens) and winter pea (Pisum sativum ssp. arvense (L.) Poir)], and four warm-season leguminous species [alfalfa (Medicago sativa), alyceclover (Alysicarpus vaginalis), soybean (Glycine max), and sunnhemp (Crotalaria juncea)] to measure their nitrogen accumulation, weed suppression and impact on yield of sugarcane.

Objectives

The objectives of this research include: 1) comparing effects of cover crop species on nitrogen return to the soil, weed suppression and yield; 2) evaluate differences in these metrics between cool season and warm season treatments.
CHAPTER II
REVIEW OF LITERATURE

History and Benefits of Cover Crops

Sustainable farming practices are a growing area of focus in agriculture, specifically environmentally sustainable practices. Recent years have brought renewed interest in the use of cover crops as a means of improving crop productivity, soil health and maintaining sustainability of agroecosystems, driven by both economic and environmental considerations (Fageria et al., 2005). Environmentally sustainable farming encompasses many areas of agriculture, including water quality, soil conservation and biodiversity (Menalled et al., 2008). Cover crops have an impact in all these areas by reducing erosion from rainfall and wind. They also improve soil microbial activity by providing carbon for microorganisms to break down, which then release polysaccharides which improve soil structure. The earliest recordings of the use of cover crops dates back more than 3,000 years ago in China (Burkey et al., 1997).

Benefits of cover crops include improvement of soil and water quality, pest-suppression, nutrient cycling, and cash crop productivity (Snapp et al., 2005). Cover crops are generally used as a method of nutrient management (Ruffo and Bollero, 2003) and can be separated into two groups: leguminous and non-leguminous. Leguminous species are used to supply nitrogen to the subsequent cash crop while non-legume species are used to reduce nutrient leaching and soil erosion (Meisinger et al., 1991). Bicultural mixtures of legumes and non-legumes have been used to achieve both results (Ranells and Wagger, 1996). Since legumes have lower C:N ratios,
immobilization of nitrogen is less likely to occur during decomposition (Ebelhar, Frye and Blevins, 1984.)

Certain characteristics improve a species suitability to be a cover crop, including rapid germination and establishment, nitrogen fixation abilities, deep root systems to mine and prevent nutrient leaching, weed suppression and cost effectiveness (Reddy, 2016). Rapid germination and establishment aids in weed suppression as well as the larger goal of reducing soil erosion since the soil is covered quickly, while nitrogen fixation and deep root systems help to preserve nutrients in the subsequent cash crop’s rooting zone and can potentially reduce fertilizer inputs.

Regarding post-termination management, cover crops can be managed one of two ways, by killing and incorporating them into the soil or letting them remain on the surface as a mulch, each presents its own benefits. Benefits observed from leaving residue as surface mulch include increasing nitrogen economy (Smith et al., 1987), conserving soil moisture (Morse, 1993), reducing soil erosion (Langdale et al., 1991), increasing nutrient retention (Staver and Brinsfield, 1998), weed suppression (Creamer and Baldwin, 2000) and increasing crop yields (Triplett, 1996). Incorporating cover crop biomass, often referred to as ‘green manure crops’, has been shown to build soil organic matter levels (Reddy et al., 2003) and result in quicker N release, with near complete decomposition seen in 15 to 20 weeks in temperate environments (Bowen et al., 1993).

When using leguminous cover crops, the main benefit observed is nitrogen contribution (Singh et al., 1992). Legumes are reported to capture 56-202 kg N ha⁻¹, where grasses only capture 78.5 kg N ha⁻¹ (Varco et al., 1985). The largest component of a cover crops nitrogen fixation capacity is the genetic potential of the species, but some soil factors such as pH, soil moisture and temperature also impact nitrogen fixation (Fageria, 2005). For nitrogen fixation to
occur, legumes require root infection with the correct strain of bacteria. Nitrogen fixation peaks at flowering for annual species (Fageria, 2005).

While cover crops are generally seen as beneficial, they do come with disadvantages as well. Not all N accumulated in biomass becomes available to subsequent cash crops. Nitrogen losses can occur in the form volatilization, the release of ammonia (NH₃) into the atmosphere, when terminated cover crops are left on the soil surface. Through the use of no-till practices, N mineralization is slow, reducing losses although some still occur (Jazen and McGinn, 1991). Cover crops can also serve as a host crop for insects, both beneficials and pests. Planting into a living cover crop can increase early season insect damage, and in some cases cause insects that were not previously a pest of concern to become one (McMechan et al., 2018). Harboring both pest and beneficial insects results in balancing of the negative effects of harboring pest (Bottenberg et al., 1999).

Cover crops have also been shown to increase soil organic matter overtime. Conventional tillage practices degrade soil structure due to the loss of soil organic matter (Grandy et al., 2002). According to Elliott (1986), cultivation led to a less stable soil than in their native state. Soil stability refers to the ability of a soil to resist erosion. This reduction in stability was also correlated to a reduction in soil organic matter concentrations. Treatments consisting of oat (Avena sativa), pea and hairy vetch showed increases in soil organic carbon and water-soluble carbohydrates, all of which increases soil aggregation and stability, compared to an oat crop (Grandy et al., 2002).
Cool-season Cover Crops

Balansa Clover

Balansa clover (*Trifolium michelianum*) is a cool-season, annual legume species that has most commonly been used as a forage in Australia (Monks et al., 2008; Hayes et al., 2008) but has recently gained interest as a fall planted cover crop in the southeastern United States. Balansa clover has not been as heavily selected as other species, thus, there is a bit of genetic variation found. Flowers are attractive to pollinator species and vary in color from white to pink. Leaf margins can be observed as smooth or serrated and leaves themselves can vary in size and shape, as well as the presence or absence of white markings. As compared to white clover, balansa clover has a more erect growth habit, with canopies reaching around 1 meter in height. Stems are large with a hollow center. The recommended seeding rate is 3.36 to 5.6 kg ha\(^{-1}\) of bare seed or 8.96 kg ha\(^{-1}\) for inoculated seed, as the coating makes up one-third of the weight. Balansa clover is considered a reseeding legume. If stands are allowed to mature for 40 days every three to four years stands will persist in the absence of tillage. However, reseeding is decreased following tillage to due its small seed being buried too deeply. When used as a cover crop, allowing reseeding is often associated with more risk than benefits, as by the time reseeding occurs, the optimal planting window is often passed for most cash crops (Dabney et al, 2012).

Previous research from Australia over a two-year period showed balansa clover accumulated 73 and 151 kg N ha\(^{-1}\) in the shoot, with a total N accumulation of 111 and 245 kg ha\(^{-1}\) while producing 2.44 and 5.11 Mg ha\(^{-1}\), respectively (Rochester and Peoples, 2005). Ovalle and others (2005), showed balansa clover accumulating 76 kg N ha\(^{-1}\) while producing 3.68 Mg ha\(^{-1}\) of biomass.
Regarding weed suppression, previous research has shown balansa clover’s ability to suppress weed biomass. A study conducted across two years showed that balansa clover treated plots resulted in weed biomass production of 1.01 and 0.51 Mg ha\(^{-1}\), which was significantly less weed biomass than control plots (2.35 and 1.37 Mg ha\(^{-1}\)) for both years. Weed biomass was assessed 14 and 15 weeks after planting in years one and two, respectively (Ross et al., 2001).

**Hairy Vetch**

Hairy vetch (*Vicia villosa*) is an annual cool-season legume that is native to the Mediterranean region and has since become naturalized to the southeastern United States (Mt. Pleasant, 1982). It can be grown as both a forage and fall planted cover crop (Wiering et al., 2019). Hairy vetch is slow growing in the fall but quickly thickens in the spring when vines can become up to 3.66 meters in length. Canopy height is not often taller than 0.9 meters unless other plants provide support (Clark et al., 2008). Recommended seeding rates for hairy vetch range from 22.4-28 kg ha\(^{-1}\) (Lemus and Rushing, 2019).

According to Thapa and others (2018), hairy vetch accumulated 3.6 Mg ha\(^{-1}\) of above ground biomass, with said biomass containing 125 kg N ha\(^{-1}\). Biomass production and nitrogen accumulation can also be impacted by termination date. Cook et al., showed these impacts, analyzing three termination dates: early, mid, and late May across two years. For both years, hairy vetch biomass production and N accumulation increased as termination was pushed later in May. During this study, biomass production was 1.6, 4.8 and 7.4 Mg ha\(^{-1}\), and N accumulation 61, 211 and 305 kg ha\(^{-1}\), respectively, across the three dates. In 2008, the same trend was observed, with biomass production of 3.6, 4.5 and 4.9 Mg ha\(^{-1}\) and N accumulation of 90, 131 and 221 kg ha\(^{-1}\), respectively (Cook et al., 2010).
Hairy vetch has been documented as having few allelopathic effects on other species (Geddes et al., 2015); however, it mainly suppresses early season weed populations by shading the ground. This effect declines as the residue decomposes, with optimal weed suppression lasting three to four weeks (Clark et al., 2008). Previous research has shown hairy vetch reduced weed density by 67% and reduced weed biomass by 93% and 94% across two locations in the same year (Mischler et al., 2010).

**White Clover**

White clover (*Trifolium repens*) is a perennial cool-season leguminous species often used as a cover crop and for forage. Recommended seeding rates range from 4.4 kg PLS ha\(^{-1}\) to 15.7 kg PLS ha\(^{-1}\) depending on location, method of planting and intended use (Curell, 2014). White clover is described as having a prostrate, stoloniferous growth habit, producing leaflets and roots at nodes along the stolon. Presence of “water marks” are found on some leaflets. Florets are typically white but can display a pink tint (Ogle and St. John, 2008). This growth habit helps to shade the soil surface and white clover’s ability to survive and outcompete other species in adverse conditions are ideal to suppress weeds (Curell, 2014).

