Determination of Optimal Cropping System for White-tailed Deer in the Southeast and Chufa Response to Nutrient Additions

by

Alexander L. Johnson

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 9, 2011

Keywords: white-tailed deer, food plot, tillage, southeast, chufa, nutrient response

Approved by

C. Wesley Wood, Co-Chair, Professor of Agronomy and Soils
David B. Weaver, Co-Chair, Professor of Agronomy and Soils
Edzard van Santen, Professor of Agronomy and Soils
Stephen S. Ditchkoff, Professor of Forestry and Wildlife Sciences

Abstract

White-tailed deer (*Odocoileus virginuanus*) are an economically important wildlife resource in the Southeast. A significant portion of expenditures related to white-tailed deer goes towards food plot production and management, yet concise information from the scientific community regarding food plot cropping systems is scarce. The objective of this research was to determine the optimal cropping system for white-tailed deer by evaluating forage yield, preference, and quality of 10 warm season and 12 cool season forage treatments. Plots were harvested two times per year during late summer and early spring. Cool season forage production ranged from 11 to 4331 kg dry matter (DM) ha^{-1} with percent dry DM removed by deer estimated between 14 and 85%. Excluding wheat and wheat in wheat mix, cool season forages met or exceeded concentration requirements for nitrogen (N), calcium (Ca), phosphorus (P), and sodium (Na). Nearly all forages had low fiber values and exhibited good forage quality. Wheat was observed as being preferred during the cool season. Warm season forage production ranged from 0 to 18441 kg DM ha^{-1} with percent DM removed falling between negative 38 and 92%. Warm season forages generally exceeded tissue N concentration requirements for growth and development. All forages excluding sorghum in sorghum mix and chufa met or exceeded Ca, P, and Na concentration requirements. Observation data suggested preference for soybean and cowpeas during the warm season. It is recommended that wheat (*Triticum aestivum* L.) be planted along with a companion forage in cool season food plots while soybean (*Glycine max* L. Merr.), iron & clay cowpea (*Vigna unguiculata* L. Walp.), or lablab (*Lablab purpureus* L. Sweet) be planted in warm season food plots.

Chufas (*Cyperus esculentus* L. var.*sativus* Boeck) are a common wildlife planting in the Southeast. Tubers from chufa plants are a preferred food for wild turkey (*Meleagris gallopavo*). However information regarding fertilization of chufa is inconclusive. During the summer of 2009 a greenhouse experiment was performed to determine chufa response to fertilization. Chufas were planted in 11-L pots, thinned to four plants per pot and fertilized with either nitrogen (N), phosphorus (P), or potassium (K). Nitrogen and K rates were; 0, 50, 100, 200, 300, 400, or 800 kg ha^{-1}. Phosphorus rates were; 0, 20, 40, 80, 160, 320, 640 kg ha^{-1}. Each treatment received a standard rate of micronutrient solution, N, P, or K as needed. Above ground growth and tubers were harvested, weighed and analyzed for nutrient uptake. Chufa exhibited an above ground yield response to N fertilization but not P or K. Nitrogen, P, and K uptake increased in above ground growth with nutrient application. Tuber weight did not respond to the treatments, while tuber count increased with N addition. No response was observed in tuber count owing to P or K addition. Tubers had no increase in either N, P, or K uptake owing to fertilization. Results suggest that limited practical response to nutrient application to chufa can be expected. However, field studies to verify these results are warranted.

Acknowledgments

The author would like to express his gratitude to his major professor, Dr. C. Wesley Wood, for his direction and support throughout the study. Appreciation is also extended to the remainder of his committee: Dr. David B. Weaver, Dr. Edzard van Santen, and Dr. Stephen S. Ditchkoff for their guidance on all aspects of the experiment. The author would also like to sincerely thank Brenda Wood, Susan Sladden and Jane Farr for their technical and laboratory assistance. Thanks are also offered to Dr. D. Ball for his extensive counsel during the project. Lastly the author would like to thank his family and friends for their support and patience throughout the study.

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List of Abbreviations

ADF	Acid detergent fiber
ADL	Acid detergent lignin
AE	Aeschynomene
AL	Alfalfa
BA	Ball clover
BR	Brassica mixture
BR_M	Brassicas in Biologic mixture
Ca	Calcium
CH	Chicory
CH_M	Chicory in the Biologic mixture
CHU	Soybean
CL_M	Clovers in the Biologic mixture
CO_CO	Corn in corn and cowpea mixture
CP	Cowpea
CP_CO	Cowpea in corn and cowpea mixture
CP_SO	Cowpea in sorghum and cowpea mixture
CP_SU	Cowpea in sunflower and cowpea mixture
CR_M	Crimson in wheat and crimson mixture

dm	Dry matter
ha	hectare
ICAP	Inductively coupled argon plasma spectrophotometry
K	Potassium
Kg	Kilogram
LL	Lablab
LU	Lupin
m	meter
mg	milligram
N	Nitrogen
NDF	Neutral detergent fiber
P	Phosphorus
PE	Peanut
RC	Red clover
SH	Sunnhemp
SO_SO	Sorghum in sorghum and cowpea mixture
SU_SU	Sunflower in sunflower and cowpea mixture
WC-I	intermediate white clover
WC-L	Ladino white clover
WH	Wheat
WH_M	Wheat in wheat and crimson mixture
WP	Winter pea

I. Literature Review

Determination of Optimal Food Plot Cropping System for White-tailed Deer in the Southeast

The state of Alabama is rich in sustainable natural resources. One of the most sought after of these is the white-tailed deer (*Odocoileus virginianus virginianus)*. In the wildlife business there is the saying “deer pay the bills”. Keegan et al., (1989) noted that white-tails are the most sought after and economically important game species in the U.S. Revenue from hunting generated 678 million dollars in 2006 in Alabama alone (U.S. DoI-FWS, 2006). Stribling et al., (1989) estimated that over 34 million dollars were spent on food plots for wildlife, with the majority being used to attract white-tailed deer during hunting season. Sources of this revenue range from fuel used during transportation and planting to specialty seed blends and consulting services. Big game made up more than 458 million dollars of the 678 million dollar total, the majority of which comes from white-tailed deer (U.S. DoI-FWS, 2006). This includes sales of firearms, ammunition, primitive weapons such as bows and black powder, treestands, scents, clothing, and much more. The sales of food plot fertilizer, seed and supplies are one of the largest sources of economic inputs from hunting and help support local economies during a generally non-profitable season.

A food plot is an area of land, managed or manipulated, to provide one or more crop plant species for feeding purposes. These areas may be simply top sown with winter annuals such as annual ryegrass (*Lolium multiforum* Lam.*)* and crimson clover (*Trifolium incarnatum* L.) or be a part of a detailed management plan where areas are maintained year round, similar to conventional row cropping. The extent to which a food plot is developed depends largely on a compromise between its goal and available funding. Originally, food plots began as a means to attract deer to an area during hunting season, and attraction remains the main purpose most individuals have for food plots (Kammermeyer et al., 2006). The other direction food plots are taking is towards herd management. With this objective, plots are established with more emphasis on herd health and habitat improvement.

For several reasons such as heat stress, lack of available quality forage, insect pests, gestation, lactation, fawn survival, antler development, and overall reduced forage intake, late summer is one of the most stressful times for deer in the Southeast (Goodrum and Reid, 1962; Hafez, 1967; Ockenfels and Bissonette, 1982; Blair et al., 1984; Keegan et al., 1989). Many individuals are striving to increase overall health of their herd by ensuring sufficient quantity and quality of browse is available throughout the year, not just during hunting season. There is, however, little scientific information regarding what is best to plant (Davis, 1961; Webb, 1963; Larson, 1966; Lunceford, 1986; Waer, 1992; Waer et al., 1992). The majority of information regarding food plot plantings is often anecdotal or from less than dependable sources. Many times information is simply inter-species applied, such as using recommendations for deer that come from cattle literature. While this is at least often backed scientifically, the fact remains that deer are a different animal than cattle, with much different nutritional needs and preferences.

Warm Season Forages

Soybean (*Glycine max* L. Merr.) is highly preferred by deer (Watt et al., 1967). Its benefits are ease of cultivation, high yield and high forage quality (Scheaffer et al., 2001). These benefits may be offset by its susceptibility to early browse pressure and management costs (Hintz et al., 1992). Soybean has several drawbacks with regard to food plot application, the main ones being low browse and low drought tolerance (Garrison and Lewis, 1987; Specht et al., 2001). Seiter et al., (2004) found yields of forage soybean up to 13.9 Mg ha^{-1}. Such large yields increase the potential for sustained browse availability under high deer densities and concurrent low acreages of food plots.

Cowpea (*Vigna unguiculata* L. Walp.) has been a staple of summer food plots for several years (Edwards et al., 2004). However, like soybean it does not persist under heavy browse pressure. Cowpea has potential to supply quality late summer forage when it is most limiting (Rao and Northup, 2009). Its benefits are similar to other warm season legumes in that it has good forage quality, requires little fertilization, has a short growing season and is easily cultivated in a wide range of locations (Ball et al. 2002). Rao and Northup, (2009) estimated cowpea forage yields up to 2405 kg ha^{-1}. Cowpea is often planted with companion forages, such as corn (*Zea mays* L.) or sorghum (*Sorghum bicolor* L. Moench) that have more vertical growth habit. The purpose of vertical forages is to provide structure for the vine to climb on. Without vertical structure cowpea yield can be reduced (Ball et al., 2002).

A wildlife forage variety of sorghum (*Sorghum bicolor* L. Moench) is commonly used for the added benefits of increasing cowpea yield and diversifying food sources during late summer (Yarrow and Yarrow, 2005). Sorghum seeds are a good source of carbohydrates and have the possibility to last long into the winter months, providing an energy rich food source when others may be lacking. Being highly drought tolerant and requiring low amounts of fertilizer, sorghum has been shown to grow well in many environments with little input (Ball et al., 2002). Limitations to sorghum use include intolerance of acidic pH and grassy weed suppression problems (Kammermeyer et al., 2006). In combination with warm season legumes such as cowpea, fertilizer requirements can be partially supplied by legume nitrogen (N) fixation furthering the benefit of sorghum-cowpea intercropping (Gilbert et al., 2003; Ncube et al., 2007).

Black oil (Peredovik) sunflower (*Helianthus annuus* L.) is often planted along with cowpea for its added vertical structure. Sunflower is commonly chosen because of its relative ease of cultivation, supposed high preference by deer, and current use in food plots (Cook and Gray, 2005; Kammermeyer et al., 2006). Sunflower has drawbacks that may reduce its usefulness in food plots: 1) somewhat low forage quality especially after reproductive initiation (Heady, 1964), 2) its vertical structure is not as sturdy as that of corn or sorghum, resulting in lodging during high winds, and 3) low browse tolerance during early stages of growth (Cook and Gray, 2005; Yarrow and Yarrow, 2005; Kammermeyer et al., 2006).

Corn (*Zea mays* L.) is another common companion crop with cowpea. Corn grain has the advantages of lasting long into the winter, thus providing a carbohydrate rich food source when others may not be available, and being highly preferred over many other food sources (Nixon et al., 1970). Corn can, however, be difficult to grow, require a large amount of fertilizer to get good yields, and have little or no forage benefits during the summer (Kammermeyer et al., 2006). Residue left from corn production works well with no-till and annual clover systems and helps to improve soil quality (Troeh et al., 2004).

Lab-lab (*Lablab purpurius* L. Sweet) is another warm season legume that has recently become popular for food plot use. Lab-lab has been shown to have high yields in the Southeast and is tolerant of low rainfall environments (Fribourg et al., 1984; Hehman and Fulbright, 1997). Hehman and Fulbright, (1997) have shown lablab's ability to withstand browse pressure better than other warm season legumes. Increased browse tolerance is especially important during the late summer when food resources are less available. Lablab forage quality is comparable to other warm season legumes and capable of producing yields in excess of 6600 kg ha^{-1} (Gonzalez, 1987; Beals et al., 1993; Feather and Fulbright, 1995). Although it has been shown to grow well in low moisture environments, it is necessary for adequate moisture to be present at time of planting for proper establishment (Kammermeyer et al., 2006).

Aeschynomene (*Aeschynomene americana* L.) is a warm season tropical legume adapted to the southeastern U.S. that has good forage quality (Moore and Hillman 1969; Moore, 1978; Keegan et al., 1989 Aiken et al., 1991). Stand establishment can be very difficult under low soil moisture conditions (Kalmbacher et al., 1993; Kammermeyer et al., 2006). The species is especially adapted to wet soils and is relatively browse tolerant (Chaparro et al., 1992). Under heavy browsing it will likely be prevented from producing enough seed to allow for self re-seeding (Keegan et al., 1989; Chaparro et al., 1992).

Sunnhemp (*Crotalaria juncea* L.) is a warm season annual legume that shows promise as a high yielding forage during the summer (Rotar and Joy, 1983; Mansoer et al., 1997). Sunnhemp will continue to exhibit rapid growth until frost leaving the possibility for providing high quality, late summer forage (Mansoer et al., 1997). Although stems are poor quality, sunnhemp leaves have nutritional value similar to that of most clovers (Ranells and Wagger, 1992; Mansoer et al., 1997). This attribute shows potential to provide adequate browse when quality forage may be limiting (Meyer et al., 1984; Barnes, 1988; Waer, 1992).

Peanut (*Arachis hypogaea* L.) is a commonly planted row crop in the Southeast. The benefit of peanut as a food plot crop is its ease of establishment, high yield and good forage quality (Larbi et al., 1999). Since peanut development is of secondary concern, less fertilizer can be used to attain adequate above ground growth. So long as the previous or following crop species is adequately fertilized, peanuts will require very little additional fertilization (Mitchell and Adams, 1994). The benefits of increased fertilization on peanut yield will likely be offset by the detrimental effects of browsing (Omokanye et al., 2001). With proper management peanut has the ability to provide high quality summer forage as well as an energy rich food source during the cool season if the peanuts are exposed.

Chufa (*Cyperus esculentus* L. var.*sativus* Boeck) is a warm season sedge more commonly used as a food source for waterfowl and turkey (Kelley and Fredrickson, 1991). Chufa tubers are a favorite food source of many species of wildlife when available (Ball and Lacefield, 2006). Being high in starch content, they have the potential to provide a high level energy rich food source during the fall and winter (Abdel-Nabey, 2001). Little is known about chufa fertilizer requirements in relationship to tuber production in the southeastern U.S. Deer are known to feed heavily on the tubers once they have been exposed by light tillage after which individuals will continue to seek them out by digging (Yarrow and Yarrow, 2005).

Cool Season Forages

White clover (*T. repens* L.) has three growth forms, small, intermediate, and large (Ball et al., 2002). Two of the more common cultivars are Durana and RegalGraze. Durana is an intermediate cultivar with increased persistence and hardiness as compared to ladino cultivars (Andrae, 2004; Kammermeyer et al., 2006). RegalGraze is a large leafed ladino cultivar. Ladino types typically have higher yield than intermediate but lack in persistence, reseeding ability, and browse tolerance (Andrae, 2004). According to Ball et al., (2002), white clovers offer the advantage of being planted in fall thus providing increased forage availability. These clovers require adequate soil moisture and exhibit reduced if any production under droughty conditions (Waer, 1992; Waer et al., 1992). White clover is easily established, provides high quality forage, and grows well in a wide range of locations excluding those previously mentioned (Ball et al., 2002).

Red clover (*T. pratense* L.) is adapted to a wide range of environmental conditions, shows exceptional seedling survival and vertical growth compared to many others (Stewart et al., 2008). These benefits may amplify red clover’s potential as a good food plot forage. Red clovers are, however, less persistent than other perennial clover types in part due to their limited reseeding ability when subjected to high stress such as browsing (Ball et al., 2002). Limited reseeding ability necessitates the practice of low rate over seeding during fall to boost stand potential. Red clover has long been regarded as one of the best choices of clover types in areas where it is adapted (Ball et al., 2002; Kammermeyer et al., 2006).