There are three types of white clover: short, intermediate, and large, which refer to general canopy height. Each type is suited for different purposes. Short, or low-growing types, are not often planted for agronomic purposes due to low yields (Hall, 1993). Intermediate and large types are used for forage and cover crop purposes. Large types have a more erect growth habit, with fewer stolons and larger leaves and do not reseed as well as short types. Intermediate types fall directly in the middle of large and short types, with more biomass production than short stature types and more stolons and better reseeding capabilities than the large types (Andrae, 2009).
Stands of white clover produce 89.7 to 145.7 kg N ha\(^{-1}\) when terminated the year following establishment. White clover contains a higher concentration of N in its root than other legumes, so partial tillage is an effective means of releasing more N than from desiccation alone. Stems and leaves decompose quickly due to low C:N ratios (Clark et al., 2008).

White clover also has a shallow root system, tolerates shade, and can withstand heavy traffic (Clark et al., 2008). These traits coupled with its short canopy height make it an excellent option for use as a living mulch, which can be defined as a cover crop that is intercropped with a cash crop after its emergence (Grubinger and Minotti, 1990). Previous research has shown white clover used in a living mulch system contributed 43.4 to 68.3 kg ha\(^{-1}\) of mineralized N (Sanders et al., 2017).

Previous research has indicated white clover to be capable of suppressing weed growth. White clover treated plots resulted in 0.87 and 0.48 Mg ha\(^{-1}\) of weed biomass, compared to 2.34 and 1.37 Mg ha\(^{-1}\) for control plots across two years (Ross et al., 2001).

**Austrian Winter Pea**

Austrian winter pea (*Pisum sativum* ssp. *arvense* (L.) Poir) are a cool-season annual legume in the southern United States but are grown as a summer annual species in more northern states. Recommended seeding rates range from 33.6 to 112 kg ha\(^{-1}\) depending on location and whether seed is broadcast or drilled (Clark et al., 2008) (Lemus and Rushing, 2019). Planting method can significantly impact establishment and productivity. Drilling AWP seed 2.5 to 7.5 cm deep is ideal to ensure sufficient moisture for seed germination, as well as providing adequate support to the plant. Broadcast seeding is an option but is more effective if followed by incorporation. Broadcast stands are more likely to suffer from lodging as the plants grow (Clark
et al., 2008). Austrian winter peas do not tolerate traffic well due to succulent stems (Hofsetter, 1988).

A study conducted in North Carolina, looking at termination date effects on biomass production and N accumulation using two varieties across two years found that termination dates between April 30th and May 13th produced the greatest amount of both biomass and accumulated nitrogen. Values ranged from 3.2 to 6.3 Mg ha\(^{-1}\) of biomass produced and 95 to 208 kg N ha\(^{-1}\) depending on the variety and location. This study also found that corn crops planted into plots that were terminated at peak biomass production and nitrogen accumulation resulted in greater corn grain yields than other termination dates (Parr et al., 2011).

Given the optimal conditions during vegetative growth, AWP can produce more than 5.6 Mg ha\(^{-1}\), up to 9 Mg ha\(^{-1}\) of dry matter biomass. Because of its low C:N ratio, this biomass is quickly broken down, providing nitrogen to the following crop quickly, but limiting the build-up of long-term organic matter and shortening the weed control window (Sarrantonio, 1994).

Previous research has shown AWP can produce more biomass and nitrogen than hairy vetch. Over the course of a three-year study winter pea produced 1.29, 2.16 and 4.13 Mg ha\(^{-1}\) of biomass and accumulating 53, 76, and 149 kg N ha\(^{-1}\), respectively (Ranells and Wagger, 1997).

Previous research indicates that AWP does not preform as well regarding weed suppression as other species. A three-year study showed that AWP failed to significantly reduce weed biomass compared fallow control plots across all three years (Baraibar, 2018). Other research has cited fast degradation of biomass for AWP’s inability to reduce early season weed biomass (Norsworthy et al., 2010)
Warm-season Cover Crops

Alfalfa

Alfalfa is perennial legume commonly planted in the fall, but spring planting is also a possibility in the South. Alfalfa seeding rates range from 16.8 to 22.4 kg ha\(^{-1}\) and seed should be planted 0.64 to 1.27 cm deep (Lemus and Rushing, 2019). Two months prior to planting a seed bed should be prepped, which can include plowing, diskin and cultipacking, with light diskin just before planting to control weeds if necessary (Silva et al., 2020). Fertility management is critical for alfalfa to be successful. Alfalfa grows best at a pH range of 6.5-6.8 (Lacefield et al., 2009). Due to alfalfa’s taproot, subsoil pH is more important than with other leguminous species and should be analyzed and managed to a level of around 5.5. Soil test should be conducted for phosphorus and potassium recommendation, as well as boron and molybdenum to ensure nodule formation for N fixation (Silva et al., 2020).

Monoculture stands of alfalfa in Mississippi has been shown to produce yields of 6 Mg ha\(^{-1}\) (White et al., 2012). Other research from Oklahoma has shown alfalfa produce 4.5 Mg ha\(^{-1}\) and foliage N accumulation of 171 kg N ha\(^{-1}\), with a total N fixation annually of 2478 kg N ha\(^{-1}\) when combining foliage N, stubble N and the top 10 cm of soil. Soil samples from alfalfa treated plots showed significantly higher N levels in the top 10 cm of soil than grass treated plots (Berg, 1990).

Alfalfa has been documented as being both autotoxic and allelopathic (Hedge and Miller, 1990). Previous research has shown alfalfa reduce root length of annual ryegrass (Lolium perenne ssp. multiflorum) 5-65% while reducing germination 10% (Zubair et al., 2017).
Alyceclover

Alyceclover is a highly nutritive, annual legume commonly used as a forage (Lemus and Rushing, 2019). Despite its name, alyceclover, is not a true clover. Alyceclover can be characterized by having an erect growth habit, slightly pubescent to glabrous stems, unifoliate leaves, and orange to pink flowers. Alyce clover is adapted to well drained soils and should be planted at rates of 16.8 to 22.4 kg ha\(^{-1}\) at a depth of 0.64 to 1.27 cm using higher rates when conditions are less favorable. Alyceclover grows best in a pH of 5.5-6.0 (Vendramini et al., 2020). Previous research has shown alyceclover can produce 2.6 Mg ha\(^{-1}\) of biomass and 44 kg N ha\(^{-1}\). This same study showed alyce clover significantly reduced weed biomass as compared to fallow treatments. Alyce clover produced 13.6 times the biomass than produced by weeds in treated plots (Linares et al., 2008).

Soybean

Soybean is leguminous, warm season species, native to Asia that has now been introduced to every continent other than Antarctica. Soybean is mainly grown as an agricultural product for oilseed production (Brown et al., 2008), but can also be used for livestock forage. Forage-type soybeans often produce more biomass than grain type soybeans if harvested at similar maturity stages (Sheaffer et al., 2001).

Forage-type soybean has been proven capable of producing 1121 to 2242 kg ha\(^{-1}\) biomass while contributing 22.5 to 67.3 kg N ha\(^{-1}\) to the soil and following crops (Caddel et al., 2017). Previous research has shown that biologically fixed N can vary significantly. Depending on the activity levels of *Bradyrhizobia*, N derived from the atmosphere can account for 0 to 98% of all N uptake, equating to 0 to 337 kg N ha\(^{-1}\) (Salvagiotti et al., 2008). Forage-type soybean should
be planted at rates ranging from 67.3 to 112 kg ha\(^{-1}\), which are consistent with seeding rates for grain production (Lemus and Rushing, 2019).

Previous research has shown soybean capable of suppressing weeds by competition and exudation of allelopathic chemicals. Root exudates reduced velvetleaf (*Abutilon theophrasti* Medic.) dry weight 15% at four weeks. Incorporated ground soybean inhibited velvetleaf germination and dry weight 46%, while also reducing foxtail millet (*Setaria italica* (L.) Beauv.) germation and dry weight 82% and 65%, respectively (Rose et al., 1984).

**Sunn hemp**

Sunn hemp is a tropical, leguminous summer annual species that originated in India (USDA, 1999). Sunn hemp is mainly grown for fiber production from the stems, but other uses include livestock feed and green manure (Sakar et al., 2015) (Narasimhulu and Manasa, 2018). Previous research has shown sunn hemp has exceptional ability to improve soil health by increasing soil organic matter and nitrogen levels (Cook and White, 1996). Seed acquisition cost are often higher than other alternatives due to an inability to produce seed in most of the United States (Mosjidis et al., 2013). ‘Tropic Sun’, a variety released by the USDA Soil Conservation Service and the University of Hawaii, Department of Agronomy and Soil Science, does not consistently produce seed north of the 28° N latitude, raising seed cost but reducing likelihood of sunn hemp becoming a weed problem (USDA, 1999).

Recommended seeding rates for sunn hemp range from 34-56 kg ha\(^{-1}\) if drilled and 45-67 kg ha\(^{-1}\) if broadcast (Rotar and Joy, 1983) but other research has shown that reducing rates to 17-34 kg ha\(^{-1}\) can provide adequate biomass production while reducing seed cost (Balkcom et al., 2011). Sunn hemp has been shown to produce large quantities of biomass and nitrogen within a short period of time. In Alabama, the variety Tropic Sun produced 5.9 Mg ha\(^{-1}\) of biomass and
accumulated 120 – 136 kg N ha\(^{-1}\) in a 9 to 12-week period (Mansoer et al., 1997). In Hawaii, sunnhemp has been reported to accumulate 165 kg N ha\(^{-1}\) over a 60-day period. (Rotar and Joy, 1983). Research conducted in Florida has shown sunnhemp accumulate 10.1 Mg ha\(^{-1}\) and 173 kg N ha\(^{-1}\) (Linares et al., 2008).