Chicory (*Cichorium intybus* L.) is a cool season perennial forb adapted to a wide range of environments. Chicory can have forage attributes similar to alfalfa when properly managed (Lancashire, 1978). Yield is greatest during early spring when growth resumes (Guangdi and Kemp, 2005). Such early growth allows for an increase in overall forage quality by diversifying forage distribution throughout the year (Kusmartonto et al., 1996; Barry, 1998). Chicory has a relatively high fertilizer requirement for maximum production, but is very tolerant of browse pressure once established and produces continuously high quality forage (Collins and McCoy, 1997). Foster et al. (2002), showed high variability among chicory cultivars with regard to deer browsing preference.

Alfalfa (*Medicago sativa* L.) can be an excellent crop for food plots but management requirements can be intensive in the Southeast (Ball et al., 2002). Allen, (1968), Martinka, (1968), Robbins et al., (1975), and Ball et al., (2002), also noted its high forage quality, browse tolerance and deer preference. In the Southeast however, there are several limitations to its current use, these being specific pH and fertilizer requirements, soil compaction and moisture, heat, disease, necessity for large amounts of fertilizer, and insect stress (Ball et al., 2002; Kammermeyer et al., 2006).

Wheat (*Triticum aestivum* L.) is one of the most commonly planted winter annual grasses in food plots in the Southeast (Waer et al., 1992; Kammermeyer et al., 2006). Its use often comes as result of its ease of cultivation and adaptability to multiple environments. Wheat has the added benefit of being highly browse tolerant although cool weather will reduce re-growth (Ball et al., 2002). While it may be highly preferred early during the growing season, forage quality and, thus, use by deer rapidly declines as the plant matures (Heady, 1964; Ball et al., 2002).

Commercially available Biologic Premium Perennial is a widely used food plot mix. The mix contains eleven species consisting of Rivendel White clover, Axi Berseem clover, Border Balansa Clover, Six Point chicory, Molina rape, FSG 9601 Red clover, Kurow rape, Teumka White clover, Mairaki rape, Browtine chicory, and Timaru II chicory. It is marketed as a highly preferred blend with increased forage quality as compared to their more commonly available constituent varieties. Little information is known on the actual effectiveness of such commercial mixes.

A brassica mix comprised of Purple Top turnips (*Brassica napus* L.) and Dwarf Essex rape (*B. napus.* L.) can be used to give some comparison to the commercial blend. Each of these are heavily planted winter annuals in the Southeast with significant forage production (Waer, 1992). They have relatively high forage quality, are easily established and adapted to a wide range of environments (Jung et al., 1984). Kammermeyer et al., (2006), also denotes the benefits of having both top and tuber growth.

Crimson clover (*T. incarnatum* L.) is likely the most widely planted food plot legume in the Southeast. This is in part due to its good forage quality, ease of establishment, low management requirements, good re-seeding capability, and seed availability (Pedersen and Ball, 1991; Waer, 1992; Waer et al., 1992; Ball et al., 2002). It has excellent early spring production under grazing conditions and has higher yield potential under low pH soils when compared to other clover species (Waer, 1992; Ball et al., 2002). With proper management enough seed is produced to allow for partial or full re-seeding (Ball et al., 2002).

Wheat and Crimson clover are two classic food plot components in the Southeast (Cook and Gray, 2005). The combination of these two forages has the potential to provide high quality forage throughout the cool season and into early summer (Waer et al., 1992). The purpose for this treatment choice would be to evaluate differences between the single species plots and the wheat crimson mix.

Arvika winter pea (*Pisum sativum* L.) is a cool season annual legume very similar to the more commonly known Austrian winter pea. Winter pea has been shown to be readily browsed by deer and has excellent forage quality (Ball et al., 2002). It is a common component of commercially available mixes, but generally is over-browsed before it reaches full potential (Kammermeyer et al., 2006). Winter pea is mostly thought of as a highly sought after, high quality species for attractive purposes during fall and early winter similar to white clover. The species in the winter pea group are high level N fixers, which reduces their need for fertilizer application.

Ball clover (*T. nigrescens* Viv.) is a highly browse tolerant cool season annual clover that is thought to be one of the originating sources for white clover (Williams et al., 2001). Unlike many other species this clover has the ability to reseed very well even after heavy grazing (Ball et al., 2002). Ball et al., (2002), also denotes the added advantage of being more tolerant to a wider range of soil pH with good germination in cooler temperatures when compared to other clovers. Brink et al., (2001) demonstrated the capability for Ball clover to out yield many other species during the first season, after which yield decreased to a level more comparable to that of other species.

Lupins (*Lupinus albus* L.) were once planted extensively in the Southeast as a winter cover/ grazing crop (Kammermeyer et al., 2006). These cool season annual legumes have the advantage of growing well in limited phosphorus (P) soils (Schulze et al., 2006). This is in part due to the formation of proteoid roots which exude compounds that increase soil P solubility (Dinkelaker et al., 1989; Neumann et al., 1999; Marschner, 2006). Like many cool season legumes they can easily be over-browsed early in the growing season.

There are several facets of traditional agriculture that can be applied to the production of food plots for deer. In agricultural experiments, tillage is often of major concern. Food plots are no different with regard to detrimental impacts that tillage can have on the soil. No-till systems have the ability to minimize degradation and loss of soil but these practices have been tested very little on food plots (Troeh et al., 2004). There is potential with no-till systems to reduce plot establishment cost and improve all aspects of soil quality (Karlen et al., 1994).

The majority of food plots are prepared via conventional tillage. Under conventional tillage, soil quality is degraded with every pass over the field (Troeh et al., 2004; Brady and Weil, 2002). Conventional tillage has the benefit of being more plastic in its applicability. There is less need for precision from a soil moisture perspective compared to no-till practices and therefore a greater window of opportunity for seed bed preparation. Food plots tend to be on a small scale which helps to reduce damage caused by erosive and soil destructive aspects of conventional tillage (Cook and Gray, 2005; Kammermeyer et al., 2006). Many individuals already possess or have access to necessary tillage equipment such as disks, chisel plows, cultipackers, and rotary tillers. They may not be willing to purchase different equipment required to adequately no-till.

Under no-till systems there is the potential for yields to decrease during the first years of practice until the system has matured (Brady and Weil, 2002). No-till systems also tend to decrease yields in poorly drained areas when there is a cool wet spring (Lal et al., 2007). With reduced tillage systems such as no-till there is a greater need for herbicidal or other no-till weed suppression (Wiese, 1985; Brady and Weil, 2002). The foremost benefit of conversion to a reduced tillage system is overall improvement of all facets of soil quality (Troeh et al., 2004). This process is attained by reducing runoff and soil erosion, increasing moisture retention ability, and improving soil structure, microbial and chemical composition (Wiese, 1985; Karlen et al., 1994; Uri, 1999; El Titi, 2003; Troeh et al., 2004; Brady and Weil, 2002).

No-till systems have the disadvantage of being sensitive to soil moisture and type. Soil moisture changes with soil type which affects the planter's ability to ensure good seed to soil contact (El Titi, 2003; Troeh et al., 2004). Proper no-till application necessitates the user to be ready to plant when conditions are optimal, which the average hunter may not be able to accomplish. The greatest benefit to hunters is reduction of planting costs due to reduced trips across the field (Uri, 1999; El Titi, 2003; Lal et al., 2007).

Conclusive literature on the subject of optimal food plot cropping systems is scarce. Waer, (1992) estimated optimal food plot forages by evaluating preference, yield, and forage quality of six warm season forages (Davis soybean, Quail Haven soybean, combine cowpea, catjang pea (*Vigna sinensis* L. Walp.), velvetbean (*Mucuna pruriens* L. DC.), and aeschynomene) and eleven cool season forages (Coker 820 oats (*Avena sativa* L.), Wren's Abruzzi rye (*Secale cereal* L.), Marshall ryegrass, Pioneer 2551 wheat, Civastro forage turnip, Osceola ladino white clover, Regal ladino white clover, Imperial Whitetail ladino white clover, Tibbee crimson clover, Mt. Barker subterranean clover (*T. subterraneum* L.), and Redland II red clover) with captive deer. Throughout the year it was determined that small grains during the fall, crimson clover during winter into early spring, ladino clover from spring into early summer, and soybeans and red clover during summer would provide the best forage for deer use in food plots (Waer, 1992). Stephens et al., (2005) recommend Durana white clover be established in food plots based on production, use by deer, and crude protein level. Lablab is often purposed to be the most adequate warm season forage in the Southeast. Out of three warm season legumes (lablab, soybean, and cowpea) lablab was found most applicable to food plot use due to browse tolerance, forage quality, and productivity (Beals et al., 1993). A similar study by Feather and Fulbright (1995) on four warm season legumes (lablab, tepary bean (*Phaseolus acutifolius* A. Gray), siratro (*Macroptilium atropurpureum* Moc. & Sessé ex DC. Urb., and cowpea) concluded lablab was the best of those tested based on nutritional quality and palatability to deer. Studies seem limiting in their comprehensiveness regarding the necessary variable interactions and dynamics associated with deer food plots. Researchers often inaccurately design experiments to determine optimal food plot cropping systems by not seeing the big picture. Use of captive deer, lack of crop mixtures, biased planting techniques and plot management, lack of tillage considerations and too few forages chosen, are common place in food plot experiments but fail to depict the true situation and may present false information (Waer et al., 1992; Beals et al., 1993; Kammermeyer et al., 1993; Feather and Fulbright, 1995; McDonald and Miller, 1995; Stephens et al., 2005; Kammermeyer et al., 2006).

In summary, there is conflicting information regarding best recommendations for food plots in the Southeast. A lack of scientifically credible sources on such recommendations does not help landowners and service providers. The goal of our research was to develop recommendations for the best food plot system for white-tailed deer in the Southeast based on three classifications: biomass production, forage quality, and deer preference.

Chufa Response to Nutrient Additions

Chufa (*Cyperus esculentus* L. var.*sativus* Boeck) is a species of sedge native to the Middle East but currently found in over 30 countries, including all of North and Central America, several European countries, South American, the Middle East, Asia and Africa (Holm et al., 1977; de Vries, 1991; Pascual et al., 2000; Li et al., 2001). Chufa also goes by the names tiger nut, ground nut, earth almond and the more commonly known yellow nutsedge (Pascual et al., 2000; Coskuner et al., 2002). *Cyperus esculentus* has two ecotypes, which at present strongly influences usage, yellow nutsedge being a particularly troublesome invasive weed and chufa being a cultivated variety with no apparent invasive nature (Pascual et al., 2000).

Differences between weed types and cultivated types have been described since pre-Linnean times and are distinguished based on their physical characteristics (Lobelius, 1581; Robinson and Fernald, 1908; de Vries, 1991). Mitchell and Martin (1986) describe chufa as being a vigorous perennial sedge with rapid growth. The stems are triangular, smooth, yellowish, 20 to 61 cm tall. The leaves appear bright green, are approximately 8 cm wide, and are rigid early on but take on a somewhat wilted and pliable appearance as the plant matures. Three to seven prominent, unequal bracts, 5 cm to 21 cm in length arise from the base of the inflorescence, with some being much longer than others. When formed, the inflorescence may be five to ten stalks varying in length with pinnate spikelets on terminal spikes. Although infrequently viable, the achenes are three-sided, yellowish and small (Mitchell and Martin, 1986). Tubers are found at the end of rhizomes and can be 0.6 cm to 1 cm long, range in shape from nearly round to oblong, and are tan to black although newly formed tubers are white (Mitchell and Martin, 1986; Kelley and Frederickson, 1991; Gifford and Bayer, 1995; Li et al., 2003). Other factors such as tuber size, color, oil content, frost tolerance, and taste help to discern between the chufa and weedy individuals (Robinson and Fernald, 1908; de Vries, 1991; Pascual et al., 2000). In reality, the invasive potential of chufa cannot be ignored, as it has the ability to propagate asexually from tubers produced at the end of rhizomes (Thullen and Keeley, 1975; Gifford and Bayer, 1995; Li et al., 2003). Studies have reported as many as 1900 shoots and 6848 tubers being generated in one year from a single tuber (Tumbleson and Kommedahl, 1961; Gifford and Bayer, 1995; Li et al., 2001). In the U.S., however, chufas are most often thought of as more of a weed species than a crop partially due to the weedy variety being present in all 50 states (Wills, 1987; Gifford and Bayer, 1995). Most research to date on *C. esculentus* has occurred on the physiological and ecological characteristics in order to better understand control of the weed types.

Chufas have been used as a food source in the Nile Valley region of Africa for thousands of years and are thought to be one of the first cultivated forages (Zohary, 1986; de Vries, 1991; Pascual et al., 2000). Cultivation of chufa has been ongoing in Europe for several centuries (de Vries, 1991; Pascual et al., 2000). Currently several countries restrict movement of root crops and other commodities that may contain nutsedge tubers to prevent further spread of the invasive biotype (Naber and Rotteveel, 1986; de Vries, 1991).

As a crop, chufas have been used as a food source for both wildlife and livestock. Planting of chufa for hogs was a common practice in parts of Florida, Georgia, and Alabama during the early to mid 1900's (Killinger and Stokes, 1951, Pascual et al., 2000). Hogs were given access to the fields after tubers matured and allowed to feed in a manner similar to feeding in peanut fields.

By far the most common use of chufa in recent times has been planting as a food source for wildlife. Specifically, tubers produced by chufa provide an excellent source of energy and are readily sought after by game animals (Mitchell and Martin, 1986; Kelley and Frederickson, 1991). Although many species of mammals and birds utilize chufas, wild turkey and waterfowl are the most prevalent beneficiaries of chufa plantings (Mitchell and Martin, 1986). Billingsley and Arner (1970) found chufas to be second only to spice bush (*Lindera benzoin* L.) in preference, use, and nutritive value by wild turkeys in Mississippi. The majority of information on chufa cultivation in the U.S. is for the purpose of providing food for turkeys and waterfowl. At present, several seed companies market chufas towards hunters for turkeys (Mitchell and Martin, 1986).

Chufas should be planted in lighter sandy soils to allow for turkeys to more easily scratch them up (Billingsley and Arner, 1970; Mitchell and Martin, 1986). Turkeys utilize chufa plantings to such an extent that stand establishment can be difficult in areas with high turkey populations (Billingsley and Arner, 1970; Mitchell and Martin, 1986). Those tubers not consumed during the winter will germinate the following spring and produce new chufa plants (Davis, 1976; Mitchell and Martin, 1986; Kelley and Frederickson, 1991).

Chufa tubers are one of the most sought after food sources by waterfowl (McAtee, 1939; Anderson, 1959; Kelly and Frederickson, 1991; Coskuner et al., 2002; Taylor and Smith, 2003). Wild varieties are commonly found in many areas, including agricultural fields and moist soil wetlands where waterfowl forage and loaf (Taylor and Smith, 2003) in all states of the country (Merrell, 1975; Thullen and Keeley, 1980; Kelly 1986). It is suspected that waterfowl are initially attracted to above ground food sources after which time they readily utilize belowground foods (Taylor and Smith, 2003; Taylor and Smith, 2005). Many species of waterfowl show a strong preference for chufa tubers (Martin and Uhler, 1939; McAtee, 1939; Stanton, 1957; Anderson, 1959; Mitchell and Martin, 1986). Martin and Uhler, (1939) report chufas as being the third most important food source for waterfowl along the Mississippi flyway and tenth overall in the U.S.

Chufas are used to produce a milky drink in Spain known as horchata de chufa (Pascual et al., 2000; Coskuner et al., 2002). This dairy drink is a low acid vegetable beverage with high nutritional quality due to oleic acid content (Cortes et al., 2004). Horchata can be found in several countries of the world including France, the United States, Mexico, Venezuela, Panama, and several others in the Dominican Republic (Cortes et al., 2004). In other parts of the world the tubers are often roasted or eaten raw (Coskuner et al., 2002). Tubers may also be used as flavoring in ice cream or dried and made into cakes (Pascual et al., 2000; Coskuner et al., 2002).

Cultivation via disking is the most prominent management practice utilized in chufa stands throughout their range (Reid et al., 1989; Kelley, 1990). Production is stimulated by disking, which removes tubers from parent plants and scarifies dormant tubers (Tumbleson and Kommedahl, 1962; Taylorson, 1967; Sanchez Tames and Vieitez, 1970; Thullen and Keeley, 1975; Taylor and Smith, 2003). Those tubers removed will then develop into additional plants and tubers in as little as 18 days (Tumbleson and Kommedahl, 1962; Sanchez Tames and Vieitez, 1970; Kelley, 1990; Taylor and Smith, 2003). Disking also increases above and belowground biomass (Kelly, 1990). Disking also serves to uncover tubers to allow wildlife such as turkeys and waterfowl to find and utilize them. Chufa tuber size increases when less competition is present, either in the form of a denser chufa stand or weed interactions (Taylor and Smith, 2003). Tillage has the added benefit of decreasing the density of compacted soils thereby increasing water infiltration, aerating the soil, raising elevation and allowing for better tuber acquisition by foraging individuals (Peters and Afton, 1993). Increased elevation has direct effects on duration of flooding and water holding capacity. Disking can be beneficial in areas that remain wet for longer periods by reducing the duration of flooding on emerging seedlings (Kelley and Frederickson, 1991; Peters and Afton, 1994).

Chufa is relatively intolerant of shade (Bell et al., 1962; Keeley and Thullen, 1978; Mitchell and Martin, 1986; Peters and Afton, 1993). Keeley and Thullen (1978) found chufa yields reduced by as little as 30% shade. A reduction in either amount or quality of light sharply decreases production (Dale and Causton, 1992; Li et al., 2001). Along with decreased overall production, shading influences other physiological factors such as, flowering, rhizome length and differentiation, aerial shoot development, and tuber production (Li et al., 2001). It is suspected that evolving alongside competitive wetland species that reduce light availability resulted in the rapid growth and development now found in chufa (Kelley, 1990). The natural occurrence of seasonal flooding allows for tubers to germinate and develop before competing species shade out chufa plants (Kelley, 1990).

Chufa has the ability to tolerate short periods of inundation which is beneficial in decreasing weed competition when established in wet areas (Kelley and Frederickson, 1991; Peters and Afton, 1993Taylor and Smith, 2003; Taylor and Smith 2005). It should be noted that chufas require moist conditions for proper germination and seedling development. Lack of adequate soil moisture drastically reduces tuber yields (Day and Russell, 1955; Taylorson, 1967; Kelley, 1990). Germination is reduced under prolonged flooding or saturated periods as well as if soil moisture is too low (Peters and Afton, 1993). Merrell (1975) noted that at least a three month period of non-flooded conditions are necessary for good tuber production (Mitchell and Martin, 1986).

Peters and Afton (1993) found 51 and 95% of tubers present in the top 10 cm and 20 cm of the soil profile respectively. Bundy et al. (1960) found tubers occurring below 15 cm of the soil surface to have a low germination rate. Placement within the soil profile has implications for the depth to which individuals can adequately feed on tubers. In heavier clay soils individuals will likely be restricted to the more upper profile while sandy and loam type soils will allow for feeding deeper in the soil (Peters and Afton, 1993). Tubers may remain dormant for up to 3.5 years when left in the soil profile (Kelley and Frederickson, 1991).

While there is adequate information regarding management practices for chufas, little information exists on chufa fertilizer response. Literature in previous studies presents inconclusive results regarding chufa response to fertilizer additions (Killinger and Stokes, 1951; Maroto et al., 1986; Pascual et al., 2000). Killinger and Stokes (1951) reported what was termed “erratic responses” to nutrient additions. Nitrogen applications between 250 – 400 kg ha^{-1} produced no significant results on tuber production while applications over 520 kg ha^{-1} led to a decrease in tuber production (Maroto et al., 1986). Pascual et al., (2000) suggests no detectable relationship can be made regarding fertilization and plant response in chufa. Most publications on chufa management recommend addition of 260 - 560 kg ha^{-1} of 10-10-10 or a similar fertilizer blend (Mitchell and Martin, 1986; Yarrow and Yarrow, 2005). This pattern seems true for both above and below ground production. With this in mind it seems necessary to more accurately determine chufa fertilizer response. The objective of the experiment was to determine chufa response to nutrient additions.

II. Determination of Optimal Cool Season Cropping System for White-tailed Deer in the Southeast

Abstract

White-tailed deer (*Odocoileus virginuanus*) have a large economic impact on the Southeast. A significant portion of this comes from food plot establishment and management. However, information regarding cropping systems for deer is inconclusive. The objective of this study was to determine the optimal cool season cropping system for white-tailed deer by evaluating forage dry matter (DM) yield, preference, and quality of 12 cool season forage treatments during 2008 through 2010. Plots were harvested during March of both years. Forage production ranged from 11 to 4331 kg dry matter (DM) ha^{-1} with wheat (*Triticum aestivum* L.) components consistently exhibiting the highest yields. Percent DM removed by deer was estimated to be between 14 and 85%, with wheat components having the highest estimates. Excluding wheat and wheat in wheat mix, cool season forages met or exceeded all requirements for nitrogen (N), calcium (Ca), phosphorus (P), and sodium (Na) concentrations. Forage fiber analyses suggested that nearly all forages had good digestibility at the time of harvest. Neutral detergent fiber (NDF) values ranged from 159 g kg^{-1} for brassica to 526 g kg^{-1} for wheat in wheat mix. Acid detergent fiber (ADF) values ranged from 115 g kg^{-1} for brassica (*Brassica napus* L.) in Biologic mix to 240 g kg^{-1} for wheat in wheat mix. Acid detergent lignin (ADL) values were more variable among treatments although wheat and wheat in wheat mix

tended to have lower fraction of ADL than most other treatments. Forage establishment under no-till proved difficult in both years of the experiment. From our findings, it is recommended that wheat be planted in cool season food plots along with a companion forage.

Introduction

The white-tailed deer is the nation's most profitable natural resource from a wildlife perspective. Each year millions of dollars are spent towards the pursuit of white-tailed deer in the United States (U.S. DoI-FWS, 2006). Alabama ranks fifth in hunting expenditures in the country. A significant portion of the investment made towards deer involves production and maintenance of food plots, and food plot expenditures likely exceed the amount spent towards hunting (Stribling et al., 1989).

Knowledge regarding food plot implementation has been borrowed from the animal science field since the first wildlife forages were also livestock forages. Research on food plots first began during the golden age of wildlife management in the 1940's and 50's as the wildlife management profession began to grow and new information on game species such as white-tailed deer was introduced (Webb, 1963; Kammermeyer et al., 2006). Food plots were established primarily to attract deer during hunting seasons, but plots now serve the dual purpose of attraction and habitat improvement (Waer et al., 1994; Kammermeyer et al., 2006). Many studies have examined various forages and their use by deer (Davis, 1961; Webb, 1963; Waer, 1992; Waer et al., 1992; Kammermeyer et al., 1993; Waer et al., 1994; Stephens et al., 2005), while other research has appraised the value of forages from a nutritional quality perspective (French et al., 1956; Waer et al., 1992; Waer et al., 1994; Stephens et al., 2005). Forage preference has been documented, but often in less than natural environments. Tillage practices in food plots have also been poorly explored. Studies that tie all factors of food plot development and management are nearly non-existent. Thus, concise information regarding cropping systems for white-tailed deer is scarce. This study evaluated cool season cropping systems for white-tailed deer in the Southeast based on forage yield, quality and deer preference.

Materials and Methods

The study was conducted from 2008 through 2010 on an upland and lowland site at the Auburn University Deer Lab at the Piedmont Substation (32°49’24.17’’N, 85°39’19.87’W, 216M elevation) near Camp Hill, AL. The soil at the upland site was a Lloyd loam, with 2 to 6 percent slopes (Fine kaolinitic thermic rhodic kanhapludult). The majority of the lower site consisted of Gwinnette – Lloyd complex, with 6 to 15 percent slopes, with both Gwinnette and Lloyd being Fine kaolinitc thermic rhodic kanhapludults. Both 0.85 ha sites (64 x 128 m) were surrounded by 3.04 m high wildlife fencing. Each site had three 3.04 m x 4.08 m double gates spaced evenly along the long sides of the site. These gates allowed for prevention of deer access during planting and stand establishment. The gates were opened to allow deer access approximately one month after planting to help ensure stand longevity throughout the growing season.

A randomized complete block design with tillage (conventional vs. no-till) and season (warm season vs. cool season) as blocks was established at both sites beginning in summer 2008 and continued through winter of 2010. Forage treatments were assigned to tillage blocks within season based on perceived performance with regard to planting method. Each treatment was replicated four times. Each plot was 3.6 x 9.1 m. Conventional tillage plots were first disked with a 1.5 m wide disk harrow, and then tilled with a rotary tiller until a smooth seed bed was prepared. No-till plots received no tillage as the treatment.

Cool season plots were planted the first week of October 2008 and the last week of September 2009. Cool season no-till plots included: ladino white clover (*Trifolium repens* L.), intermediate white clover (*T. repens* L.), alfalfa (*Medicago sativa* L.), chicory (*Cichorium intybus* L.), red clover (*T. pretense* L.), Biologic Premium Perennial that consisted of a combination of Rivendel white clover (*T. repens* L.), Axi berseem clover (*T.alexandrinum* L.), Border balansa clover (*T. michelianum* Savi.), Six point chicory (*C. intybus* L.), Molina rape (*B. napus* L.), FSG 9601 red clover (*T. pratense* L.), Kurow rape (*B. napus* L.), Temuka white clover (*T. repens* L.), Mairaki rape (*B. napus* L.), Browtine chicory (*C. intybus* L.), and Timaru II chicory (*C. intybus* L.), wheat mixture that consisted of crimson clover (*T. incarnatum* L.) and wheat(*Tricum aestivum* L.), a brassica mixture that consisted of *Brassica rapa* L. and *B. napus* L., Arvika winter pea (*Pisum sativum* L.), and ball clover (*T. nigrescens*). Cool season conventional tillage plots included: Arvika winter pea, Biologic Premium Perennial, wheat mix, lupin (*Lupinus albus* L.), ball clover, wheat, and the brassica mixture.

Treatments were established with a 2.4 m Great Plains no-till drill. Due to small seed size ball clover was hand seeded. Each site was soil sampled prior to the start of the experiment and limed and fertilized according to Auburn University Soil Testing recommendations. Subsequent soil testing did not show need for liming other than the initial sampling.

A 1 m diameter exclosure made from 5.1 x 10.2 cm mesh welded wire was placed at random in each plot after germination to prevent deer browsing. Biomass yield samples were harvested by hand clipping appropriate planted species from a randomly selected 0.25 m^2 quadrat area in both the open and exclosed portion of the plot and placed in paper bags. The gates to each site were opened the first week of December during both years which gave deer access to the plots for approximately 3 months. The upland site was harvested on 3 March 2009 and 30 March 2010. The lowland site was harvested on 6 March 2009 and 24 March 2010. Biomass samples were dried in a forage drier at 55°C to a common moisture content and weighed to determine dry matter production. Yields were calculated from the exclosed sample area from each plot and are reported as kg dry matter (DM) ha^{-1}. Percent DM removed was calculated as the open DM yield divided by the exclosed DM yield x 100, and is used as an estimate of deer preference. For sampling purposes, species mixtures were separated into their respective species components.

Forage quality samples were collected on the same days as biomass harvest. Quality samples were collected by hand picking only those portions of plants that were seen to be browsed by deer (leaves, pods, and petioles). These samples were taken from open areas to assess forage quality of plant material consumed by deer. As with biomass samples, each species component of the treatment was kept separate for the quality samples to allow for species comparisons among treatments. All plant biomass samples were dried in a forage drier at 55°C to a common moisture content, and ground to pass a 1 mm screen with a Wiley mill. Nitrogen was determined by dry combustion using a

LECO TruSpec CN (Leco Corp, St. Joseph, MI). Phosphorus, Ca, and Na concentrations were determined via inductively coupled argon plasma spectrophotometry (ICAP) (SPECTROCIROS CCD, Side-on plasma. Germany). Neutral detergent fiber, ADF and ADL were determined using methods described by Van Soest and Wine (1968).

Observation data was collected from fully enclosed box blinds elevated 4.5 m above ground level. For each site, eight dates were randomly chosen throughout the growing season as observation dates. The blinds were placed approximately halfway down the length of the longest side of each site and 3 m from the fence. The blinds were entered at least three hours before sunset to allow for roughly one hour for the area to settle down prior to a two-hour observation period. The observation period was started as soon as deer entered the site. Since individuals had free access to the sites there were many observation days when deer were observed but did not enter the site. A tripod mounted spotting scope with a 20-60 power lens was used to identify 0.12 x 0.17 m plot markers printed with plot number and ear tags on deer. Deer were identified by freeze branded numbers on the front shoulder and rear hip, ear tags, and/or body features. Those individuals not tagged were recorded by sex and age class. During the observation period, data was taken on each individual within the site every five minutes such that there was a total of 24 intervals in the two hour period. Individuals were recorded as feeding, walking, standing, or bedded. Feeding was defined as those individuals actively biting on forage. Individuals that were taking a bite while moving were recorded as feeding rather than walking. Standing was defined as those individuals standing but not taking a bite. Deer that were chewing cud were not recorded as feeding. Location was recorded as either the plot number in which the observation occurred or as alley. Alley consisted of all non-planted border areas within the site. The number of observation days was equally divided between the two sites so that there were 8 days at each site during the season.

Treatment effects and interactions were deemed significant at the $P \leq 0.05$ level by analysis of variance using PROC GLIMMIX in SAS 9.1.3 (SAS, 2003). Simulated adjusted pairwise comparisons were performed where applicable to denote differences between forage yields, percent removed, feeding observations, and forage quality. Due to the low number of feeding observations, tillage was not taken into account during statistical analyses. Observation data was log transformed to achieve a normal distribution. Winter pea treatments were omitted from all analyses except feeding observations due to winter kill prior to harvest. Red clover treatments were omitted from all yield and percent removed analyses due to poor stand establishment.

Results and Discussion

Production

Analysis of variance indicated the Site x Year x Forage interaction was significant for conventional tillage treatment dry matter yields, while only the forage treatment effect was significant for no-till treatment yields (Table 1). Production in conventional tillage plots at the upland site differed less than those at the lowland site (Tables 2 and 3). Production also differed between years at each site with differences occurring less frequently in 2009 than in 2008. Overall production was less in 2009, and was likely the result of below average temperatures and above average rainfall (Figure 1). This decreased production may have led to the fewer differences in 2009.

Wheat had the greatest production of single forage treatments for all sites and years under conventional tillage (Tables 2 and 3). Similar studies found small grains to out-produce other common food plot species (Waer 1992; Waer et al., 1992; and Stephens et al., 2005). Wheat had greater production when compared to all other forages (both single and mixed) for each Site x Year effect excluding the upland site in 2009 when wheat production was not different from any other treatment component. Lupin production was greater than brassica in Biologic mix, but less than wheat, and wheat in wheat mix at the lowland site in 2008. At the upland site in 2008 lupin production was less than wheat and wheat in wheat mix but greater than clover in Biologic mix. Lupin production in 2009 was less when compared to wheat at the lowland site. Excessive soil moisture is known to reduce stand establishment in N fixing forages, and lupin can be particularly susceptible to waterlogged soils (Sarlistyaningsih et al., 1996). Excessive rainfall in 2009 (Figure 1), may have decreased lupin production resulting in fewer differences compared to other treatment components. Brassica production was less than wheat at each site during both years except for the upland site in 2009 when there was no difference. Brassica production was also less than wheat in wheat mix at the lowland site in 2008 and clover in Biologic mix and crimson clover in wheat mix at the upland site in 2008. Production of wheat in wheat mix was greater than any other mixed forage component for all sites and years. Wheat in wheat mix production was generally above that of all other mixed forage components excluding brassica in Biologic mix and crimson clover in wheat mix at both sites in 2009.

Production was greater for wheat in wheat mix than any other no-till forage treatment component (Table 4). No other differences occurred regarding no-till forage treatments. Due to poor stand establishment, alfalfa, brassica in Biologic mix, chicory in Biologic mix, chicory, and red clover were not used in the analyses. Lack of differences among forage treatments most likely occurred because of poor stand establishment under no-till in the soils at the two sites.