Previous research has shown actively growing sunnhemp reduce weed biomass 57 and 96% at two locations compared to untreated control plots, with greater reductions seen with higher seeding rates (Mosjidis and Wehtje, 2011). Other research showed an 80% reduction in goosegrass (Eleusine indica) and a 61% reduction in livid amaranth (Amaranthus blitum) germination from sunnhemp residue (Adler and Chase, 2007), implicating the allelopathic abilities of sunnhemp.

**Sugarcane/Energycane**

Sugarcane (Saccharum officinarium) is a perennial grass species native to Asia. It is the most widely cultivated crop worldwide, accounting for 26.9 M ha in production with mean yields of 70.9 Mg ha\(^{-1}\) (Khan et al., 2016). Sugarcane is normally grown as a perennial crop, with the first harvest being referred to as the plant crop and subsequent harvest referred to as ratoon crops (Cock, 2003). Under Louisiana conditions, two to four ratoon crops are economically viable before yields decline from damage caused by equipment during harvest and pathogen infection. In Louisiana, the 2021 statewide yield mean was 80.7 Mg ha\(^{-1}\) across 187,369.5 ha (American Sugar Cane League, 2021).

Energycane (Saccharum ssp.) is the result of crossing traditional sugarcane with the species S. spontaneum. Benefits of this cross include increased cold tolerance and disease resistance. These progeny are often then backcrossed to commercial sugarcane to increase sugar production to economically viable levels. When breeding energycane genotypes, cold tolerance
is one of the most important traits. Some energycane varieties have been released to market due to a need for feedstock for a biofuel industry (Fageria et al., 2013). These genotypes, HO 00-961 and L 79-1002, have been shown to have greater biomass yields in the third ratoon crop, 23.6 and 28.3 Mg ha$^{-1}$, respectively, than LCP 85-384, 15.9 Mg ha$^{-1}$, a commonly grown Louisiana sugarcane cultivar (White et al., 2011). Another released energycane variety, HO 02-113, had a mean yield of 45.3 Mg ha$^{-1}$ across four years, which was 21%, 33%, 17% and 21% greater total biomass than L 79-1002 in each year, respectively, in Schriever, Louisiana (Hale et al., 2012).
**Literature Cited**


ASCL of the USA, Inc. (2020). *The Louisiana Sugar Industry.* Thibodaux, LA


CHAPTER III
MATERIALS AND METHODS

Plant Material and Study Site
This research was conducted at the Bearden Dairy Research Center (33.39499, -88.74101) near Starkville, MS beginning in the fall of 2020. Two soil types are found across the study site but were segregated to the two years of testing. Freestone fine sandy loam soils comprise the 2020 plot area and are considered prime farmland soils, moderately well drained and classified as siliceous, semiactive, thermic Glossaquic paleudalfs. Kipling silty clay loams comprise the 2021 plot area and are also considered to be prime farmland, somewhat poorly drained and classified as fine, smectitic, thermic, vertic paleudalfs. Cover crop seed used in this study was sourced from Hancock Seed Co. (Dade City, FL); alfalfa ‘Bulldog 505’, hairy vetch, sunnhemp, and white clover. The Wax Company (Amory, MS); Austrian winter pea. Outsidepride (Independence, OR) provided ‘Fixation’ balansa clover and Seed Ranch (Odessa, FL); alyceclover and ‘Laredo’ forage soybean. Energycane germplasm, AFRI 15-3, was provided by Dr. Anna Hale (USDA-ARS,SRU, Houma, LA).

Plot Establishment
Furrows were pulled on row spacing of 0.96 m with cane planted in every other furrow, giving a 1.9 m row spacing between cane. Canes were cut to a uniform length of 2.4 m (apical meristems removed). This is done to break apical dominance and ensure an equal number of nodes and thus shoots planted in each plot. Canes were then laid into the designated furrows with
each cane overlapping by one-third. Cane plots were single row, 3.66 m in length, with a cane border row on each side. A tractor mounted three-point tilt scraper blade was used to pull soil from adjacent bed tops into furrows. Cane planting occurred on 17 November 2020 and 8 November 2021. Following cane planting, cover crop seedbeds were prepared by using a rotary tiller between planted cane rows. Cool-season cover crops were broadcast in their assigned plots on 31 December 2020 and 10 November 2021. Seeding rates for cool season species of balansa clover, hairy vetch, white clover and winter pea were: 11.2, 22.4, 11.2 and 39.2 kg PLS ha\(^{-1}\), respectively. Spring cover crop planting used, alfalfa, alyce clover, soybean and sunnhemp seed broadcast 8 April 2022, at seeding rates of 22.4, 22.4, 67.3 and 44.8 kg PLS ha\(^{-1}\), respectively. Warm-season cover crops were broadcast in 2021 but resulted in an unacceptable stand of both cover crops and cane. The 2021 warm-season part of the test was abandoned but was reinitiated in 2022.

**Cover Crop Biomass Sampling**

Biomass subsamples were taken from each plot to determine biomass production and nutrient content of biomass. Samples were collected by using 0.09 m\(^2\) quadrat, cutting all biomass contained within the quadrat to 1 cm above the soil surface. These samples were dried to completion, weighed, ground to pass a 2 mm screen and ground samples were then analyzed for nutrient content by Waypoint Analytical (Memphis, TN). Samples were collected from cool season species on 24 July 2021 and 9 May 2022, respectively.

Warm-season cover crops were sampled immediately before termination using a 0.18 sq. m quadrat, removing all biomass contained within the quadrat to 1 cm above the soil surface. Weeds were placed in a separate bag from cover crops, then samples were handled the same as cool-season cover crop samples.
**Cover Crop Termination**

Cover crops were terminated at the onset of flowering. Cool season species were terminated using paraquat dichloride (30.1%) at a rate of 4.68 L ha\(^{-1}\) on the 16 July 2021. This application alone failed to provide a sufficient burndown, so a follow-up application of dimethylamine salt of dicamba (48.2%) was applied at a rate of 2.33 L ha\(^{-1}\) on the 25 July 2021. In 2022, one burndown application of paraquat dichloride 30.1% was made on 10 May and this resulted in a satisfactory burndown.

Warm-season cover crops were terminated by mowing (DR Field and Brush mower\(^{®}\) South Burlington, VT). Variable flowering dates across species resulted in different termination dates for each species. Soybean were terminated 19 August 2022, alyceclover on 16 September 2022, and alfalfa and sunnhemp on 30 September 2022.

**Cane Heights and Stand Counts**

These data were not collected in 2021, however due to observed differences between plots during 2021, data were collected in 2022. Beginning on 9 May 2022, cane stalk height and stand counts were collected on a bi-weekly basis throughout the growing season to measure the impact of treatments on these metrics. Three stalks from each plot were randomly selected and measured to the last collared leaf and every stalk in each plot was counted. This data was then used to construct growth curves to determine treatment effects on cane growth and when cane growth had slowed and harvest could begin.

**Weed Density Counts**

Twenty-eight days following termination of cool-season species, 22 July 2021, and 7 June 2022, respectively, weed density counts were conducted to assess the weed suppression
capabilities of the decaying biomass. A 0.09 sq. m quadrat was placed in three random locations within each plot and each living plant within the quadrat was counted.

For warm-season cover crop species, weed suppression was assessed based on the ability of the living cover crop to limit weed establishment. At the time of cover biomass sampling, weed species were collected in a separate bag, weighed, dried to completion, and weighed again to determine biomass production.

**Single Stalk and Whole Plot Harvest**

Immediately prior to harvest, a single millable cane was chosen from each plot to obtain height (cm), fresh weight (kg) and stem diameter at the lowest internode (mm). A millable cane was characterized by the presence of senesced leaves and a height representative of the mean for the plot. This was to ensure that young tillers were not selected. Chosen stalks were crushed in a three-roller electric sugarcane juicer (Plant Based Pros®; Jersey City, NJ). Total extracted sap volume (mls) and a °Brix value of the sap were recorded for each cane. Crushed stalks were weighed, dried to completion, and weighed again.

Entire plot harvest followed using a Cibus S Winterstieger plot harvester (Innkreis, Austria). Plot weights were recorded (kg) and a sub-sample of chopped material was obtained for moisture content.

Data were analyzed in SAS 9.4 and subjected to PROC MEANS and PROC GLM for mean separation at $\alpha = 0.05$ using Tukey’s HSD test.
CHAPTER IV

RESULTS

Cool-season Cover Crops

Data Separated by Year and Location

Three years of cool-season cover crop treatment data were analyzed: the plant cane (PC) year of 2020 planting location (harvested in 2021), the ratoon year of the 2020 planting location (harvested in 2022) and the PC year of the 2021 planting location (harvested in 2022). Results were presented in this order. Data between PC year were compared to each other, as well as between PC year and ratoon year for the 2020-2021 PC year. Significant differences between plot site and year were assessed at $\alpha=0.05$ unless stated otherwise.
Cover Crop Biomass Production

2021

In 2021, significant differences were observed among treatments (Fig. 4.1). white clover accumulated significantly more biomass (3.7 Mg ha\(^{-1}\)) than the 0 kg N ha\(^{-1}\) treatment (1.3 Mg ha\(^{-1}\)). Balansa clover, hairy vetch and winter pea failed to produce significantly more biomass than the 0 N treatment. Mean biomass production for all treatments was 2.4 Mg ha\(^{-1}\).

![Bar chart showing biomass production by cool-season cover crop species for the PC year of the 2020 planting location. (P=.0205 LSD=2.2089)](chart)

*Columns with the same letter are not significantly different from each other.
† Biomass produced from winter weeds.

Figure 4.1  Mean biomass production by cool-season cover crop species for the PC year of the 2020 planting location. (P=.0205 LSD=2.2089)
In the ratoon year of the 2020 planting treatment did not significantly affect biomass production (Fig. 4.2). Mean biomass production for all treatments was 1.76 Mg ha\(^{-1}\).