Percent Dry Matter Removed

For each tillage regime, forage treatment was the only significant effect, indicating that percent DM removed be analyzed across all years and sites within tillage (Table 5). Treatment components containing wheat had the greatest percent DM removed estimate of the forage treatments suggesting a high degree of preference for wheat (Table 6). Waer (1992) also found wheat to be utilized more heavily by deer when compared to other forages. No difference was found between wheat in wheat mix and wheat in conventional tillage plots, suggesting the presence of crimson clover in wheat mix had no impact on wheat in wheat mix percent DM removed. Percent DM removed for wheat was above that of ball clover, clover in Biologic mix, and crimson clover in wheat mix in conventional tillage plots. Percent DM removed for wheat in wheat mix was above that of ball clover, clover in Biologic mix, and crimson clover in wheat mix in conventional tillage plots but not different from any percent DM removed estimates in no-till plots. Lupin exhibited the second highest percent DM removed estimate of conventional tillage plots suggesting preference for lupin over other species excluding wheat. This pattern follows anecdotal evidence from other studies where deer showed preference for lupin (Reeves et al., 1995; Noffsinger et al., 1998). Lupin percent DM removed was greater than ball clover and clover in Biologic mix. Brassica percent DM removed estimates fell in the middle of the range but were not different from any other forage. No comparisons were made with brassica in Biologic mix or chicory in Biologic mix in either tillage regime as result of poor stand establishment. It is likely under better stand establishment similar findings may have occurred regarding brassica and brassica in Biologic mix, since little preference for these types of forages has been reported (Waer, 1992; Waer et al. 1992).

No differences were found between percent DM removed for any no-till forage treatment (Table 5). Wheat in wheat mix tended (P=0.0695) to have the greatest percent DM removed estimate while ladino white clover had the least for no-till treatments (Tables 5 and 6). Other research suggests ladino white clover preference is greater than we observed (Waer, 1992; Waer et al., 1992; Stephens et al., 2005). Percent DM removed estimates for both ball clover and clover in Biologic mix were numerically greater under no-till than conventional tillage. Wheat in wheat mix and crimson in wheat mix percent DM removed estimates were less under no-till than conventional tillage. Brassica, alfalfa, red clover, brassica in Biologic mix, chicory in Biologic mix, and chicory were omitted from percent removed analysis due to lack of yield that resulted in a non-estimable percent DM removed. Lack of comparison differences under no-till may be owing to the increased variability and difficulty with stand establishment under no-till.

Tissue Nitrogen Concentration

Analysis of variance indicated the three way interaction of Year x Site x Forage was significant for tissue N concentration in cool season forages (Table 7). Overall there was little variability in tissue N concentration for cool season forages (Tables 8-15). All forage components regardless of tillage met or exceeded N requirements for lactating does and weaned fawns (22.4 and 35.2 g N kg^{-1}), which are the greatest physiological requirements during a deer's life cycle (French et al., 1956; McEwen et al., 1957; Ullrey et al., 1967; Holter et al., 1979). There was less variation in tissue N concentration for no-till (Tables 8 - 13) than conventional tillage (Tables 14 and 15). The only disparities in tissue N concentration for no-till species occurred at the upland site in 2009 (Tables 12 and 13), but no defining theme could be established with regards to the differences in tissue N concentration for no-till components. There was more variation in tissue N concentration under conventional tillage. There was more variation at the lowland site than the upland site as well as more variation in 2009 than 2008. Ball clover tissue N concentration exceeded that of all other cool season treatment species during 2009 at the lowland site (Table 15). Lupin had the second greatest tissue N concentration in 2009 at both sites (Table 15). While trends in tissue N concentration were noted, the majority of variation seemed to be random among forage treatment components. Forages that exceed requirements for maintenance may serve to supply a large portion of the nutritional requirements for developing individuals such as fawns and yearlings during the cool season, a time when natural browse can be limiting.

Mineral Analyses

Analysis of variance for cool season forage mineral concentration indicated the Year x Site x Tillage x Forage interaction was significant for Ca, while the Site x Forage and Site x Tillage x Forage interactions were significant for Na and P, respectively (Table 16). Calcium concentration ranged from 1.8 to 32.7 g kg^{-1}(Table 17). Brassica and brassica in Biologic mix tended to have greater Ca concentrations (13.2 to 32.7 g kg^{-1}) than other forages while wheat and wheat in wheat mix tended to have the least Ca (1.8 to 6.8 g kg^{-1}). Clover Ca ranged from 9.6 to 18.7 g kg^{-1}. Lupin Ca concentration fell between 4.1 and 6.8 g kg-1. Calcium requirements have been reported as 4 to 6.4 g kg^{-1}for optimal growth (McEwen et al., 1957; Ullrey et al., 1975; Ullrey, 1981). Excluding wheat, wheat in wheat mix and lupin, all forages either met or exceeded the proposed requirements. Calcium is most needed during antlerogenesis in males and lactation in females (Grassman and Hellgren 1993; Atwood and Weeks 2003). Harvest timing likely influenced Ca concentration. Since individuals are typically in physiological maintenance during the fall and winter, Ca concentration for wheat, wheat in wheat mix and lupin may be sufficient. During periods of increased Ca requirement individuals go through an osteoporotic like state in which minerals, especially Ca and P, are resorbed to meet elevated demand (Banks et al., 1968; Grassman and Hellgren 1993). It is during other times of year that these mineral banks are restocked. The greater Ca concentration of the brassica forages could serve to more rapidly restore mineral reserves.

There are discrepancies regarding the range of P in forage required for white-tailed deer. The requirement range for P as reported by McEwen et al., (1957), Ullrey et al., (1975) and Ullrey (1981), is from 2.8 to 5.6 g kg^{-1} while Grassman and Hellgren (1993) report requirements as 1.2 to 1.8 g kg^{-1}. Regardless of the proposed range, all cool season forages exceeded the proposed P requirements, suggesting P should not be a limiting factor in cool season forages (Table 18). Similar to Ca concentration, brassica and brassica in Biologic mix forages tended to have greater P concentration when compared to other forages. Phosphorus is the second most limiting mineral to white-tailed deer behind only Na (Grassman and Hellgren 1993; McDowell 1985). The dramatic seasonal shifts in P requirements follow the same trend previously mentioned for Ca requirements. Increased P needs during antlerogenesis and lactation are ameliorated through seasonal osteoporotic resorption of minerals. Forages with elevated levels of P could serve to more efficiently restock P deposits within the body.

Sodium has been described as the most limiting mineral to white-tailed deer (Grassman and Hellgren 1993; Hellgren and Pitts 1997; Atwood and Weeks 2003). Forages can be low in Na as result of its ease of leaching from the soil. Hellgren and Pitts (1997) described Na requirements for maintenance as 0.023 to 0.075 g kg^{-1}. According to this range, all cool season forages exceeded the requirements at the time of sampling and were in fact one to two orders of magnitude greater than that of proposed requirements for physiological maintenance (Table 19). Following the same trend for Ca and P, wheat and wheat in wheat mix tended to have a low Na concentration compared to most other forages. Chicory and chicory in Biologic mix exhibited greater Na levels than other forages used regardless of tillage. Peak Na requirements occur during lactation and antlerogenesis (Atwood and Weeks 2003). These two physiological seasons do not coincide with the presence of cool season forages and therefore Na concentration in fall forages may not be a driving factor with regard to an individual’s preference for one forage over the other. However, forages with elevated Na concentration such as chicory and chicory in Biologic mix may more efficiently supply Na throughout the growing season.

Fiber Concentration

Since forage digestibility depends on fiber concentration, an estimation of forage quality can be made from fiber determination (Van Soest 1994). Neutral detergent fiber (NDF) is the amount of total fiber in a forage or the insoluble components of the cell wall, constituted mostly of hemicelluloses, cellulose, and lignin. Acid detergent fiber

(ADF) is a measure of indigestible fiber, which is mostly cellulose and lignin or the least soluble portions of the cell wall. Acid detergent lignin (ADL) is a measure of completely indigestible fiber which is predominately lignin.

Analysis of variance indicated Site x Forage interaction as significant for NDF (Table 20). The four way interaction of Year x Site x Tillage x Forage was found significant for ADF values while ADL values were affected by the interaction of Year x Forage. Cool season NDF had little variation (Table 21). However, NDF values for wheat and wheat in wheat mix were greater than that of all other forages. Brassica and brassica in Biologic mix NDF values were less than all other forages.

As expected, wheat and wheat in wheat mix ADF values were greater than that of other forages (Table 22). Acid detergent fiber was greater in 2009 than 2008 for most forages. This may be due to a slightly later harvest date in 2009. Similar to NDF values, the ADF values for brassica and brassica in Biologic mix tended to be less than that of other forages.

Analysis of ADL indicated that wheat and wheat in wheat mix had less proportions of lignin than most other forages (Table 23). Acid detergent lignin values were greater in 2009 than in 2008. This suggests that the fiber fraction found in wheat and wheat in wheat mix was comprised proportionally of more cellulose than lignin. These values are similar to those presented by Waer et al. (1992) and suggest that most forages were adequately digestible at the time of harvest.

Deer Feeding Observations

Analysis of variance for cool season feeding observations indicated forage treatment, year and site as significant effects while no interactions were significant (Table

24). Tillage was considered in the analyses due to the low number of feeding observations. Deer were observed in all forage treatments except chicory at some point during the cool season (Table 25). The data suggest that Biologic mix treatments were less preferred when compared to other treatments and non-planted areas. Biologic mix observations ha^{-1} were less than all treatments excluding wheat mix, ladino white clover, and the alley. Wheat observations ha^{-1} were above that of wheat mix suggesting there was preference for wheat over wheat mix. Observations for wheat mix were surprisingly low when considering the percent DM removed data for wheat mix (Table 6). Lupin, which had one of the top estimates for percent DM removed (Table 6), had greater observations ha^{-1} only when compared to wheat mix and Biologic mix. Several of the treatments that experienced low yields had high numbers of observations ha^{-1}. Individuals could have been feeding on volunteer winter annuals that were present in large amounts in some plots. These treatments include red clover, chufa, alfalfa, white clover intermediate, and ladino white clover. Chufa did not have a winter treatment. Therefore, feeding observations reflect only the volunteer plants found in a winter fallow system. The occurrence of feeding observations in nearly all treatments implies that deer will utilize nearly any forage provided during the cool season. One aspect that must be taken into account is the access deer had to the plots with regard to observation data taken. Individuals were not forced into the sites as was the case in other published studies. The lower number of observations ha^{-1} do not necessarily reflect a lower preference for some treatments. Individuals could have simply visited the sites at times other than during observation periods. Overall, observations ha^{-1} were not different between treatments except when compared to Biologic mix for which feeding observations were less, and wheat mix and wheat for which feeding observations were greater.

Summary and Conclusions

The wheat and wheat in wheat mix treatment components had the greatest production of the cool season treatments. These same treatment components also had the greatest percent DM removed of cool season treatments which suggests a strong preference for wheat in this study. This preference may be linked to the greater production exhibited by wheat and wheat in wheat mix.

Deer were observed feeding in all treatments except chicory during the cool season feeding observation period. Of the treatments with high numbers of feeding observations, wheat was the only forage in which a large amount of volunteer vegetation was not present. Few differences were found when comparing between treatments, implying less reliance on forage preference and more on forage availability.

Cool season tissue N concentration estimates varied little among treatments and exceeded the proposed requirements for a deer's physiological maintenance. Lupin tissue N concentration was consistently above that of other forages. All cool season forages met the concentration requirement for Ca except wheat, wheat in wheat mix and lupin. The Ca estimates for brassica and brassica in Biologic mix were above that of other treatments which may allow these forages to more efficiently restock physiological reserves. These same forages also exhibited greater levels of P than did other treatments which, would also allow for more efficient P replenishment of skeletal reserves. All other cool season forages met or exceeded proposed P requirements. Although Na is often limiting in natural systems, all cool season forages contained adequate Na concentrations. Similarly to Ca and P estimates, wheat and wheat in wheat mix tended to have lower Na concentration than did other forages. The estimates for chicory and chicory in Biologic mix were greater than that of other treatments suggesting these forages may better serve to provide Na than other forages.

Cool season forages had little variation in fiber concentration. Wheat and wheat in wheat mix exhibited greater fiber concentration than all other forages while brassica and brassica in Biologic mix tended to have lower fiber concentrations than other cool season forages. Overall, most forages proved to have low fiber fractions suggesting good digestibility at the time of harvest.

Establishment of no-till treatments proved difficult throughout all seasons and years. It is not recommended that food plots be established via no-till methods without a proper herbicide program. Care must be taken when selecting forages if mixtures are to be planted to retain the capability for weed control. If complex forage mixtures are used, weed control may prove difficult.

Based on our findings, there are certain aspects of food plot establishment and management that should be noted. Cool season food plots may benefit by inclusion of wheat along with a companion forage. A companion forage will help to diversify the timing of forage production, increase forage quality, and improve overall nutrition. The choice of companion forages is largely based on personal preference and environmental conditions. The choice of which companion forage to use should be made based on several factors including management goals, environmental conditions, food plot size and perceived deer densities.

Table 1. Analysis of variance probability of greater F (Pr>F) for cool season conventional and no-till single and mixed forage yields.

Effect	Conventional tillage	No-till
	---------------------Pr>F------------------	
Site	0.9071	0.3862
Forage	<0.0001	<0.0001
Site x Forage	0.0690	0.0733
Year	<0.0001	0.9565
Site x Year	<0.0001	0.7642
Year x Forage	<0.0001	0.3241
Site x Year x Forage	0.0001	0.0870

Table 2. Lowland dry matter (DM) yield estimates, standard errors, and simulated adjusted pairwise P-values for cool season conventional tillage single and mixed forage treatments.

Year	Forage[†]	Estimate	StdErr	BR	BR_M	CL_M	CH_M	LU	WH	WH_M	CR_M
		---kg DM ha^{-1}---		---Adjusted P---							
2008	BA	525	277	0.9986	0.8113	1	§	0.7677	<0.0001	<0.0001	0.9997
	BR	255	373	‡	0.9992	0.9996	§	0.5455	<0.0001	0.0001	1
	BR_M	22	214	0.9992	‡	0.7955	§	0.015	<0.0001	<0.0001	0.944
	CL_M	459	214	0.9996	0.7955	‡	§	0.4667	<0.0001	<0.0001	1
	LU	1078	237	0.5455	0.015	0.4667	§	‡	<0.0001	0.0018	0.3623
	WH	3727	373	<0.0001	<0.0001	<0.0001	§	<0.0001	‡	0.042	<0.0001
	WH_M	2384	237	0.0001	<0.0001	<0.0001	§	0.0018	0.042	‡	<0.0001
	CR_M	373	237	1	0.944	1	§	0.3623	<0.0001	<0.0001	‡
2009	BA	1420	277	0.8544	0.1764	0.0215	0.0012	0.2777	0.0094	1	0.1548
	BR	7340	373	‡	0.9999	0.974	0.7354	1	0.0003	0.8625	0.9996
	BR_M	510	224	0.9999	‡	0.9968	0.7588	1	<0.0001	0.1318	1
	CL_M	265	214	0.974	0.9968	‡	0.9944	0.9893	<0.0001	0.0101	0.9993
	CH_M	11	214	0.7354	0.7588	0.9944	‡	0.6777	<0.0001	0.0003	0.8578
	LU	566	237	1	1	0.9893	0.6777	‡	<0.0001	0.2298	1
	WH	3081	373	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	‡	0.0025	<0.0001
	WH_M	1378	237	0.8625	0.1318	0.0101	0.0003	0.2298	0.0025	‡	0.1193
	CR_M	470	237	0.9996	1	0.9993	0.8578	1	<0.0001	0.1193	‡

† ball clover (BA), brassica mix (BR), brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), chicory in Biologic mix (CH_M), lupin (LU), wheat (WH), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M)

‡Indicates a self comparison;

§ Data does not exist for 2008 due to poor stand establishment

Table 3. Upland dry matter (DM) yield estimates, standard errors, and simulated adjusted pairwise P-values for cool season conventional tillage single and mixed forage treatments.

Year	Forage†	Estimate	StdErr	BR	BR_M	CL_M	CH_M	LU	WH	WH_M	CR_M
		----kg DM ha^{-1}----		----------Adjusted P----------							
2008	BA	633	277	0.3837	0.0441	0.8333	§	0.7585	<0.0001	<0.0001	0.9712
	BR	1608	373	‡	1	0.0117	§	0.9763	0.0001	0.2661	0.0451
	BR_M	1677	2146	1	‡	0.0001	§	0.7401	<0.0001	0.0443	0.0004
	CL_M	149	214	0.0117	0.0001	‡	§	0.0161	<0.0001	<0.0001	0.9998
	LU	1187	237	0.9763	0.7401	0.0161	§	‡	<0.0001	0.0005	0.0913
	WH	4331	373	0.0001	<0.0001	<0.0001	§	<0.0001	‡	0.0022	<0.0001
	WH_M	2622	237	0.2661	0.0443	<0.0001	§	0.0005	0.0022	‡	<0.0001
	CR_M	276	237	0.0451	0.0004	0.9998	§	0.0913	<0.0001	<0.0001	‡
2009	BA	930	277	0.8167	0.4633	0.2324	0.1607	0.7798	1	1	0.8385
	BR	213	373	‡	1	1	1	1	0.6824	0.5513	1
	BR_M	216	214	1	‡	1	0.9992	1	0.4063	0.1263	0.9998
	CL_M	82	214	1	1	‡	1	0.9939	0.2265	0.0396	0.9854
	CH_M	24	214	1	0.9992	1	‡	0.9779	0.1676	0.0213	0.9587
	LU	352	237	1	1	0.9939	0.9779	‡	0.6548	0.3901	1
	WH	1141	373	0.6824	0.4063	0.2265	0.1676	0.6548	‡	1	0.715
	WH_M	1070	237	0.5513	0.1263	0.0396	0.0213	0.3901	1	‡	0.4628
	CR_M	389	237	1	0.9998	0.9854	0.9587	1	0.715	0.4628	‡

† ball clover (BA), brassica mix (BR), brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), chicory in Biologic mix (CH_M), lupin (LU), wheat (WH), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M)

‡ Indicates a self comparison

§ Data not included due to poor stand establishment

Table 4. Dry matter (DM) yield estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till single and mixed forage treatments.

Forage†	Estimate	StdErr	CL_M	WC-I	WC-L	WH_M	CR_M
	---kg DM ha^{-1}---		-------------------------Adjusted P-----------------------				
BA	436	113	0.304	0.7348	0.6866	<0.0001	0.8116
CL_M	141	86	‡	0.9999	1	<0.0001	0.9451
WC-I	173	155	0.9999	‡	1	<0.0001	0.9971
WC-L	158	155	1	1	‡	<0.0001	0.9944
WH_M	1714	95	<0.0001	<0.0001	<0.0001	‡	<0.0001
CR_M	254	95	0.9451	0.9971	0.9944	<0.0001	‡

† ball clover (BA), clover in Biologic mix (CL_M), white clover intermediate (WC-I), ladino white clover (WC-L), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M)

‡ Indicates a self comparison

Table 5. Analysis of variance probability of greater F (Pr>F) for cool season conventional and no-till single and mixed forage treatment percent dry matter removed.

Effect	Conventional tillage	No-till
	--------------------Pr>F--------------------	
Site	0.4853	0.8331
Forage	0.0000	0.0695
Site x Forage	0.5443	0.9275
Year	0.8760	0.1011
Site x Year	0.6998	0.4084
Year x Forage	0.6657	0.7330
Site x Year x Forage	0.9869	0.8300

Table 6. Percent dry matter (DM) removed estimates, standard errors, and simulated pairwise adjusted P-values for cool season single and mixed forage treatments.

Forage[†]	Estimate	StdErr	BR	CL_M	LU	WC-I	WC-L	WH	WH_M	CR_M
	-% DM removed-		---Adjusted P---							
					Conventional tillage					
BA	23	10	0.8376	1	0.0299	§	§	0.0055	<0.0001	0.8751
BR	51	19	‡	0.7627	0.9975	§	§	0.7962	0.6564	0.9969
CL_M	21	9	0.7627	‡	0.0111	§	§	0.0029	<0.0001	0.7399
LU	64	9	0.9975	0.0111	‡	§	§	0.8573	0.5243	0.3361
WH	84	14	0.7962	0.0029	0.8573	§	§	‡	1	0.0584
WH_M	85	8	0.6564	<0.0001	0.5243	§	§	1	‡	0.0015
CR_M	39	8	0.9969	0.7399	0.3361	§	§	0.0584	0.0015	‡
					No -till					
BA	55	21	¶	0.9964	§	0.8557	0.8005	§	0.8978	0.8265
CL_M	43	17	¶	‡	§	0.9668	0.9265	§	0.5077	0.9641
WC-I	20	24	¶	0.9668	§	‡	1	§	0.2617	1
WC-L	14	25	¶	0.9265	§	1	‡	§	0.2309	0.998
WH_M	79	13	¶	0.5077	§	0.2617	0.2309	§	‡	0.0732
CR_M	26	14	¶	0.9641	§	1	0.998	§	0.0732	‡

† ball clover (BA), brassica mix (BR), clover in Biologic mix (CL_M), lupin (LU), wheat (WH), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M), white clover intermediate (WC-I), ladino white clover (WC-L)

‡ Indicates self comparison

§ Treatment did not exist in this tillage

¶Yield prevented data from being included

Table 7. Analysis of variance probability of greater F (Pr>F) for cool season forage tissue nitrogen concentration.

Effect	---Pr>F---
Year	0.4037
Site	0.7335
Year x Site	0.4551
Forage	0.0000
Year x Forage	0.0730
Site x Forage	0.1221
Year x Site x Forage	0.0120
Tillage	0.0056
Year x Tillage	0.1152
Site x Tillage	0.3671
Year x Site x Tillage	0.8391
Tillage x Forage	0.0880
Year x Tillage x Forage	0.4963
Site x Tillage x Forage	0.3432
Year x Site x Tillage x Forage	0.3746

Table 8. Lowland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till single and mixed species forage treatments.

Forage[†]	Estimate	StdErr	BA	BR_M	CL_M	CR_M	WCI	WCL	WH_M
	-------g kg^{-1}------		---------------------------------Adjusted P------------------------------						
BA	46.4	1.9	‡	0.9999	0.9999	0.4396	1	0.7936	0.2752
BR_M	44.5	5.5	0.9999	‡	1	0.9983	0.9999	0.9986	0.9956
CL_M	45.0	3.2	0.9999	1	‡	0.9519	0.9999	0.9785	0.8926
CR_M	41.5	1.7	0.4396	0.9983	0.9519	‡	0.9588	1	1
WCI	47.0	5.5	1	0.9999	0.9999	0.9588	‡	0.9685	0.9274
WCL	41.3	3.2	0.7936	0.9986	0.9785	1	0.9685	‡	1
WH_M	40.9	1.6	0.2752	0.9956	0.8926	1	0.9274	1	‡

† ball clover (BA), brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 9. Upland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till single and mixed species forage treatments.

Forage†	Estimate	StdErr	BA	BR	BR_M	CL_M	CR_M	RC	WCI	WCL	WH_M
	-------g kg^{-1}-------		--Adjusted P--								
AL	43.5	5.5	1	0.9998	1	1	1	0.9967	0.9993	0.9999	0.9998
BA	45.9	2.1	‡	0.7944	0.9993	0.9529	0.9998	0.8423	0.6731	0.9078	1
BR	39.7	3.2	0.7944	‡	0.9806	0.9994	0.9353	1	1	1	0.5683
BR_M	43.8	2.1	0.9993	0.9806	‡	0.9999	1	0.961	0.9428	0.9944	0.9749
CL_M	42.3	2.1	0.9529	0.9994	0.9999	‡	0.9986	0.9929	0.9961	0.9998	0.7661
CR_M	44.4	1.7	0.9998	0.9353	1	0.9986	‡	0.9303	0.8631	0.9795	0.9868
RC	36.7	5.5	0.8423	1	0.961	0.9929	0.9303	‡	1	1	0.7311
WCI	38.9	3.2	0.6731	1	0.9428	0.9961	0.8631	1	‡	1	0.4188
WCL	39.7	3.9	0.9078	1	0.9944	0.9998	0.9795	1	1	‡	0.7831
WH_M	46.8	1.7	1	0.5683	0.9749	0.7661	0.9868	0.7311	0.4188	0.7831	‡

† alfalfa (AL), ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clovers in Biologic mix (CL_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 10. Lowland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till single species forage treatments.

Forage[†]	Estimate	StdErr	BA	BR	CH	RC	WCI	WCL
	------g kg^{-1}------		-------------------------------Adjusted P-------------------------------					
AL	41.1	2.4	0.9024	0.857	0.9973	0.9996	0.9024	0.9517
BA	47.5	3.2	‡	0.1255	0.3609	0.8121	1	1
BR	34.4	3.2	0.1255	‡	0.9994	1	0.1012	0.1723
BR_M	39.1	1.9	0.4858	0.9775	1	1	0.4292	0.6075
CH	37.7	2.4	0.3609	0.9994	‡	1	0.3118	0.4703
CH_M	39.9	2.1	0.6559	0.9472	0.9998	1	0.6182	0.7659
CL_M	40.0	2.1	0.6828	0.9364	0.9998	0.9999	0.6474	0.7892
CR_M	43.3	1.5	0.9871	0.2914	0.7049	0.9818	0.9882	0.9968
RC	36.3	5.5	0.8121	1	1	‡	0.8268	0.8625
WCI	47.0	2.7	1	0.1012	0.3118	0.8268	‡	1
WCL	46.9	3.2	1	0.1723	0.4703	0.8625	1	‡
WH_M	39.8	1.6	0.5423	0.9231	0.9998	0.9999	0.4793	0.6731

† alfalfa (AL), ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clovers in Biologic mix (CL_M), chicory (CH), chicory in Biologic mix (CH_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 11. Lowland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till mixed species forage treatments.

Forage[†]	Estimate	StdErr	BR_M	CH_M	CL_M	CR_M	WH_M
	--------g kg^{-1}--------		--------------------------------Adjusted P----------------------				
AL	41.1	2.4	0.9999	1	1	0.9998	1
BA	47.5	3.2	0.4858	0.6559	0.6828	0.9871	0.5423
BR	34.4	3.2	0.9775	0.9472	0.9364	0.2914	0.9231
BR_M	39.1	1.9	‡	1	1	0.8434	1
CH	37.7	2.4	1	0.9998	0.9998	0.7049	0.9998
CH_M	39.9	2.1	1	‡	1	0.9655	1
CL_M	40.0	2.1	1	1	‡	0.9741	1
CR_M	43.3	1.5	0.8434	0.9655	0.9741	‡	0.8896
RC	36.3	5.5	1	1	0.9999	0.9818	0.9999
WCI	47.0	2.7	0.4292	0.6182	0.6474	0.9882	0.4793
WCL	46.9	3.2	0.6075	0.7659	0.7892	0.9968	0.6731
WH_M	39.8	1.6	1	1	1	0.8896	‡

† alfalfa (AL), ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clovers in Biologic mix (CL_M), chicory (CH), chicory in Biologic mix (CH_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 12. Upland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till single species forage treatments.

Forage[†]	Estimate	StdErr	BA	BR	CH	RC	WCI	WCL
	-------g kg^{-1} -------		---------------------------------Adjusted P------------------------------					
Al	41.1	2.4	0.8808	1	0.7493	1	0.9107	0.9468
BA	47.5	3.2	‡	0.9763	0.004	1	1	0.0194
BR	34.4	3.2	0.9763	‡	0.1388	1	0.9864	0.3958
BR_M	39.1	1.9	0.0062	0.358	0.9919	0.9046	0.0086	1
CH	37.7	2.4	0.004	0.1388	‡	0.6139	0.0055	1
CH_M	39.9	2.1	0.2708	0.9939	0.4207	0.9996	0.334	0.8148
CL_M	40.0	2.1	0.1724	0.9668	0.6808	0.9972	0.2213	0.9548
CR_M	43.3	1.5	0.2543	0.995	0.3586	0.9996	0.3175	0.7702
RC	36.3	5.5	1	1	0.6139	‡	1	0.8286
WCI	47.0	2.7	1	0.9864	0.0055	1	‡	0.0258
WCL	46.9	3.2	0.0194	0.3958	1	0.8286	0.0258	‡
WH_M	39.8	1.6	0.0561	0.8214	0.854	0.9874	0.0777	0.9925

† alfalfa (AL), ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clovers in Biologic mix (CL_M), chicory (CH), chicory in Biologic mix (CH_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 13. Upland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for cool season no-till mixed species forage treatments.

Forage†	Estimate	StdErr	BR_M	CH_M	CL_M	CR_M	WH_M
	------g kg^{-1}-------		--------------------------Adjusted P-------------------------				
Al	41.1	2.4	0.9821	1	1	1	0.9999
BA	47.5	3.2	0.0062	0.2708	0.1724	0.2543	0.0561
BR	34.4	3.2	0.358	0.9939	0.9668	0.995	0.8214
BR_M	39.1	1.9	‡	0.8271	0.9824	0.7472	0.9992
CH	37.7	2.4	0.9919	0.4207	0.6808	0.3586	0.854
CH_M	39.9	2.1	0.8271	‡	1	1	0.9987
CL_M	40.0	2.1	0.9824	1	‡	1	1
CR_M	43.3	1.5	0.7472	1	1	‡	0.9972
RC	36.3	5.5	0.9046	0.9996	0.9972	0.9996	0.9874
WCI	47.0	2.7	0.0086	0.334	0.2213	0.3175	0.0777
WCL	46.9	3.2	1	0.8148	0.9548	0.7702	0.9925
WH_M	39.8	1.6	0.9992	0.9987	1	0.9972	‡

† alfalfa (AL), ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clovers in Biologic mix (CL_M), chicory (CH), chicory in Biologic mix (CH_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL)

‡ Indicates a self comparison

Table 14. Tissue nitrogen concentration for 2008 estimates, standard errors, and simulated adjusted pairwise P-values for cool season conventional tillage single and mixed species forage treatments.

Site	Forage†	Estimate	StdErr	BR	BR_M	CL_M	CR_M	LU	WH	WH_M
		------g kg^{-1}-------		------------------------------------Adjusted P---------------------------------						
Lowland	BA	47.6	1.8	0.9969	0.0122	0.9004	0.1135	0.9741	0.0334	0.0005
	BR	44.0	5.0	‡	0.7048	1	0.9998	0.9999	0.9208	0.9253
	BR_M	33.9	3.5	0.7048	‡	0.0738	0.5143	0.0506	0.9975	0.9741
	CL_M	44.8	1.3	1	0.0738	‡	0.6632	0.9999	0.1975	0.0104
	CR_M	41.4	1.5	0.9998	0.5143	0.6632	‡	0.522	0.8698	0.6691
	LU	45.4	1.4	0.9999	0.0506	0.9999	0.522	‡	0.1445	0.0061
	WH	37.0	2.9	0.9208	0.9975	0.1975	0.8698	0.1445	‡	1
	WH_M	37.7	1.5	0.9253	0.9741	0.0104	0.6691	0.0061	1	‡
Upland	BA	44.5	1.8	0.3432	0.5348	0.3511	0.9999	0.9999	0.1557	0.3223
	BR	37.7	2.5	‡	0.986	0.9971	0.454	0.137	0.9999	0.999
	BR_M	40.2	1.3	0.986	‡	1	0.6846	0.1495	0.8863	0.9997
	CL_M	39.7	1.3	0.9971	1	‡	0.4751	0.0664	0.9476	1
	CR_M	43.6	1.5	0.454	0.6846	0.4751	‡	0.9899	0.2155	0.4363
	LU	45.4	1.4	0.137	0.1495	0.0664	0.9899	‡	0.0471	0.066
	WH	36.5	2.5	0.9999	0.8863	0.9476	0.2155	0.0471	‡	0.9762
	WH_M	39.3	1.4	0.999	0.9997	1	0.4363	0.066	0.9762	‡

† ball clover (BA), brassica (BR), brassicas in Biologic mix (BR_M), clover in Biologic mix (CL_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), lupin (LU), wheat (WH)

‡ Indicates a self comparison

Table 15. Tissue nitrogen concentration for 2009 estimates, standard errors, and simulated adjusted pairwise P-values for cool season conventional tillage single and mixed species forage treatments.