![Figure 4.2](image.png)

**Figure 4.2**  Mean biomass production by cool-season cover crop species for the ratoon of the 2020 planting location. (P=0.3248 LSD=2.5456)

*Columns with the same letter are not significantly different from each other.
† Biomass produced from winter weeds.
In the PC year of the 2021 planting location, treatment did not significantly affect biomass production (Fig. 4.3). Mean biomass production for all treatments was 3.1 Mg ha\textsuperscript{-1}.

![Bar chart showing mean biomass production by cool-season cover crop species for the PC year of the 2021 planting location. (P=0.1573 LSD=3.1428) *Columns with the same letter are not significantly different from each other. † Biomass produced from winter weeds.](image-url)
Nitrogen Accumulation

2021

Analysis of variance showed significant differences in nitrogen accumulation by treatment (Fig. 4.4). White clover (103.4 kg N ha\(^{-1}\)) and hairy vetch (73.4 kg N ha\(^{-1}\)) accumulated significantly greater nitrogen than all other treatments. Balansa clover and winter pea (14.9 and 21.6 kg N ha\(^{-1}\), respectively) failed to separate from the 0 N treatment (12.8 kg N ha\(^{-1}\)). Mean nitrogen accumulation for all treatments was 45.2 kg N ha\(^{-1}\).

Figure 4.4  Mean nitrogen accumulation by cool-season cover crop species for the PC year of the 2020 planting location. (P=<.0001 LSD=43.724)

*Columns with the same letter are not significantly different from each other.
†Nitrogen accumulated in weed biomass.
In the ratoon of the 2020 planting location treatment did significantly affect nitrogen accumulation (Fig. 4.5). White clover (65 kg N ha\(^{-1}\)) accumulated significantly more nitrogen than the weedy biomass of the 0 N treatment (19.7 kg N ha\(^{-1}\)). Mean nitrogen accumulation for all treatments was 40.3 kg N ha\(^{-1}\).

![Figure 4.5](image_url)

**Figure 4.5** Mean nitrogen accumulation by cool-season cover crop species for ratoon year of the 2020 planting location. (P=.0334 LSD=42.971)

*Columns with the same letter are not significantly different from each other.
† Nitrogen accumulated in weed biomass.
In the PC year of the 2021 planting location, balansa clover accumulated significantly more nitrogen than the weed biomass of the 0 N treatment at $\alpha=0.07$ (Fig. 4.6). Mean nitrogen accumulation for all treatments was 64.0 kg N ha$^{-1}$.

![Graph showing nitrogen accumulation by cool-season cover crop species](image)

**Figure 4.6** Mean nitrogen accumulation by cool-season cover crop species for the PC year of the 2021 planting location. (P=.0509 LSD=61.816)

*Columns with the same letter are not significantly different from each other. † Nitrogen accumulated in weed biomass.*
Weed Density

2021

In 2021, treatment had a significant effect on weed density (Fig. 4.7). White clover (35.2 plants m\(^2\)) resulted in significantly less weed density than hairy vetch (78.7 plants m\(^2\)) and the 0 N treatment (86.1 plants m\(^2\)). Mean weed density for all treatments was 67.7 plants m\(^2\). A significant replication effect was also noted (P<.0001). Plots within rep three resulted in significantly higher weed densities than other replications.

![Figure 4.7](image)

Figure 4.7  Mean weed density in cool-season cover crops plots 28 days post cover crop termination for the PC year of the 2020 planting location. (P=.0072 LSD=41.331)

*Columns with the same letter are not significantly different from each other.
For the ratoon year of the 2020 planting location, treatment had a significant impact on weed density (Fig. 4.8). White clover and balansa clover (7.4 and 71.3 plants m$^{-2}$, respectively), were the only treatments to significantly reduce weed density as compared to the 0 N treatment (113 plants m$^{-2}$). All other treatments resulted in similar weed density as the 0 N treatment. Mean weed density for all treatments was 83.9 plants m$^{-2}$. A significant replication effect was also noted (P=.0209). Plots within replication one had significantly higher weed density than plots in replications two.

Figure 4.8  Mean weed density in cool-season cover crop plots 28 days post cover crop termination for the ratoon of the 2020 planting location. (P=<.0001 LSD=40.64)

*Columns with the same letter are not significantly different from each other.
In the PC year of the 2021 planting location, treatment had a significant effect on weed density (Fig. 4.9). White clover (3.7 plants m$^{-2}$) resulted in significantly lower weed density than balansa clover (23.1 plants m$^{-2}$), hairy vetch (27.2 plants m$^{-2}$) and winter pea (24.1 plants m$^{-2}$) plots. Mean weed density for all treatments was 20.1 plants m$^{-2}$.

![Figure 4.9](image)

*Columns with the same letter are not significantly different from each other.*

Figure 4.9  Mean weed density in cool-season cover crop plots 28 days post cover crop termination for the PC year of the 2021 planting location. (P=0.0099 LSD=19.058)

*Columns with the same letter are not significantly different from each other.*
Individual Cane Harvest

Heights

2021

In 2021, for individually harvested canes, analysis of variance showed no significant impact on cane height by treatment (Fig. 4.10). Mean heights of individually harvested canes for all treatments was 263.83 cm.

Figure 4.10  Mean height of individually harvested canes by cool-season cover crop species for the PC year of the 2020 planting location. (P=.2750 LSD=32.378)

*Columns with the same letter are not significantly different from each other.
For the ratoon crop of the 2020 planting location, analysis of variance showed no
significant differences by treatment on height of individually harvested canes (Fig. 4.11). Mean
height for all treatments was 223.6 cm.

Figure 4.11  Mean height of individually harvested canes by cool-season cover crop species for
the ratoon year of the 2020 planting location. (P=.5931 LSD=61.985)

*Columns with the same letter are not significantly different from each other.
For the PC year of the 2021 planting location, treatment resulted in a significant effect on mean height of individually harvested canes (Fig. 4.12). All treatments resulted in significantly taller canes than white clover (155.7 cm). Mean height for all treatments was 203.1 cm.

Figure 4.12  Mean height of individually harvested canes by cool-season cover species for the PC year of the 2021 planting location. (P=.0012 LSD=35.926)

*Columns with the same letter are not significantly different from each other.
**Fresh Weight**

**2021**

In 2021, analysis of variance showed no significant effect by treatment on fresh weight of individually harvested canes (Fig. 4.13). Mean fresh weight of individually harvested canes for all treatments was 830.4 g cane\(^1\).

![Bar chart showing mean fresh weight of individually harvested canes by cool-season cover crop species for the PC year of the 2020 planting location.](image)

*Columns with the same letter are not significantly different from each other.*
For the ratoon crop of the 2020 planting location, analysis of variance showed no significant effect by treatment on the fresh weight of individually harvested canes (Fig. 4.14). Mean fresh weight for all treatments was 684.4 g cane\(^{-1}\).

**Figure 4.14**  Mean fresh weight of individually harvested canes by cool-season cover crop species for the ratoon year of the 2020 planting location. (P=.3834 LSD= 280.24)

*Columns with the same letter are not significantly different from each other.*
For the PC year of the 2021 planting location, analysis of variance indicated a significant effect by treatment on fresh weight of individually harvested canes (Fig. 4.15). Canes harvested from white clover plots weighted significantly less (513.7 g) than all other treatments except for winter pea. Mean fresh weight for individually harvested canes for all treatments was 691.2 g cane\(^{-1}\).

![Graph showing fresh weight of canes](image)

*Figure 4.15*  Mean fresh weight of individually harvested canes by cool-season cover crop species for the PC year of the 2021 planting location. (P=0.0455 LSD=225.81)

*Columns with the same letter are not significantly different from each other.*
Sap Production

2021

Since the same energycane genotype was planted in all plots, the fiber portion of a fiber:sap ratio would be expected to be uniform. Extractable sap, while conditioned by fiber percentage among genotypes, can show variation if impacted by treatment (Gravois and Milligan, 1992).

In 2021, analysis of variance showed no significant effect by treatment on sap volume of individually harvested canes (Fig. 4.16). Mean sap volume for all treatments was 326.1 ml kg\(^{-1}\) of stalk.

![Figure 4.16](image)

**Figure 4.16** Mean sap volume kg\(^{-1}\) stalk by cool-season cover crop species for the PC year of the 2020 planting location. (P=.6779 LSD=46.693)

*Columns with the same letter are not significantly different from each other.*
For the ratoon crop of the 2020 planting location, analysis of variance showed no significant effect by treatment on sap volume kg$^{-1}$ of stalk (Fig. 4.17). Mean sap volume for all treatments was 307.9 ml kg$^{-1}$ of stalk.

Figure 4.17  Mean sap volume kg$^{-1}$ stalk by cool-season cover crop species for the ratoon year of the 2020 planting location. (P=.5301 LSD=59.078)

*Columns with the same letter are not significantly different from each other.*
For the PC year of the 2021 planting location, treatment resulted in a significant effect on sap volume kg\(^{-1}\) stalk (Fig. 4.18). Canes harvested from white clover plots (255.3 ml kg\(^{-1}\) stalk) produced significantly less sap than canes from balansa clover, hairy vetch 0 N, and 168 kg N ha\(^{-1}\) treated plots. Mean sap volume for all treatments was 292.7 ml kg\(^{-1}\) stalk.

![Graph showing sap volume kg\(^{-1}\) stalk by cool-season cover crop species](image)

**Figure 4.18** Mean sap volume kg\(^{-1}\) stalk by cool-season cover crop species for the PC year of the 2021 planting location. (P=0.0033 LSD=39.99)

*Columns with the same letter are not significantly different from each other.

**\(^\circ\)Brix**

Treatment did not significantly affect mean \(^\circ\)Brix. \(^\circ\)Brix ranged from 12.1 to 14.9 for all treatments across all harvest events.
Energycane Fresh Weight Yield

2021

Energycane fresh weight yield was significantly affected by treatment (Fig. 4.19). White clover (50.8 Mg ha\(^{-1}\)) and balansa clover (49.7 Mg ha\(^{-1}\)) and the 168 kg N ha\(^{-1}\) treatment (55.7 Mg ha\(^{-1}\)) resulted in significantly greater yields than winter pea (32.0 Mg ha\(^{-1}\)). Mean fresh weight yield across all plots was 45.8 Mg ha\(^{-1}\).