Site	Forage[†]	Estimate	StdErr	BR	BR_M	CH_M	CL_M	CR_M	LU	WH	WH_M
		------g kg^{-1}-------		----------Adjusted P----------							
Lowland	BA	53.5	1.8	<0.0001	<0.0001	<0.0001	<0.0001	0.0085	0.0347	<0.0001	<0.0001
	BR	32.9	2.5	‡	0.8539	0.9296	0.1146	0.0011	0.0008	0.9949	0.7189
	BR_M	37.0	1.2	0.8539	‡	1	0.4436	0.001	0.0006	1	1
	CH_M	36.6	1.4	0.9296	1	‡	0.4272	0.0015	0.001	1	0.9991
	CL_M	40.7	1.3	0.1146	0.4436	0.4272	‡	0.3489	0.2201	0.7176	0.8547
	CR_M	45.1	1.4	0.0011	0.001	0.0015	0.3489	‡	1	0.0397	0.0144
	LU	45.8	1.6	0.0008	0.0006	0.001	0.2201	1	‡	0.0232	0.0082
	WH	35.9	2.5	0.9949	1	1	0.7176	0.0397	0.0232	‡	0.9982
	WH_M	37.9	1.4	0.7189	1	0.9991	0.8547	0.0144	0.0082	0.9982	‡
Upland	BA	46.6	1.9	0.2044	0.0086	0.0968	0.9805	0.3936	0.9896	0.4806	0.0493
	BR	37.8	2.9	‡	1	0.9998	0.6201	0.9783	0.0264	0.9998	1
	BR_M	38.0	1.4	1	‡	0.9961	0.0953	0.7963	<0.0001	0.9985	0.9999
	CH_M	39.7	1.5	0.9998	0.9961	‡	0.5527	0.9985	0.0025	1	1
	CL_M	44.0	1.6	0.6201	0.0953	0.5527	‡	0.9441	0.4389	0.9234	0.3514
	CR_M	41.3	1.5	0.9783	0.7963	0.9985	0.9441	‡	0.0248	0.9999	0.9775
	LU	49.1	1.8	0.0264	<0.0001	0.0025	0.4389	0.0248	‡	0.0782	0.001
	WH	40.1	2.5	0.9998	0.9985	1	0.9234	0.9999	0.0782	‡	0.9999
	WH_M	38.9	1.6	1	0.9999	1	0.3514	0.9775	0.001	0.9999	‡

[†] ball clover (BA), brassica (BR), brassicas in Biologic (BR_M), chicory in Biologic mix (CH_M), clover in Biologic mix (CL_M), crimson clover in wheat mix (CR_M), wheat in wheat mix (WH_M), lupin (LU), wheat (WH)

[‡] Indicates a self comparison

Table 16. Analysis of variance probability of greater F (Pr>F) for cool season forage calcium (Ca), sodium (Na), and phosphorus (P) elemental concentration.

Effect	Ca	Na	P
	---------------------	Pr > F	------------------
Year	0.0001	<0.0001	0.3235
Site	<0.0001	0.3188	0.6862
Year x Site	0.0029	<0.0001	<0.0001
Forage	<0.0001	<0.0001	<0.0001
Year x Forage	<0.0001	0.6127	0.0014
Site x Forage	0.1309	0.0240	0.0597
Year x Site x Forage	0.0317	0.1150	0.3603
Tillage	0.0982	0.0530	0.2224
Year x Tillage	0.1365	0.0258	0.0619
Site x Tillage	0.5864	0.3551	0.4405
Year x Site x Tillage	0.0895	0.0652	0.9254
Tillage x Forage	0.2725	0.3065	0.8366
Year x Tillage x Forage	0.0017	0.1667	0.7358
Site x Tillage x Forage	0.2782	0.7334	0.0478
Year x Site x Tillage x Forage	0.0019	0.9548	0.5212

Table 17. Least square means comparisons of cool season forage calcium concentration.

Year x Site x Tillage[†]	Forage[‡]	Estimate							
		--g kg^{-1}--							
2009 x Upland x NT	BR	32.71				A[§]			
2009 x Upland x CT	BR	32.67				A			
2009 x Upland x CT	BR_M	26.55				B			
2009 x Upland x NT	BR_M	23.32		C		B			
2009 x Lowland x NT	BR	23.14		C		B			
2009 x Lowland x CT	BR	22.98		C		B			
2008 x Lowland x CT	BR	22.67		C		B		D	
2008 x Upland x NT	BR	21.09		C				D	
2009 x Upland x NT	BR_M	20.65		C				D	
2008 x Upland x CT	BR	19.83		C		E		D	
2009 x Lowland x CT	BR_M	19.10				E		D	
2009 x Lowland x NT	BR_M	18.46		F		E		D	
2009 x Upland x CT	CL_M	18.17		F	G	E		D	
2009 x Upland x NT	CH	17.59	H	F	G	E		D	
2009 x Upland x CT	BA	16.96	H	F	G	E			
2008 x Upland x CT	BR_M	15.83	H	F	G	E		I	
2009 x Upland x NT	CH_M	15.31	H	F	G	E		I	
2008 x Upland x CT	CL_M	15.15	H	F	G	E		I	
2009 x Upland x CT	CH_M	15.10	H	F	G	E		I	
2009 x Upland x NT	CL_M	14.96	H	F	G	E		I	
2009 x Upland x NT	BA	14.72	H	F	G	E		I	
2009 x Upland x NT	WCI	14.08	H	F	G	E		I	J
2008 x Lowland x NT	BR_M	14.02	H	F	G	E	K	I	J
2009 x Lowland x CT	CL_M	13.86	H	F	G		K	I	J
2009 x Upland x CT	CR_M	13.83	H	F	G		K	I	J
2009 x Lowland x NT	CL_M	13.53	H	F	G		K	I	J
2009 x Upland x NT	AL	13.51	H	F	G		K	I	J
2009 x Lowland x CT	BA	13.40	H	F	G		K	I	J
2009 x Lowland x NT	RC	13.31	H	F	G		K	I	J
2008 x Lowland x CT	BR_M	13.20	H		G		K	I	J
2008 x Upland x CT	BA	13.14	H		G		K	I	J
2009 x Upland x NT	WCL	12.96	H		G		K	I	J
2009 x Upland x NT	RC	12.82	H		G		K	I	J
2008 x Lowland x CT	CL_M	12.75	H				K	I	J

† Conventional tillage (CT), No-till (NT)

‡ ball clover (BA), brassica (BR), brassica in Biologix mix (BR_M), clover in Biologic (CL_M), chicory in Biologic mix (CH_M), chicory (CH), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), crimson clover in wheat mix (CR_M), alfalfa (AL)

§ Entries with the same letter are not significantly different (α = 0.05)

Table 17. continued.

Year x Site x Tillage†	Forage‡	Estimate							
		--g kg^{-1}--							
2009 x Lowland x NT	CH	12.67	H§				K	I	J
2008 x Upland x NT	WCI	12.65	H				K	I	J
2009 x Lowland x NT	BA	12.44	H				K	I	J
2008 x Upland x NT	BA	12.24	H				K	I	J
2008 x Lowland x CT	BA	12.17	H				K	I	J
2008 x Lowland x NT	WCI	12.11	H			L	K	I	J
2008 x Lowland x NT	BA	12.04	H			L	K	I	J
2009 x Upland x NT	CR_M	11.98	H			L	K	I	J
2009 x Lowland x CT	CH_M	11.73	H			L	K	I	J
2008 x Lowland x NT	CL_M	11.61	H			L	K	I	J
2008 x Upland x NT	WCL	11.60	H			L	K	I	J
2008 x Upland x NT	AL	11.56	H			L	K	I	J
2008 x Lowland x NT	WCL	11.02				L	K	I	J
2008 x Upland x NT	CL_M	10.89				L	K	I	J
2009 x Lowland x NT	WCI	10.68				L	K	I	J
2008 x Upland x NT	RC	10.67		M		L	K	I	J
2008 x Lowland x CT	CR_M	10.45		M		L	K		J
2009 x Lowland x NT	WCL	10.05		M		L	K		J
2009 x Lowland x NT	CR_M	10.03		M		L	K		
2008 x Lowland x NT	CR_M	9.97		M		L	K		
2009 x Lowland x NT	CH_M	9.92		M		L	K		
2008 x Upland x NT	CR_M	9.88		M		L	K		
2009 x Lowland x CT	CR_M	9.72		M		L	K		
2008 x Upland x CT	CR_M	9.69		M		L	K		
2009 x Lowland x NT	AL	8.84		M		L	K		
2008 x Upland x CT	WH_M	6.85		M		L			
2008 x Upland x CT	LU	6.81		M		L			
2009 x Upland x CT	LU	6.77		M		L		N	
2008 x Lowland x CT	LU	5.04		M		O		N	
2008 x Upland x CT	WH	5.00		M	P	O		N	
2009 x Upland x NT	WH_M	4.30			P	O		N	
2009 x Lowland x CT	LU	4.17			P	O			
2008 x Upland x NT	WH_M	3.69			P	O			
2008 x Lowland x CT	WH_M	3.37			P	O			

† Conventional tillage (CT), No-till (NT)

‡ ball clover (BA), clover in Biologic (CL_M), chicory in Biologic mix (CH_M), lupin (LU), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), wheat (WH), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M), alfalfa (AL)

§ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 17. continued.

Year x Site x Tillage†	Forage‡	Estimate		
		--g kg^{-1}--		
2009 x Upland x CT	WH_M	3.13	P§	O
2008 x Lowland x NT	WH_M	2.96	P	O
2009 x Upland x CT	WH	2.90	P	O
2008 x Lowland x CT	WH	2.79	P	O
2009 x Lowland x NT	WH_M	2.04	P	
2009 x Lowland x CT	WH_M	1.92	P	
2009 x Lowland x CT	WH	1.86	P	

† Conventional tillage (CT), No-till (NT)

‡ ball clover (BA), clover in Biologic (CL_M), chicory in Biologic mix (CH_M), lupin (LU), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), wheat (WH), wheat in wheat mix (WH_M), crimson clover in wheat mix (CR_M), alfalfa (AL)

§ Entries with the same letter are not significantly different (α = 0.05)

Table 18. Least square means comparisons of cool season forage phosphorus concentration.

Site x Tillage[†]	Forage[‡]	Estimate		
		--g kg^{-1}--		
2 x CT	WH	5.1		A[§]
1 x CT	BR	5.1		A
2 x NT	BR	5.1		A
2 x CT	BR	5.0		A
1 x NT	BR	4.7	B	A
1 x CT	WH	4.6	B	A
2 x CT	WH_M	4.6	B	A
1 x NT	CH	4.6	B	A
2 x NT	WH_M	4.6	B	A
2 x NT	CH_M	4.5	B	A
1 x NT	BR_M	4.5	B	A
2 x CT	BR_M	4.3	B	A
1 x NT	BA	4.2	B	A
1 x CT	BA	4.2	B	A
1 x NT	WH_M	4.2	B	A
2 x NT	CR_M	4.1	B	A
2 x NT	BA	4.1	B	A
1 x CT	CR_M	4.0	B	A
2 x NT	WCI	4.0	B	A
1 x NT	CR_M	4.0	B	A
2 x NT	RC	4.0	B	A
2 x CT	CH_M	4.0	B	
1 x CT	WH_M	3.9	B	
2 x CT	CR_M	3.9	B	
1 x CT	CL_M	3.9	B	
1 x NT	WCL	3.9	B	
2 x CT	BA	3.8	B	
2 x NT	CL_M	3.8	B	

† Conventional tillage (CT), No-till (NT)

‡ ball clover (BA), brassica (BR), brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), chicory in Biologic mix (CH_M), chicory (CH), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), crimson clover in wheat mix (CR_M), wheat (WH), wheat in wheat mix (WH_M), lupin (LU)

§ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 18. continued.

Site x Tillage[†]	Forage[‡]	Estimate	
		--g kg^{-1}--	
2 x NT	WCL	3.8	B[§]
1 x NT	CL_M	3.8	B
1 x NT	WCI	3.8	B
2 x NT	CH	3.8	B
1 x CT	CH_M	3.8	B
2 x NT	BR_M	3.7	B
1 x CT	BR_M	3.7	B
2 x CT	CL_M	3.7	B
1 x NT	CH_M	3.6	B
2 x NT	AL	3.4	B
1 x NT	AL	3.3	B
1 x CT	LU	3.1	B
2 x CT	LU	3.0	B
1 x NT	RC	3.0	B

† Conventional tillage (CT), No-till (NT)
‡ brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), chicory in Biologic mix (CH_M), chicory (CH), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), alfalfa (AL), lupin (LU)
§Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 19. Least square means comparisons of cool season forage sodium concentration.

Site	Forage[†]	Estimate				
		--g kg^{-1}--				
		Conventional tillage				
Upland	CH_M	4.4			A[‡]	
Lowland	CH_M	3.2			B	
Upland	BR_M	1.6			C	
Upland	BA	1.6			C	
Lowland	BR_M	1.3	D		C	
Lowland	LU	1.3	D		C	
Upland	LU	1.2	D		C	
Upland	CL_M	1.2	D		C	
Lowland	BA	1.2	D		C	E
Lowland	CL_M	1.2	D		C	E
Lowland	BR	1.0	D	F	C	E
Upland	BR	1.0	D	F	C	E
Lowland	CR_M	0.9	D	F		E
Upland	CR_M	0.8	D	F		E
Lowland	WH	0.8	D	F		E
Lowland	WH_M	0.8		F		E
Upland	WH_M	0.5		F		
Upland	WH	0.4		F		
		No-till				
Upland	CH_M	4.0			A	
Upland	CH	3.6	B		A	
Lowland	CH_M	2.8	B		C	
Upland	BR_M	2.0	D		C	
Lowland	CH	1.9	D		C	E
Upland	BA	1.7	D		C	E
Upland	BR	1.6	D		C	E
Lowland	BA	1.5	D		C	E
Lowland	BR_M	1.5	D		C	E

[†] ball clover (BA), brassica (BR), brassica in Biologic mix (BR_M), clover in Biologic mix (CL_M), chicory in Biologic mix (CH_M), chicory (CH), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), crimson clover in wheat mix (CR_M), wheat (WH), wheat in wheat mix (WH_M), lupin (LU)

[‡] Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 19. continued.

Site	Forage[†]	Estimate				
		--g kg^{-1}--				
Lowland	CR_M	1.1	D[‡]	F	C	E
Lowland	CL_M	1.1	D	F	C	E
Lowland	WCL	1.1	D	F	C	E
Upland	WCL	1.0	D	F	C	E
Upland	CR_M	0.9	D	F	C	E
Lowland	RC	0.9	D	F	C	E
Upland	AL	0.9	D	F		E
Upland	WCI	0.9		F		E
Upland	CL_M	0.9		F		E
Lowland	WH_M	0.8		F		E
Upland	WH_M	0.6		F		E
Lowland	WCI	0.6		F		E
Upland	RC	0.6		F		E
Lowland	BR	0.5		F		E
Lowland	AL	0.4		F		

† crimson clover in wheat mix (CR_M), brassica (BR), clover in Biologic mix (CL_M), red clover (RC), white clover intermediate (WCI), ladino white clover (WCL), wheat in wheat mix (WH_M), alfalfa (AL)

‡ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 20. Analysis of variance probability of greater F (Pr>F) for cool season forage neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) concentration.

Effect	NDF	ADF	ADL
	-------------Pr>F-----------		
Year	0.0021	0.0008	0.0000
Site	0.0525	0.0013	0.0059
Year x Site	0.3124	0.1276	0.0000
Forage	0.0000	0.0000	0.0000
Year x Forage	0.0014	0.2746	0.0000
Site x Forage	0.0000	0.0097	0.8983
Year x Site x Forage	0.1856	0.8660	0.5105
Tillage	0.4048	0.1197	0.4700
Year x Tillage	0.3273	0.2997	0.1009
Site x Tillage	0.3465	0.1287	0.7270
Year x Site x Tillage	0.4699	0.7826	0.6663
Tillage x Forage	0.9440	0.4504	0.8324
Year x Tillage x Forage	0.0964	0.6273	0.5803
Site x Tillage x Forage	0.6799	0.1397	0.3988
Year x Site x Tillage x Forage	0.8249	0.0004	0.7423

Table 21. Least square means comparisons of cool season forage neutral detergent fiber concentration.

Site	Forage[†]	Estimate		
		-----g kg^{-1}-----		
Lowland	WH_M	526		A[‡]
Upland	WH	505	B	A
Lowland	WH	461	B	C
Upland	WH_M	448		C
Upland	AL	280		D
Upland	WCL	256		D
Upland	CR_M	253		D
Lowland	AL	249		D
Lowland	CR_M	235		D
Upland	CL_M	233		D
Upland	RC	230		D
Upland	CH	227		D
Lowland	LU	225		D
Lowland	CH	219		D
Upland	LU	217		D
Lowland	WCI	210		D
Upland	CH_M	208		D
Upland	BA	201		D
Upland	WCI	200		D
Lowland	WCL	196		D
Lowland	CL_M	190		D
Lowland	CH_M	186		D
Lowland	RC	182		D
Upland	BR_M	171		D
Lowland	BR_M	171		D
Upland	BR	167		D
Lowland	BA	167		D
Lowland	BR	159		D

† wheat in wheat mix (WH_M), wheat (WH), alfalfa (AL), white clover ladino (WCL), crimson clover in wheat mix (CR_M), clover in Biologic mix (CL_M), red clover (RC), chicory (CH), lupin (LU), white clover intermediate (WCI), ball clover (BA), chicory in Biologic mix (CH_M), brassica in Biologic mix (BR_M), brassica (BR)

‡ Entries with the same letter are not significantly different (α=0.05)

Table 22. Least square means comparisons of cool season forage acid detergent fiber concentration.

Year x Site x Tillage[†]	Forage[‡]	Estimate							
		----g kg^{-1}----							
2009 x Upland x CT	WH_M	240				A[§]			
2009 x Upland x CT	WH	239				A			
2009 x Lowland x CT	WH	234				A			
2009 x Upland x NT	CH	232		B		A			
2009 x Upland x CT	CH_M	226		B		A		C	
2009 x Lowland x CT	WH_M	225		B		A		C	
2009 x Upland x NT	WH_M	222		B		A		C	
2009 x Lowland x NT	WH_M	222		B		A		C	
2008 x Upland x CT	WH	210		B	D	A		C	
2008 x Lowland x NT	WH_M	203		B	D	A		C	
2008 x Upland x NT	WH_M	201	E	B	D	A		C	
2009 x Upland x CT	CR_M	199	E	B	D	A		C	
2008 x Lowland x CT	WH_M	198	E	B	D	A		C	
2008 x Lowland x CT	WH	198	E	B	D	A		C	
2008 x Lowland x NT	CL_M	197	E	B	D	A		C	F
2008 x Upland x CT	WH_M	197	E	B	D	A		C	F
2008 x Upland x NT	RC	196	E	B	D	A	G	C	F
2008 x Upland x NT	AL	192	E	B	D	A	G	C	F
2009 x Lowland x NT	CH	191	E	B	D		G	C	F
2009 x Lowland x NT	AL	190	E	B	D		G	C	F
2009 x Upland x CT	LU	190	E		D		G	C	F
2009 x Lowland x CT	LU	185	E		D		G	C	F
2009 x Upland x NT	CL_M	184	E		D		G	C	F
2009 x Upland x CT	BA	184	E		D		G		F
2009 x Upland x NT	CH_M	183	E		D		G		F
2009 x Upland x NT	CR_M	181	E		D		G		F
2008 x Upland x CT	CL_M	179	E		D		G		F
2009 x Upland x CT	CL_M	178	E		D		G		F

† Conventional tillage (CT), No-till (NT)

‡ wheat in wheat mix (WH_M), wheat (WH), alfalfa (AL), white clover ladino (WCL), crimson clover in wheat mix (CR_M), clover in Biologic mix (CL_M), red clover (RC), chicory (CH), lupin (LU), white clover intermediate (WCI), ball clover (BA), chicory in Biologic mix (CH_M), brassica in Biologic mix (BR_M), brassica (BR)

§ Entries with the same letter are not significantly different (α=0.05)

Table 22.continued.

Year x Site x Tillage[†]	Forage[‡]	Estimate							
		----g kg^{-1}----							
2008 x Upland x NT	WCL	172	E[§]		D	H	G		F
2009 x Lowland x NT	CL_M	167	E		D	H	G		F
2009 x Lowland x CT	CL_M	166	E		D	H	G		F
2009 x Upland x NT	BR	166	E		D	H	G		F
2008 x Upland x CT	CR_M	166	E		D	H	G		F
2009 x Lowland x CT	CH_M	165	E		D	H	G		F
2009 x Upland x NT	WCL	163	E		D	H	G		F
2008 x Lowland x CT	LU	159	E		D	H	G		F
2009 x Upland x CT	BR	159	E	I	D	H	G		F
2008 x Upland x CT	LU	156	E	I	D	H	G		F
2009 x Lowland x NT	RC	156	E	I	D	H	G	J	F
2009 x Upland x NT	WCI	156	E	I		H	G	J	F
2008 x Lowland x CT	BR	155	E	I		H	G	J	F
2009 x Lowland x NT	CR_M	154	E	I		H	G	J	F
2009 x Lowland x CT	CR_M	150	E	I		H	G	J	F
2009 x Lowland x CT	WCL	150	E	I		H	G	J	F
2009 x Lowland x NT	CH_M	150		I		H	G	J	F
2008 x Upland x NT	WCI	149		I		H	G	J	F
2008 x Lowland x CT	CR_M	148		I		H	G	J	F
2008 x Upland x CT	CR_M	148		I		H	G	J	F
2009 x Upland x NT	BR_M	147		I		H	G	J	F
2009 x Lowland x NT	WCI	147		I		H	G	J	F
2008 x Upland x NT	BA	146		I		H	G	J	F
2009 x Lowland x CT	BR	145		I		H	G	J	F
2008 x Lowland x NT	CR_M	143		I		H	G	J	F
2008 x Lowland x NT	WCL	143		I		H	G	J	F
2009 x Upland x CT	BR_M	142		I		H	G	J	F
2008 x Upland x CT	BA	140		I		H	G	J	F

† Conventional tillage (CT), No-till (NT)

‡ wheat in wheat mix (WH_M), wheat (WH), alfalfa (AL), white clover ladino (WCL), crimson clover in wheat mix (CR_M), clover in Biologic mix (CL_M), red clover (RC), chicory (CH), lupin (LU), white clover intermediate (WCI), ball clover (BA), chicory in Biologic mix (CH_M), brassica in Biologic mix (BR_M), brassica (BR)

§ Entries with the same letter are not significantly different (α=0.05)

Table 22.continued.

Year x Site x Tillage[†]	Forage[‡]	Estimate					
		----g kg^{-1}----					
2009 x Upland x NT	AL	140	I[§]	H	G	J	F
2008 x Upland x NT	CL_M	139	I	H	G	J	
2009 x Lowland x CT	BR_M	139	I	H	G	J	
2008 x Lowland x CT	CL_M	138	I	H	G	J	
2009 x Lowland x NT	WCL	137	I	H	G	J	
2009 x Lowland x NT	BR_M	137	I	H	G	J	
2009 x Upland x NT	BA	134	I	H	G	J	
2008 x Upland x CT	BR	133	I	H	G	J	
2009 x Lowland x CT	BA	133	I	H	G	J	
2008 x Lowland x CT	BA	132	I	H	G	J	
2008 x Lowland x NT	WCI	128	I	H	G	J	
2009 x Lowland x NT	BA	128	I	H		J	
2009 x Lowland x NT	BR	127	I	H		J	
2008 x Lowland x NT	BA	124	I			J	
2008 x Upland x NT	BR	122	I			J	
2008 x Upland x CT	BR_M	121	I			J	
2008 x Upland x NT	BR_M	115				J	

† Conventional tillage (CT), No-till (NT)

‡ wheat in wheat mix (WH_M), wheat (WH), alfalfa (AL), white clover ladino (WCL), crimson clover in wheat mix (CR_M), clover in Biologic mix (CL_M), red clover (RC), chicory (CH), lupin (LU), white clover intermediate (WCI), ball clover (BA), chicory in Biologic mix (CH_M), brassica in Biologic mix (BR_M), brassica (BR)

§ Entries with the same letter are not signifcantly different (α=0.05)

Table 23. Least square means comparisons of cool season forage acid detergent lignin concentration.

Year	Forage†	Estimate			
		------g kg^{-1}-------			
2009	CH	52		A‡	
2009	WCL	46	B	A	
2009	AL	46	B	A	
2009	WCI	44	B	C	
2009	CH_M	37	B	C	
2009	BA	36	B	C	
2009	CL_M	35	B	C	D
2009	RC	34	B	C	D
2009	LU	33		C	D
2009	CR_M	32		C	D
2008	WCL	30		C	D
2008	RC	30	E	C	D
2009	BR_M	29	E		D
2009	BR	28	E		D
2008	WCI	27	E		D
2008	CL_M	26	E		D
2008	CR_M	25	E		D
2008	BA	25	E		D
2009	WH	25	E		D
2009	WH_M	24	E		D
2008	LU	24	E		D
2008	WH_M	24	E		D
2008	WH	23	E		D
2008	AL	21	E		D
2008	BR	18	E		
2008	BR_M	16	E		

† wheat in wheat mix (WH_M), wheat (WH), alfalfa (AL), white clover ladino (WCL), crimson clover in wheat mix (CR_M), clover in Biologic mix (CL_M), red clover (RC), chicory (CH), lupin (LU), white clover intermediate (WCI), ball clover (BA), chicory in Biologic mix (CH_M), brassica in Biologic mix (BR_M), brassica (BR)

‡ Entries with the same letter are not significantly different (α=0.05)

Table 24. Analysis of variance probability of greater F (Pr>F) for cool season feeding observations.

Effect	--Pr>F--
Forage	<0.0001
Year	0.0017
Site	0.014
Year x Forage	0.2691
Forage x Site	0.1724
Year x Site	0.2529
Year x Forage x Site	0.4587

Table 25. Estimates, standard errors, and simulated adjusted pairwise P-values for log transformed cool season observations.

Forage†	Estimate ‡	Estimate	StdErr	BA	BR	CHU	LU	RC	AL
	observations ha^{-1}	log observations ha^{-1}		---------------------------------Adjusted P--------------------------------					
WP	54.02	1.73	0.11	0.775	1	0.8201	1	0.9524	0.9818
BA	30.44	1.48	0.08	§	0.9479	0.017	0.3293	0.4457	0.3286
BR	46.22	1.66	0.10	0.9479	§	0.4664	0.9998	0.8677	0.8998
CHU	108.41	2.04	0.13	0.017	0.4664	§	0.8762	1	1
LU	59.51	1.77	0.09	0.3293	0.9998	0.8762	§	0.9736	0.9927
RC	151.52	2.18	0.29	0.4457	0.8677	1	0.9736	§	1
AL	107.14	2.03	0.20	0.3286	0.8998	1	0.9927	1	§
WH	131.05	2.12	0.09	0.0001	0.0367	1	0.217	1	1
WH _ CR	23.11	1.36	0.04	0.9741	0.1636	0.0002	0.0023	0.181	0.0684
BIO	16.02	1.20	0.06	0.1929	0.0057	<0.0001	0.0001	0.0497	0.0095
WC-I	125.83	2.10	0.12	0.0013	0.1572	1	0.5257	1	1
WC-L	75.76	1.88	0.20	0.8067	0.9991	1	1	0.9998	1
Alley	43.26	1.64	0.14	0.9994	1	0.6421	0.9998	0.8704	0.9127

† winter pea (WP), ball clover (BA), brassica mix (BR), chufa (CHU), lupin (LU), red clover (RC), alfalfa (AL), wheat (WH), wheat and crimson clover mix (WH_CR), Biologic mix (BIO), white clover intermediate (WC-I), ladino white clover (WC-L), non planted borders and alleys (Alley)

‡ Estimates were back-transformed to observations ha^{-1} for interpretation

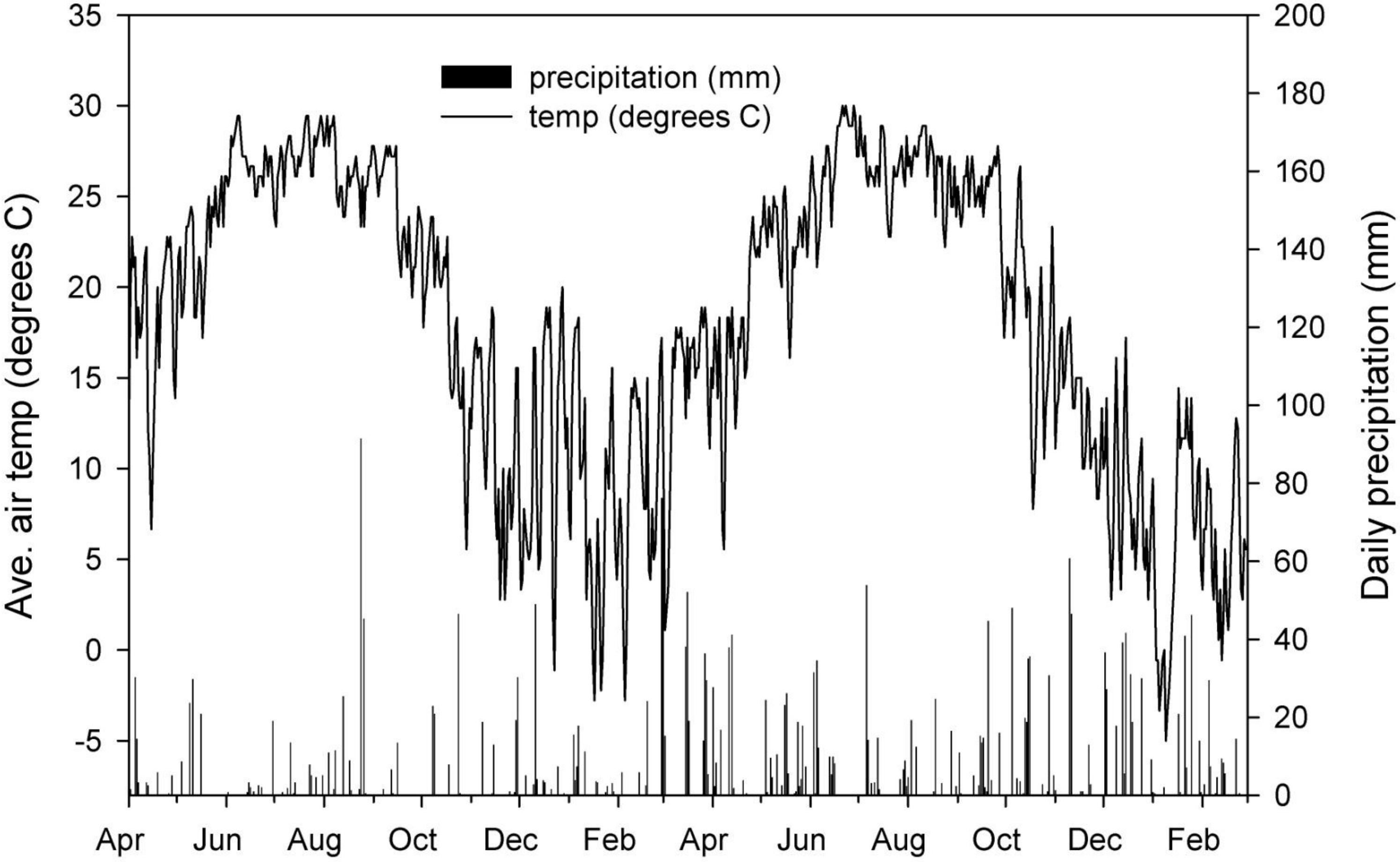
§ Indicates self comparison

Table 25. continued.