![Figure 4.19: Mean energycane fresh weight yield by cool-season cover crop species for the PC year of the 2020 planting location. (P=.0055 LSD=16.616)](image)

*Columns with the same letter are not significantly different from each other.

2022

In the ratoon year of the 2020 planting location, no significant differences were observed among treatments regarding energycane fresh weight yield (Fig. 4.20). Mean yield for all treatments was 47.0 Mg ha\(^{-1}\).
Figure 4.20  Mean energycane fresh weight yield by cool-season cover crop species for ratoon year of the 2020 planting location. (P=.3370 LSD=24.834)

*Columns with the same letter are not significantly different from each other.

During the PC year of the 2021 planting location, significant differences were observed in energycane fresh weight yield by treatment (Fig. 4.21). All treatments were significantly greater than white clover (6.1 Mg ha\(^{-1}\)). Mean yield for all treatments was 37.6 Mg ha\(^{-1}\). A significant replication effect was also observed (P=.0048). Plots in replication one (50.1 Mg ha\(^{-1}\)) yielded significantly greater than replications two, three, and four (35.0, 34.5, and 30.8 Mg ha\(^{-1}\), respectively).
In 2021, energycane dry weight yield was significantly affected by treatment (Fig. 4.22). Winter pea (8.9 Mg ha\(^{-1}\)) resulted in significantly lower dry weight yields than all other treatments except for hairy vetch (11.7 Mg ha\(^{-1}\)). Mean yield of all treatments was 12.7 Mg ha\(^{-1}\). A significant rep effect was observed (P=.0083). Dry weight yields from rep two (14.0 Mg ha\(^{-1}\)) were significantly greater than yields from rep four (10.8 Mg ha\(^{-1}\)).
Figure 4.22  Mean energycane dry weight yield by cool-season cover crop species for the PC year of the 2020 planting location. ($P=0.0005$ LSD=3.9846)

*Columns with the same letter are not significantly different from each other.
2022

For the ratoon year of the 2020 planting location, treatment did not result in a significant effect on energycane dry weight yield (Fig. 4.23). Mean dry weight yield for all treatments was 16.1 Mg ha\(^{-1}\).

![Figure 4.23](image) Mean energycane dry weight yield by cool-season cover crop species for the ratoon year of the 2020 planting location. (P=.4518 LSD= 9.9141)

*Columns with the same letter are not significantly different from each other.

For PC year of the 2021 planting location, treatment did result in a significant effect on dry weight yields (Fig. 4.24). All treatments resulted in greater dry weight yields than white clover (2.0 Mg ha\(^{-1}\)). All other treatments produced similar yields to each other. Mean dry weight yield for all treatments was 12.6 Mg ha\(^{-1}\). A significant replication was also noted (P=.0148). Plots within rep one (25.4 Mg ha\(^{-1}\)) produced significantly greater yields than rep four (16.2 Mg ha\(^{-1}\)).
Figure 4.24  Mean energycane dry weight yield by cool-season cover crop species for the PC year of the 2021 planting location. (P=<.0001 LSD=10.24)

*Columns with the same letter are not significantly different from each other.

**Warm-season Cover Crops**

Due to a stand failure of energycane and cover crops in the PC year of the 2020 planting location, there are only two sets of data for warm-season cover crops: the ratoon year of the 2020 planting location and the PC year of the 2021 planting location, both were harvested in 2022. Alfalfa failed to establish a stand in any plot and was therefore not carried forward in the data set.

**Cover Crop Biomass Production**

Cover crop biomass yield did not significantly differ for either location. Mean dry matter biomass for all treatments ranged from 2.2 to 17.1 Mg ha$^{-1}$.
Nitrogen Accumulation

Treatment did not result in a significant effect on mean nitrogen accumulation of warm-season cover crops for the ratoon year of the 2020 planting location (Fig 4.25). Mean nitrogen accumulation for all treatments was 65.3 kg N ha\(^{-1}\).

Figure 4.25  Mean nitrogen accumulation by warm-season cover crop species for the ratoon year of the 2020 planting location. (P=.0738 LSD=76.901)

*Columns with the same letter are not significantly different from each other.
† Nitrogen accumulated in weed biomass.

Treatment was significant regarding nitrogen accumulation for the PC year of the 2021 planting location (Fig. 4.26). Sunnhemp plots accumulated significantly more nitrogen (304.1 kg N ha\(^{-1}\)) than was assessed in the plant material from the 168 kg N ha\(^{-1}\) treatment (62.5 kg N ha\(^{-1}\)). Mean nitrogen accumulation for all treatments was 169.5 kg N ha\(^{-1}\).
Figure 4.26 Mean nitrogen accumulation by warm-season cover crop species for the PC year of the 2021 planting location. (P=.0106 LSD=241.37)

*Columns with the same letter are not significantly different from each other.
† Nitrogen accumulated in weed biomass.

**Weed Biomass**

Treatment did result in a significant effect on weed biomass for the ratoon year of the 2020 planting location (Fig 4.27). Soybean (1.9 Mg ha\(^{-1}\)), Sunnhemp (2.7 Mg ha\(^{-1}\)) and alyce clover (3.1 Mg ha\(^{-1}\)) used in co-culture, all resulted in significantly less weed dry matter biomass than the 168 kg N ha\(^{-1}\) treatment (6.1 Mg ha\(^{-1}\)). Mean weed dry matter biomass for all treatments was 3.7 Mg ha\(^{-1}\).
Figure 4.27  Mean weed dry matter biomass by warm-season cover crop species for the ratoon year of the 2020 planting location. (P=.0082 LSD=2.9174)

*Columns with the same letter are not significantly different from each other.

For the PC year of the 2021 planting location, treatment did result in a significant effect on mean weed dry matter biomass (Fig. 4.28). Soybean (0.4 Mg ha\(^{-1}\)) and alyce clover (0.7 Mg ha\(^{-1}\)) plots had significantly less weed biomass than the 0 N treatment (5.3 Mg ha\(^{-1}\)). Mean weed dry matter biomass for all treatments was 2.8 Mg ha\(^{-1}\)).
Figure 4.28  Mean weed dry matter biomass by warm-season cover crop species for the PC year of the 2021 planting location. (P=.0133 LSD=4.3762)

*Columns with the same letter are not significantly different from each other.

**Individual Cane Harvest**

**Heights**

Treatment did not significantly affect mean height of individually harvested canes for either location. Mean heights ranged from 167.8 cm to 231 cm.

**Fresh Weight**

Treatment did not significantly affect mean fresh weight of individually harvested canes for either location. Mean fresh weights ranged from 513 g to 820 g.

**Sap Production**

Treatment did not significantly affect mean sap production of individually harvested canes for either location. Sap production ranged from 278.2 to 322.6 ml sap kg\(^{-1}\) of stalk.

53
°Brix

Treatment did not significantly affect mean °Brix of individually harvested canes for either location. Mean °Brix values ranged from 14.8 to 16.3.

Energycane Fresh Weight Yield

Treatment did not significantly affect mean energycane fresh weight yield for either location. Mean fresh weight yields ranged from 22.7 to 34.5 Mg ha⁻¹.

Energycane Dry Weight Yield

Treatment did not significantly affect mean energycane dry weight yield for either location. Mean dry weight yields ranged from 5.2 to 12 Mg ha⁻¹.
CHAPTER V
DISCUSSION

Comparison of Plant Cane Years Across Locations and Comparison of Plant Cane Year and Ratoon Year for 2020 Planting Location

Cool-season Cover Crops

Cover Crop Biomass Production

Plant Cane Year Comparison

There was no significant difference for cover crop biomass production between the PC year of the 2020 and 2021 planting locations (P=.0525). In general, dry matter biomass by species was greater in 2022 than 2021. Mean cover crop biomass production for all treatments in 2021 was 2.4 Mg ha⁻¹, while in 2022 the mean was 3.1 Mg ha⁻¹. Mean dry matter biomass yields for balansa clover increased from 1.9 Mg ha⁻¹ in 2021 to 4.4 Mg ha⁻¹ in 2022 and winter pea increased from 2.2 to 3.7 Mg ha⁻¹. Hairy vetch yields declined from 3.3 Mg ha⁻¹ in 2021 to 2.7 Mg ha⁻¹ in 2022. An earlier cover crop planting date for the 2021 planting location likely led to better establishment of balansa clover and winter pea, increasing their biomass production.

Following cover crop seeding at the 2021 planting location, there was no rainfall received for 15 days. Spotty rain continued for the following weeks. Hairy vetch being a larger seed than the clover species and having a coating that was not present on winter pea, is believed to have a larger water requirement for germination. Lack of rain coupled with broadcast seeding is likely the reason for the reduction in hairy vetch production in 2022.
**Plant Cane vs Ratoon Year Comparison**

There was a significant difference between the PC year and the ratoon year of the 2020 planting location with regards to cover crop biomass production (P=.0322). Cover crop biomass was greater in the PC year than the ratoon year (2.4 Mg ha\(^{-1}\) and 1.8 Mg ha\(^{-1}\), respectively). Generally, all cover crop species produced greater biomass in the PC year than the ratoon.

Hairy vetch and winter pea biomass production values in this study (1.6-3.9 Mg ha\(^{-1}\)) were within ranges reported by previous researchers (1.3-7.4 Mg ha\(^{-1}\)) (Cook et al., 2010; Ranells and Wagger, 1997). Biomass of balansa clover plots (1.9-4.4 Mg ha\(^{-1}\)) were within ranges cited by Rochester and Peoples (2005) (2.4-5.1 Mg ha\(^{-1}\)) for their study for one of three locations in this study.

**Nitrogen Accumulation**

**Plant Cane Year Comparison**

Nitrogen accumulation is directly tied to cover crop biomass production, so it is not surprising that changes that occurred in cover crop biomass production are reflected in nitrogen accumulation. There were significant differences between years regarding nitrogen accumulation (P=.0109). Mean nitrogen accumulation was significantly greater in 2022 (64 kg ha\(^{-1}\)) than in 2021 (45.2 kg ha\(^{-1}\)). Improved establishment of balansa clover and winter pea in the PC year of the 2021 planting location compared to the 2020 planting location led to significantly greater nitrogen accumulation by these species. Balansa clover increased mean nitrogen accumulation from 14.9 kg N ha\(^{-1}\) in 2021 to 81.5 kg N ha\(^{-1}\) in 2022, while winter pea increased from 21.6 kg N ha\(^{-1}\) to 69.8 kg N ha\(^{-1}\). Hairy vetch saw a reduction from 73.4 kg N ha\(^{-1}\) in 2021 to 49.9 kg N ha\(^{-1}\) in 2022, due to the previously mentioned reduction in biomass across years.
**Plant Cane vs Ratoon Year Comparison**

Year was not significant with regards to mean nitrogen accumulation (P=.3834). Mean nitrogen accumulation for all treatments was similar for both years, 45.2 kg N ha\(^{-1}\) in 2021 and 40.3 kg N ha\(^{-1}\) in 2022. There was a significant year X species interaction (P=.0064). Balansa clover increased mean nitrogen accumulation from 14.9 to 50.8 kg N ha\(^{-1}\) in 2022 and was the only treatment to have such an increase. Winter pea remained relatively consistent, increasing slightly from 21.6 to 25.5 kg N ha\(^{-1}\). Hairy vetch declined, from 73.4 to 43.3 kg N ha\(^{-1}\) and white clover declined from 103.4 to 65.0 kg N ha\(^{-1}\). The values for balansa clover, hairy vetch and winter pea coincide with the previously mentioned increase in biomass production for balansa clover and decrease for hairy vetch and winter pea. Since these values are tied to biomass production, factors such as planting date, rainfall and planting method, which impact cover crop establishment and growth, would also be expected to impact nitrogen accumulation.

Balansa clover (14.9-81.5 kg N ha\(^{-1}\)) and hairy vetch (43.3-73.4 kg N ha\(^{-1}\)) accumulated less nitrogen for all locations of this study than reported by Rochester and Peoples (2005) (111-245 kg N ha\(^{-1}\)) and Cook et al. (2010) (43.3-73.4 kg N ha\(^{-1}\)). Nitrogen accumulation values for white clover matched those reported by Clark et al. (2008) (43-145.7 kg N ha\(^{-1}\)) for all locations of this study (65-103.4 kg N ha\(^{-1}\)), while the nitrogen accumulation values of this study for winter pea were similar to those reported by Ranells and Wagger (1997) (53-149 kg N ha\(^{-1}\)) for one of three locations in this study (69.8 kg N ha\(^{-1}\)).

**Weed Density**

**Plant Cane Year Comparison**

Analysis of variance indicated a significant effect by year on weed density (P=<.0001). Mean weed density was significantly higher in 2021 (67.7 plants m\(^{-2}\)) than 2022 (20.1 plants m\(^{-2}\).
White clover had 59.7% the weed density of the 0 N treatment on average. White clover also had the greatest biomass production this year, leading to more complete ground coverage, more material decomposing following burndown, and subsequently a longer period of soil shading by the decaying material compared to other treatments.

In 2022, white clover reduced weed density compared to the 0 N treatment, with 16.7% the weed density of the 0 N treatment. White clover's biomass production (3.6 Mg ha\(^{-1}\)) was similar to the previous year. The burndown application in 2022 was also not completely lethal to white clover, resulting in both a living stand of white clover along with some decaying material that helped reduce weed density. Of the four cover crop species, hairy vetch produced the lowest biomass (2.7 Mg ha\(^{-1}\)) in 2022 and was also the only treatment to result in significantly greater weed density than the 0 N treatment (162.5% of the 0 N treatment). Inconsistent establishment due to previously mentioned lack of rainfall immediately following planting led to large empty spaces in hairy vetch plots, providing locations for weedy species to establish following cover crop termination.

**Plant Cane vs Ratoon Year Comparison**

Year did have a significant effect on mean weed density (P=.0108). This is likely responsible for the reduction in weed density across years. Weed density was significantly greater in the ratoon year (83.9 plants m\(^{-2}\)) than the PC year (67.7 plants m\(^{-2}\)). Mean weed density in white clover plots was reduced in 2022 compared to 2021, down to 7.4 plants m\(^{-2}\) from 35.2 plants m\(^{-2}\). This reduction is likely due to the 2022 burndown being non-lethal to white clover, resulting in a continued living stand and additional soil shading compared to decaying material alone. Weed density in hairy vetch and winter pea plots increased in 2022 compared to 2021. Hairy vetch mean weed density increased from 78.7 plants m\(^{-2}\) to 100, while mean biomass of
hairy vetch declined from 3.3 Mg ha\textsuperscript{-1} to 1.9 in 2022. Winter pea followed the same trend, an increase in weed density (71.3 plants m\textsuperscript{-2} to 116.7 plants m\textsuperscript{-2}) while the mean biomass of winter pea declined from 2.2 to 1.6 Mg ha\textsuperscript{-1}. Mean weed density of the negative control plots also increased from 86.1 to 113 plants m\textsuperscript{-2}. Termination date was earlier in 2022, 10 May, compared to 16 July in 2021. This could be tied to an increase in available moisture and optimal soil temperature for early season weed germination, leading to an increase in weed density in 2022.

There is a paucity of literature regarding specific cover crop species’ impact on the degree of weed suppression. Instead, general terms are mentioned regarding the overall suppression effects of cover crops (Clark, 2008).

**Individual Cane Heights**

**Plant Cane Year Comparison**

Location was significant regarding mean height of individually harvested canes (P\textless.0001). Canes harvested in 2021 were significantly taller (263.8 cm) than canes harvested in 2022 (203.1 cm). Mean height for all treatments were shorter in 2022, most notably in white clover plots, which decreased 100 cm from the prior location. This is likely due to the previously mentioned incomplete burndown in white clover plots, resulting in a maintenance of cooler soil temperatures delaying cane growth. Another key factor regarding reduced growth of energycane would be the reflection of green light from the residual living white clover. Extended periods of excess green light have been shown to negatively impact growth of emerging plants (Folta, 2004). Also, rainfall was reduced in 2022 compared to 2021. From 1 April through 20 October 2021, 1066 mm of rain was received, while in 2022 only 668 mm was received in the same time frame (Delta Agricultural Weather Center, 2023). The 61% reduction in rainfall likely reduced overall cane growth.
**Plant Cane vs Ratoon Year Comparison**

Year was significant regarding mean height of individually harvested canes (P=<.0001). Canes harvested in 2021 were significantly taller (263.3 cm) than canes harvested in 2022 (223.6 cm). Mean height for all treatments were shorter in 2022 than 2021, again with white clover plots declining the most (53.8 cm less than the previous year). Again, the likely cause is incomplete burndown in white clover plots which lead to a green light effect delaying emergence coupled with decreased soil temperatures due to shading by residual clover; inhibiting cane growth compared to other treatments where burndown was lethal. All treatments were negatively affected by reduced rainfall in 2022 compared to 2021.

**Individual Cane Fresh Weight**

**Plant Cane Year Comparison**

Locations differed significantly regarding mean fresh weight of individually harvested canes (P=<.0001). Canes harvested in 2021 weighed significantly more (830.4 g) than canes harvested in 2022 (691.2 g). Mean fresh weight of individual canes were less in 2022 for all treatments. White clover plots showed the greatest decrease, from 900.6 g to 513.7 g stalk\(^{-1}\) in 2022. These trends correlate to previously mentioned trends in reduction in stalk heights in 2022 versus 2021 and are likely a result of the same environmental factors.

**Plant Cane vs Ratoon Year Comparison**

Year did significantly affect the mean fresh weight of individually harvested canes (P=.0002). Mean weight was significantly greater in 2021 (830.4 g) than in 2022 (684.4 g). Mean fresh weight declined for all treatments in 2022. Canes harvested from balansa clover plots showed the largest reduction, from 915.6 g in 2021 to 592.5 g in 2022. Balansa clover increased
in mean cover crop biomass production in 2022, doubling from 1.9 to 3.8 Mg ha\(^{-1}\) in 2022. The larger quantity of biomass takes more time to decompose, leading to extended soil shading. This leads to a slower increase in soil temperature and slower growth of cane in the early season. All treatments were impacted by a 61% reduction in rainfall in 2022 leading to reduced growth of energycane.

**Individual Cane Sap Production**

**Plant Cane Year Comparison**

Analysis of variance indicated a significant effect by location on mean sap production of individually harvested canes (P=.0001). Mean sap production was significantly greater in 2021 (328.8 ml kg\(^{-1}\) of stalk) than 2022 (292.7 ml kg\(^{-1}\) of stalk). Mean sap production declined for all treatments in 2022 compared to 2021, the largest reduction was in canes harvested from white clover plots which decreased from 334.7 ml kg\(^{-1}\) of stalk to 305 ml kg\(^{-1}\) of stalk. The decrease in sap production matches previously established trends in reduction of height and fresh weight between years, due to variance in burndown efficacy and rainfall amount.

**Plant Cane vs Ratoon Year Comparison**

Analysis of variance indicated a significant effect by year on mean sap production of individually harvested canes (P=.0043). Mean sap production was significantly greater in 2021 (326.1 ml kg\(^{-1}\) of stalk) than in 2022 (307.9 ml kg\(^{-1}\) of stalk). Mean sap production declined for all treatments in 2022 with the largest decline being canes harvested from white clover plots, which declined from 334.7 ml kg\(^{-1}\) of stalk to 255.3 ml kg\(^{-1}\) of stalk. This reduction from white clover follows previously mentioned effects of nonlethal burndown limiting early season growth.
of canes. This inhibition was then compounded by a reduction in rainfall, which lead to a decrease in sap production across all treatments.

**Individual Cane °Brix**

**Plant Cane Year Comparison**

Analysis of variance indicated a significant effect by year on mean °Brix values (BV) of individually harvested canes (P=<.0001). Mean BV were greater in 2022 (14.9) than 2021 (12.1). Mean BV increased for all treatments in 2022 compared to 2021. °Brix is a measure of dissolved carbohydrates in the sap extracted from the cane, expressed roughly as a percentage. As such, canes harvested in 2022 contained a higher concentration of carbohydrates than canes harvested in 2021. °Brix often decrease following rainfall, as more water is taken up through the roots and into the plant diluting the concentration of dissolved carbohydrates. Decreased rainfall in 2022 that led to a reduction in growth and sap volume would have led to an increase in BV (Dalri et al., 2021).

**Plant Cane vs Ratoon Year Comparison**

Analysis of variance indicated a significant effect by year on mean BV of individually harvested canes (P=<.0001). Mean BV were greater in 2022 (14.3) than 2021 (12.1). Mean BV were greater for all treatments in 2022 compared to 2021. This matches the previously mentioned effects of reduced rainfall in 2022 reducing growth and sap production but increasing the concentration of dissolved solids within the sap thus raising BV.
**Energy cane Fresh Weight Yield**

**Plant Cane Year Comparison**

Analysis of variance indicated a significant year x species interaction regarding energycane fresh weight yield (P=.0054). Mean yields were greater in 2021 (45.8 Mg ha\(^{-1}\)) than in 2022 (37.6 Mg ha\(^{-1}\)). Balansa clover and white clover treatments had reduced yields in 2022 compared to 2021. Energycane yields from balansa clover plots decreased from 49.7 Mg ha\(^{-1}\) to 37.7 Mg ha\(^{-1}\) (24.1%) in 2022, attributed to greater biomass production from balansa clover in 2022 inhibiting early season emergence of cane confounded by reduced rainfall. Cane in white clover plots showed the greatest change in yield of any treatment, decreasing from 50.8 to 6.1 Mg ha\(^{-1}\), an 88% reduction in yield. White clover plots had a significant reduction in stand density and cane height in compared to itself in 2021 and to the other treatments in 2022. This difference is attributed to ineffective burndown in white clover plots. As mentioned before, the green light effect and slower soil warming due to shading early in the year, delayed emergence and early cane growth in the white clover plots, put it behind throughout the balance of the 2022 growing season.

Hairy vetch and 0 N ha\(^{-1}\) plots remained relatively similar across years, increasing from 42.1 to 43.1 Mg ha\(^{-1}\) (2.3%) and 47 to 48.9 Mg ha\(^{-1}\) (4%), respectively. Winter pea treated plots increased in yield from 32 to 37 Mg ha\(^{-1}\) (15.6%) in 2022, attributed to an increase in nitrogen accumulation in 2022 (69.8 kg N ha\(^{-1}\)) from 2021 (21.6 kg N ha\(^{-1}\)).

**Plant Cane vs Ratoon Year Comparison**

Between the PC and ratoon years at the 2020 planting location, only species had a significant effect across years on energycane fresh weight yield (P=.0428). Across both years, plots treated with 168 kg N ha\(^{-1}\) (53.5 Mg ha\(^{-1}\)) resulted in significantly greater energycane fresh...
weight yield than winter pea treated plots (37.9 Mg ha\(^{-1}\)). All other treatments yielded similarly to each other. Mean yields across all treatments were similar in both years at 45.8 Mg ha\(^{-1}\) in 2021 and 47 Mg ha\(^{-1}\) in 2022. Only white clover and 168 kg N ha\(^{-1}\) plots saw a mean decrease in energycane yield in 2022 compared to 2021. White clover decreased from 50.8 to 38.2 Mg ha\(^{-1}\) (24.8\%) while the 168 kg N ha\(^{-1}\) treatment decreased from 55.7 to 51.8 Mg ha\(^{-1}\) (7\%). All other treatments increased, the greatest of which was winter pea which increased 36.6\% from 32 to 43.7 Mg ha\(^{-1}\).

Regarding the PC years, only the 168 kg N ha\(^{-1}\) treatment resulted in yields similar to values from previous research (Eason, 2022). In that study, the same energycane genotype and the same fertilizer rate (168 kg N ha\(^{-1}\)) were used. Lower yields are to be expected from cover crop treatments in this study, as the no cover crop treatment accumulated nitrogen equal to 168 kg N ha\(^{-1}\). All cover crop treatments provided cane yields the ratoon year less than those reported in previous research (Eason, 2022).

**Energycane Dry Weight Yield**

**Plant Cane Year Comparison**

Analysis of variance indicated a significant year x species interaction regarding energycane dry weight yield (P=.0002). The same trends that were noted in the PC year comparison for fresh weight yield can be applied to dry weight yields. Balansa clover and white clover treatments had reduced energycane dry weight yields in 2022 compared to 2021. Energycane in balansa clover plots decreased from 13.5 to 12.5 Mg ha\(^{-1}\), a 7.4\% reduction. The most notable change was a decrease in energycane from white clover plots from 12.9 Mg ha\(^{-1}\) to 2 Mg ha\(^{-1}\) in 2022, an 84.6 \% reduction which corresponds to the 88\% reduction in fresh weight yield seen in the same comparison. Energycane in hairy vetch plots increased from 11.7 to 15.2,
a 28.8% increase. Winter pea increased from 8.9 to 13.1 Mg ha\(^{-1}\), a 47.2% increase. The 0 N treatment increased from 13.1 to 16.1 Mg ha\(^{-1}\), a 23.8% increase. Increased energycane dry weight yields in hairy vetch and the 0 N treatments compared to their increase in energycane fresh weight yield could be tied to decreased rainfall in 2022 compared to 2021, along with increased BV.

**Plant Cane vs Ratoon Year Comparison**

Analysis of variance indicated that year resulted in a significant effect regarding energycane dry weight yield (P=.0044). Mean energycane dry weight yields were greater in the ratoon (16.1 Mg ha\(^{-1}\)) than the PC year (12.7 Mg ha\(^{-1}\)). All treatments increased energycane dry weight yield in 2022 compared to 2021, except for white clover which remained the same. The largest increase in energycane dry weight yield was from the 0 N treatment, which increased from 13 to 19.4 Mg ha\(^{-1}\), a 49.2% increase. Across all treatments, dry matter percentage increased 7 to 9% in 2022 compared to 2021, leading to an increase in energycane dry weight yield despite reductions in energycane fresh weight yields. This is likely due to a combination of previously mentioned factors. Reduced rainfall in 2022 led to decreased sap volume but increased BV. Samples used to determine dry weight yields were not pressed to extract sap. Thus, following the drying process, sap was removed this way, but the dissolved solids were left behind, increasing cane dry weight yields despite a decrease in cane fresh weight yield.

All cover crop treatments in PC years produced energycane dry weight yields similar to previous research conducted at the same location, while all treatments in the ratoon year produced lower dry weight yield than previous research (Eason, 2022).
Warm-season Cover Crops Comparison Between Locations

Due to the failed stand of both warm-season cover crops and energycane in the PC year of the 2020 planting location, only one comparison will be made between locations: the ratoon energycane crop of the 2020 planting location (harvested in 2022) and the PC year of the 2021 planting location (harvested in 2022). Due to the previously mentioned failed stand of cover crops in 2021, the ratoon crop received no benefits from this planting in its PC year.

Cover Crop Biomass Production

Analysis of variance indicated significant differences between locations regarding warm-season cover crop biomass production (P=.0127). Mean cover crop biomass for all treatments were significantly greater at the PC location (7.9 Mg ha$^{-1}$) than the ratoon location (4.6 Mg ha$^{-1}$). All treatments had greater mean biomass values at the 2021 planting location, except for the 168 kg N ha$^{-1}$ treatment, which decreased from 6.1 Mg ha$^{-1}$ to 4.3 Mg ha$^{-1}$. The greatest increase was from forage soybean, which increased from 3.2 Mg ha$^{-1}$ to 13.6 Mg ha$^{-1}$, a 325% increase between locations.

All species produced similar or greater biomass at both locations compared to previous research (1.1-10 Mg ha$^{-1}$) (Mansoer et al., 1997; Linares et al., 2008; Caddel et al., 2017).

Nitrogen Accumulation

Analysis of variance indicated significant differences between locations on mean nitrogen accumulation by warm-season cover crop treatment (P=.0009). Mean nitrogen accumulation for all species was significantly greater at the 2021 planting location (169.5 kg N ha$^{-1}$) than the 2020 planting location (65.3 kg N ha$^{-1}$). All treatments had greater mean nitrogen accumulation values at the 2021 planting location, except for the 168 kg N ha$^{-1}$ treatment, which declined from 84.4
kg N ha to 62.5 kg N ha$^{-1}$. The largest increase in nitrogen accumulation was from forage soybean, which increased from 83.4 kg N ha$^{-1}$ to 297.6 kg N ha$^{-1}$, a 256% increase.

Forage soybean (83.4-297.6 kg N ha$^{-1}$) exceed previously reported values (22.5-67.3 kg N ha$^{-1}$) at both locations, while sunnhemp (93.6-304.1 kg N ha$^{-1}$) exceeded values determined by previous researchers at one location (120-173 kg N ha$^{-1}$) (Mansoer et al., 1997; Caddel et al., 2017). Alyce clover at the 2021 planting location (89.9 kg N ha$^{-1}$) exceeded previous reported values (44 kg N ha$^{-1}$) (Linares et al., 2008), while under preforming those values at this study’s 2020 planting location (31.4 kg N ha$^{-1}$).

**Weed Biomass**

Location did not significantly affect mean weed biomass by warm-season cover crop treatment (P=.1206). Across both locations, warm-season cover crop species had a significant impact mean weed biomass (P=.0003). Forage soybean (1.1 Mg ha$^{-1}$) and alyce clover (1.9 Mg ha$^{-1}$) resulted in significantly less weed biomass than the 168 kg N ha$^{-1}$ (5.2 Mg ha$^{-1}$). Generally, weed biomass was greater at the 2020 (ratoon) planting location (3.7 Mg ha$^{-1}$) than the 2021 (PC) planting location (2.8 Mg ha$^{-1}$).

**Individual Cane Height**

Analysis of variance indicated significant differences between locations regarding mean height of individually harvested canes (P=.0100). Canes harvested from the 2020 planting location were significantly taller (205.2 cm) than canes harvested from the 2021 planting location (189.8 cm), as would be expected in a normal ratoon crop. All treatments had greater mean heights at the 2020 planting location except for the 0 N treatment, which remained the
same. The largest increase in mean height was from canes harvested from Sunnhemp treated plots, which increased from 167.8 to 208.5 cm, a 24.3% increase.

*Individual Cane Fresh Weight*

Location (P=.0727), treatment (P=.2993) and location x species (P=.3170) were all nonsignificant regarding mean fresh weight of individually harvested canes across both locations.

*Individual Cane Sap Volume*

Location (P=.1859), species (P=.1560) and location x species (P=.7805) were all nonsignificant regarding mean sap volume of individually harvested canes across both locations

*Individual Cane °Brix*

Location (P=.7946), species (P=.1809) and location x species (P=.8000) were all nonsignificant regarding mean BV of individually harvested canes across both locations. For both locations, mean BV for all treatments was the same (15.7).

*Energycane Fresh Weight Yield*

Location (P=.7139), species (P=.1880) and location x species (P=.1433) were all nonsignificant regarding mean energycane fresh weight yield across both locations.

At both locations, all treatments resulted in less cane fresh weight yield than reported in previous research (Eason, 2022). This was expected, as it is likely nitrogen accumulated in warm-season cover crops grown in co-culture would not be available energycane until the following year, if at all.
**Energy cane Dry Weight Yield**

Location (P=.5644), species (P=.2459) and location x species (P=.1395) were all nonsignificant regarding mean energy cane dry weight yield across both locations.

At both locations, all treatments resulted in cane dry weight yields less than yields reported by Eason (2022), matching the trend observed from fresh weight yields.
Literature Cited


CHAPTER VI
SUMMARY AND CONCLUSIONS

For cover crop adoption to increase, they must have positive implications for the following/accompanying cash crop to be harvested. Industry uses a calculation of weight x BV to predict sugar turnout. Therefore, since no treatment significantly impacted BV, the most important metric to consider from this study is the cover crop’s impact on energycane fresh weight yield. Table 6.1 shows energycane fresh weight yield for each harvest broken out by cool-season cover crop treatment.

Table 6.1  Energycane fresh weight (Mg ha\(^{-1}\)) yield for each harvest by cool-season cover crop treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2020 PC year</th>
<th>2021 PC year</th>
<th>Ratoon of 2020 planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balansa Clover</td>
<td>49.7</td>
<td>37.7</td>
<td>46.3</td>
</tr>
<tr>
<td>Hairy Vetch</td>
<td>42.1</td>
<td>43.1</td>
<td>46.2</td>
</tr>
<tr>
<td>White Clover</td>
<td>50.8</td>
<td>6.1</td>
<td>38.2</td>
</tr>
<tr>
<td>Winter Pea</td>
<td>32.0</td>
<td>37.0</td>
<td>43.7</td>
</tr>
<tr>
<td>0 N</td>
<td>47.0</td>
<td>48.9</td>
<td>55.5</td>
</tr>
<tr>
<td>168 kg N ha(^{-1})</td>
<td>55.7</td>
<td>52.7</td>
<td>51.8</td>
</tr>
</tbody>
</table>

Energycane fresh weight yield varied by treatment each year and appears to be impacted by a combination of treatment and age of cane planting (PC vs. ratoon). Balansa clover, hairy vetch and the 0 N treatment all yielded similarly to the 168 kg N ha\(^{-1}\) treatment for all three harvests. Ineffective burndown of white clover plots resulted in substantial yield drags for both the 2021 PC harvest and the 2020 ratoon harvest, however this effect was not observed in the
2020 PC harvest, when white clover was fully terminated. This yield drag was likely a combination of the green-light effect and cool soils delaying cane emergence. This would indicate that managing white clover as a living mulch negatively impacts energycane yield. Further research is needed to determine best management practices regarding cover crop species (especially perennial species), seeding rate and termination timing; enabling optimization of cool-season cover crops in energycane production.

Warm-season cover crops resulted in lower energycane yields than cool-season cover crops. For both harvests of warm-season plots, no differences were observed in energycane fresh weight yield by treatment. It is worth noting that in a co-culture system, nitrogen accumulated by warm-season cover crops would not be available to energycane until the following season, if at all. Thus, it is possible that any benefits warm-season cover crops could have regarding energycane yield would not be seen until the season following cover crop termination. Any benefits seen in the initial year would be due to another factor such as pathogen suppression such as those reported with Crotalaria juncea culture (Wang and McSorely, 2004; McSorley et al., 2009). Further research is needed to explore potential long-term effects of warm-season cover crops grown alongside energycane.

APPENDIX A

SUPPLEMENTAL DATA
Cool-season data

Figure A.1  Mean energycane stalk number plot\(^{-1}\) by cool-season treatment for the ratoon year of the 2020 planting location (2022)

Figure A.2  Mean height of energycane stalks by cool-season treatment for the ratoon of the 2020 planting location (2022)
Figure A.3  Mean stalk number plot$^{-1}$ by cool-season treatment for the PC year of the 2021 planting location (2022)

Figure A.4  Mean height of energycane stalks by cool-season treatment for the PC year of the 2021 planting location (2022)
Figure A.5  Mean BV by cool-season treatment for the PC year of the 2020 planting location (P=.3538 LSD=3.51)
*Columns with the same letter are not significantly different from each other.

Figure A.6  Mean BV by cool-season treatment for the ratoon year of the 2020 planting location (P=.2457 LSD=2.2052).
*Columns with the same letter are not significantly different from each other.
Figure A.7  Mean BV by cool-season treatment for the PC year of the 2021 planting location (P=.9495 LSD=1.7114)

*Columns with the same letter are not significantly different from each other.
Warm-season data

**Figure A.8** Mean energycane stalk number plot$^{-1}$ by warm-season treatment for the ratoon year of the 2020 planting location (2022)

**Figure A.9** Mean height of energycane stalks by warm-season treatment for the ratoon year of the 2020 planting location (2022)
Figure A.10  Mean energycane stalk number plot\(^1\) by warm-season treatment for the PC year of the 2021 planting location (2022)

Figure A.11  Mean height of energycane stalks by warm-season treatment for the PC year of the 2021 planting location (2022)
**Figure A.12**  Mean biomass production of warm-season cover crop treatments for the ratoon year of the 2020 planting location (P=.1292 LSD=4.947)

*Columns with the same letter are not significantly different from each other.  
† Biomass produced from summer weeds.

**Figure A.13**  Mean biomass production of warm-season cover crop treatments for the PC year of the 2021 planting location (P=.0874 LSD=11.64)

*Columns with the same letter are not significantly different from each other.  
† Biomass produced from summer weeds.
Figure A.14  Mean height of individually harvested energycane stalks for the ratoon year of the 2020 planting location (P=.2506 LSD=43.864)

*Columns with the same letter are not significantly different from each other.

Figure A.15  Mean height of individually harvested canes for the PC year of the 2021 planting location (P=.7375 LSD=70.615)

*Columns with the same letter are not significantly different from each other.
Figure A.16  Mean fresh weight of individually harvested canes from the ratoon year of the 2020 planting location (P=.0446 LSD=322.17)

*Columns with the same letter are not significantly different from each other.

Figure A.17  Mean fresh weight of individually harvested canes from the PC year of the 2021 planting location (P=.9167 LSD=322.14)

*Columns with the same letter are not significantly different from each other.
Figure A.18  Mean sap production of individually harvested canes from the ratoon year of the 2020 planting location ($P=.0649$ LSD=132.19)

*Columns with the same letter are not significantly different from each other.

Figure A.19  Mean sap production of individually harvested canes from the PC year of the 2021 planting location ($P=.9699$ LSD=117.28)

*Columns with the same letter are not significantly different from each other.
Figure A.20  Mean BV of individually harvested canes from the ratoon year of the 2020 planting location (P=.4174 LSD=2.6947)

*Columns with the same letter are not significantly different from each other.

Figure A.21  Mean BV of individually harvested canes from the PC year of the 2021 planting location (P=.3057 LSD=1.7232)

*Columns with the same letter are not significantly different from each other
Figure A.22  Mean energycane fresh weight yield by warm-season treatment for the ratoon year of the 2020 planting location (P=.9248 LSD=29.113)

*Columns with the same letter are not significantly different from each other.

Figure A.23  Mean energycane fresh weight yield by warm-season treatment for the PC year of the 2021 planting location (P=.0504 LSD=19.766)

*Columns with the same letter are not significantly different from each other.
Figure A.24  Mean energycane dry weight yield by warm-season treatment for the ratoon year of the 2020 planting location (P=.6391 LSD=9.8237)

*Columns with the same letter are not significantly different from each other.

Figure A.25  Mean energycane dry weight yield by warm-season treatment for the PC year of the 2021 planting location (P=.0828 LSD=15.972)

*Columns with the same letter are not significantly different from each other. Hidden test to allow template to find last page in document