Forage[†]	WH	WH _ CR	BIO	WC-I	WC-L	Alley
	------------------------------------	Adjusted P	------------------------------------			
WP	0.2235	0.0795	0.0026	0.4745	1	1
BA	0.0001	0.9741	0.1929	0.0013	0.8067	0.9994
BR	0.0367	0.1636	0.0057	0.1572	0.9991	1
CHU	1	0.0002	<0.0001	1	1	0.6421
LU	0.217	0.0023	0.0001	0.5257	1	0.9998
RC	1	0.181	0.0497	1	0.9998	0.8704
AL	1	0.0684	0.0095	1	1	0.9127
WH	‡	<0.0001	<0.0001	1	0.9967	0.1723
WH _ CR	<0.0001	‡	0.6668	<0.0001	0.3505	0.8129
BIO	<0.0001	0.6668	‡	<0.0001	0.0748	0.211
WC-I	1	<0.0001	<0.0001	‡	0.9994	0.3388
WC-L	0.9967	0.3505	0.0748	0.9994	‡	0.999
Alley	0.1723	0.8129	0.211	0.3388	0.999	‡

† winter pea (WP), ball clover (BA), brassica mix (BR), chufa (CHU), lupin (LU), red clover (RC), alfalfa (AL), wheat (WH), wheat and crimson clover mix (WH_CR), Biologic mix (BIO), white clover intermediate (WC-I), ladino white clover (WC-L), non planted borders and alleys (Alley)

‡ Indicates self comparison



Month (April 2008 – March 2010)

Figure 1. Average air temperature at 2 m and daily precipitation in Auburn, AL over the study.period.

III. Determination of Optimal Warm Season Cropping System for White-tailed Deer in the Southeast

Abstract

Each year millions of dollars are spent on food plots for white-tailed deer (*Odocoileus virginuanus*) in the Southeast. Much of this is directed towards the establishment of warm season forages. The objective of this study was to determine the optimal warm season cropping system for white-tailed deer by evaluating forage dry matter (DM) yield, preference, and quality of 15 warm season and 7 cool season forage treatments with warm season persistence during 2008 through 2010. Plots were harvested during August of each year. Forage production ranged from 0 to 18441 kg dry matter (DM) ha^{-1} with percent DM removed by deer ranging between -38 and 92%, with soybean (*Glycine max* (L.) Merr) having the highest estimates. Warm season forages generally exceeded nitrogen (N) requirements for growth and development of white-tailed deer. All forages excluding sorghum (*Sorghum bicolor* (L.) Moench ssp. Bicolor) in sorghum mix and chufa (*Cyperus esculentus* (L.) var. *sativus* Boeck) met or exceeded calcium (Ca), phosphorus (P), and sodium (Na) concentration requirements. Nearly all forages had low fiber fractions which indicated good forage quality. Observation data suggested preference for soybean and cowpea during the warm season. Forage establishment under no-till proved difficult, and lower yields were observed under no-till than those established under conventional tillage in both years of the experiment. Our

findings indicate that soybean, iron & clay cowpea (*Vigna unguiculata* L. Walp.), or lablab (*Lablab purpurieus* L. Sweet) be planted in warm season food plots in the Southeast.

Introduction

The white-tailed deer is the nation's most profitable natural resource from a wildlife perspective. Each year millions of dollars are spent towards the pursuit of white-tailed deer in the United States (U.S. DoI-FWS, 2006). Alabama ranks fifth in hunting expenditures in the country. A significant portion of the investment made towards deer involves production and maintenance of food plots, and food plot expenditures likely exceed the amount spent towards hunting (Stribling et al., 1989).

Knowledge regarding food plot implementation has been borrowed from the animal science and agronomic field, and the first deer plantings were chosen from the wide range of livestock forages and conventional forages deer were known to utilize naturally (Kammermeyer, et al., 2006). Food plots were originally established primarily to attract deer during hunting seasons. However, plots now serve the dual purpose of attraction and habitat improvement (Higginbotham and Kroll, 1990; Beals et al., 1993; Waer et al., 1994; Kammermeyer et al., 2006). Specifically, warm season plots are often directed towards improving a herd's nutrition (Waer et al., 1992; Beals et al., 1993; Waer et al., 1994; Feather and Fulbright, 1995; Hehman and Fulbright, 1997).

Many studies have examined various warm season forages and their usage by deer (Davis, 1961; Webb 1963; Keegan et al., 1989; Waer et al., 1992; Feather and Fulbright, 1995). Other research has appraised the value of forages from a nutritional quality perspective (French et al., 1956; Waer et al., 1992; Beals et al., 1993). Forage preference has been documented, but often in less than natural environments. Tillage practices in food plots have been poorly explored. Studies that example all of these factors of food plot development and management are nearly non-existent. Thus, concise information regarding warm season cropping systems for white-tailed deer is scarce. This study evaluated warm season cropping systems for white-tailed deer in the Southeast based on forage yield, quality and deer preference.

Materials and Methods

The study was conducted from 2008 through 2010 on two sites at the Auburn University Deer Lab at the Piedmont Substation (32°49’24.17’’N, 85°39’19.87’W, 216M elevation) near Camp Hill, AL The soil at the upland site was a Lloyd loam with 2 to 6 percent slopes (Fine kaolinitic thermic rhodic kanhapludult). The majority of the lower site consisted of Gwinnette – Lloyd complex, with 6 to 15 percent slopes, with both Gwinnette and Lloyd being Fine kaolinitc thermic rhodic kanhapludults. Both 0.85 ha sites were surrounded by 3.04 m high wildlife fencing. Each site had three 3.04 m x 4.08 m double gates spaced evenly along the long sides of the site. These gates allowed for prevention of deer access during planting and stand establishment. The gates were opened to allow deer access approximately one month after planting to help ensure stand longevity throughout the growing season.

A randomized complete block design with tillage (conventional vs. no-till) and season (warm season vs. cool season) as blocks was established beginning in summer 2008 and continued through winter of 2010. Each plot was 3.6 x 9.1 m. Forage treatments were assigned to tillage blocks within season based on perceived performance with regards to planting method. Each treatment combination was replicated four times at each site. Conventional tillage plots were first disked with a 1.5 m wide disk harrow, and then tilled with a rotary tiller until a smooth seed bed was prepared. No-till plots received no tillage as the treatment.

Warm season treatments were planted during the second and third weeks of May 2008 and the fourth week of April and first week of May 2009. Warm season conventional tillage treatments included: corn (*Zea mays* L.) in combination with iron & clay cowpea (*Vigna unguiculata* L. Walp), grain sorghum in combination with iron & clay cowpea, sunflower in combination with iron & clay cowpea, chufa, soybean, iron & clay cowpea, sunnhemp (*Crotalaria juncea* L.), lablab (*Lablab purpureus* L. Sweet), and peanut (*Arachis hypogeae* L.). Cool season forages with warm season persistence that were established in no-till plots include: ladino white clover (*Trifolium repens* L.), intermediate white clover (*T. repens* L.), alfalfa (*Medicago sativa* L.), chicory (*Cichorium intybus* L.), and red clover (*T. pratense* L.). Corn in combination with iron & clay cowpea, sorghum in combination with iron & clay cowpea, sunflower in combination with iron & clay cowpea, soybean, iron & clay cowpea, lablab, peanut, and aeschynomene (*Aeschynomene americana* L.) were planted as forage treatments in no-till plots.

Treatments were established with a 2.4 m wide Great Plains no-till drill with 0.19-m row spacing, excluding cowpea and corn in combination with cowpea, which were planted with a four row John Deere MaxEmerge $^{\text{TM}}$ XP planter with 0.91-m row spacing. Each site was soil sampled prior to the start of the experiment and limed and fertilized according to Auburn University Soil Testing recommendations. Subsequent soil testing did not show need for liming other than the initial sampling.

A 1-m diameter exclosure made from 0.05 x 0.010-m mesh welded wire was placed at random in each plot after germination to prevent deer browsing. Biomass yield samples were harvested by hand clipping appropriate planted species from a randomly selected 0.25-m^2 quadrat area in both the open and exclosed portion of the plot and placed in paper bags. The lowland site was harvested on 12 August in 2008 and 4 August in 2009. Harvest occurred on the upland site on 15 August, 2008, and 4 September, 2009. The biomass samples were dried in a forage drier at 55°C to a common moisture content and weighed to determine dry matter production. Percent DM removed was calculated as the open DM yield divided by the exclosed DM yield x 100, and was used as an estimate of deer preference. For sampling purposes, species mixtures were separated into their respective species components.

Forage quality samples were collected on the same days as biomass samples. Quality samples were collected by hand picking only those portions of plants that were seen to be browsed by deer (leaves, pods, and petioles). These samples were taken from open areas to assess forage quality of plant material eaten by deer. As with biomass samples, each species component of the treatment was kept separate for the quality samples to allow for species comparison among and within treatments. All samples were dried in a forage drier at 55°C to a common moisture content, and ground to pass a 1-mm screen with a Wiley mill. Nitrogen was determined by dry combustion using a LECO TruSpec CN (Leco Corp, St. Joseph, MI). Phosphorus, Ca, and Na concentrations in forages were determined via inductively coupled argon plasma spectrophotometry

(ICAP), (SPECTROCIROS CCD, Side-on plasma. Germany). Neutral detergent fiber, ADF and ADL values were determined using methods described by Van Soest and Wine (1968).

Deer feeding observation data was collected from fully enclosed box blinds elevated 4.5 m above the ground. For each site, eight dates were randomly chosen on which to collect observation data. The blinds were placed approximately halfway down the length of the longest side of the site and 3 m from the fence. The blinds were entered at least three hours before sunset to allow for roughly one hour for the area to settle down prior to the two hour observation period. The observation period was started as soon as deer entered the site. Since individuals had free access to the sites there were many observation days when deer were observed but did not enter the site. A tripod mounted spotting scope equipped with a 20-60x lens was used to identify individuals by freeze branded numbers on the front shoulder and rear hip, ear tags, and/or body features. Those individuals not tagged were recorded by sex and age class. During the observation period, data was taken on each individual within the site every five minutes such that there was a total of 24 intervals in the two hour period. Individuals were recorded as feeding, walking, standing, or bedded. Feeding was defined as those individuals actively biting on forage. Individuals that were taking a bite while moving were recorded as feeding rather than walking. Standing was defined as those individuals standing but not taking a bite. Deer that were chewing cud were not recorded as feeding. Location was recorded as either the plot number in which the observation occurred or as alley. Alley consisted of all non-planted border areas within the site. The number of observation days was equally divided between the two sites so that there were eight days at each site during each season.

Treatment effects and interactions were deemed significant at the $P \leq 0.05$ level by analysis of variance using PROC GLIMMIX in SAS 9.1.3 (SAS, 1993). Simulated adjusted pairwise comparisons were performed where applicable to denote differences between forage yields, percent DM removed, observations, and forage quality data. Excluding chicory, cool season forages were not found to have adequate warm season persistence and were not able to be accounted for in statistical analyses. It is believed this is due, in part, to the management practices chosen such as lack of herbicide use in clover plots. Interactions and tillage could not be considered in the statistical analyses due to the low number of feeding observations on warm season forages. Observation data was log transformed to achieve a normal distribution.

Results and Discussion

Production

Analysis of variance on warm season forage treatment DM yields indicated no significant effects for conventional tillage plots, while the three way interaction Site x Year x Forage was significant for no-till plots (Table 26). Overall production for no-till plots was less in 2009 than 2008 (Tables 27 and 28). No differences in production were found at the upland site. Cowpea production was greater at the lowland site in 2008 than any other Site x Year combination. Cowpea production was greater than all other no-till treatment components at the lowland site in 2008, except soybean. Sorghum in sorghum mix production was less than other treatment species. Sorghum in sorghum mix production was less than cowpea, cowpea in corn mix, soybean, and cowpea in sunflower mix. Lablab production was less than that of all soybean and all cowpea components at lowland site in 2008. Soybean production was second only to cowpea at the lowland site during 2008. Similar studies indicated that soybean, lablab, and cowpea yields are greater than other warm season food plot species (Waer, 1992; Waer et al. 1992; Beals et al., 1993; Feather and Fulbright, 1995; Hehman and Fulbright, 1997). Feather and Fulbright (1995) reported greater production of cowpea than other forages used including lablab. Feather and Fulbright (1995) found lablab to have greater production than cowpea during dry conditions, an advantage that often directs use of lablab in food plots in the Southeast (Beals et al., 1993). Production estimates for conventional tillage plots are shown in Table 29.

Percent Dry Matter Removed

Analysis of variance indicated that warm season percent DM removed was impacted by the interaction of Year x Forage (Table 30). No effects or interactions were found to be significant for no-till treatments. All differences found for percent DM removed under conventional tillage occurred in 2009 (Tables 31 and 32). Soybean exhibited the greatest percent DM removed in 2009. Studies including soybean have consistently found deer preference for soybean to be greater than for other warm season forages (Waer, 1992; Waer et al., 1992, Beals et al., 1993). While preference may be biased towards soybean, less browse tolerance than other forages such as cowpea and lablab may reduce soybean's acceptability for food plot usage (Beals et al., 1993; Feather and Fulbright, 1995). Percent DM removed for lablab was only greater than corn in corn mix, sorghum in sorghum mix, and sunnhemp in 2009. Lablab was not found to be preferred, as indicated by percent DM removed, over conventional tillage cowpea or soybean. The lack of preference may be the result of low production due to dry conditions (Figure 2), which reinforces the idea that preference is dependent on forage productivity (Waer, 1992; Beals et al., 1993; Waer et al., 1994; Hehman and Fulbright, 1997). During periodic evaluations of our forages for deer browsing, corn in corn mix, sorghum in sorghum mix, and sunnhemp were rarely found to be browsed, which partially accounts for the low estimates of percent DM removed. Both peanut and sunflower in sunflower mix were excluded from the 2009 percent DM removed comparisons due to poor stand establishment.

No-till percent DM removed estimates and standard errors were only estimable for cowpea in sorghum mix (64 ± 19) and cowpea in sunflower mix (37 ± 33). The amount of variability in stand establishment following the measures an average hunter might exercise suggests no-till during the warm season will likely be extremely difficult in the Piedmont physiographic region of the Southeast. The lack of differences in utilization during 2008 did not come as a surprise. Very little browsing was evident on the majority of treatment species until near the end of the season. One explanation for the lack of browsing is the effect of social influence on browse preference. Many species of animals are thought to pass on forage preferences and biases to their young through social interactions (Provenza et al., 1992; Mirza and Provenza, 1994). Since 2008 was the first year these individuals had seen the majority of these forages, they had to determine which forages were palatable and which were not. During the second year, adults and yearlings had experience with the forages and were more inclined to utilize them.

Tissue Nitrogen Concentration

Warm season tissue N concentration was impacted by the three way interaction Year x Site x Forage (Table 33). For warm season forages there was more variation in tissue N concentration during 2008 (Tables 34 to 37) than 2009 (Tables 38 to 41). During 2008 there was more variation in tissue N concentration at the lowland site than at the upland site. While differences in tissue N concentration did occur, there seemed to be few distinct patterns excluding legume estimates being greater than those of non-legumes. Both sorghum in sorghum mix and chufa exhibited low tissue N concentration estimates when compared to other forages. This information reinforces percent DM removed and observation data that suggests there may have been a low preference for these forages. All tissue N concentration estimates for forages excluding chufa and sorghum in sorghum mix were above the requirement of 20.8 to 27.2 g kg^{-1} for favorable growth and development (French et al., 1956; McEwen et al., 1957; Ullrey et al., 1967; Holter et al., 1979). Only chufa, chicory, and sorghum in sorghum mix estimates fell short of requirements for growth and development. However, all tissue N concentration estimates meet the requirements for maintenance, which fall between 6 and 16 g kg^{-1} N (French et al., 1956; McEwen et al., 1957; Ullrey et al., 1967; Holter et al., 1979). Since samples were taken during the same period in which does were lactating, emphasis should be to meet protein requirements of lactation between 22.4 and 35.2 g kg^{-1} N (French et al., 1956; McEwen et al., 1957; Ullrey et al., 1967; Holter et al., 1979). Nearly all forages met or exceeded this proposed range, suggesting that forage plantings can provide adequate protein during the late summer, a period of significant nutritional demand.

Mineral Analyses

Analysis of variance indicated the four way interaction of Year x Site x Tillage x Forage as significant for Ca and P concentration (Table 42). No significant interactions were found for Na concentration, therefore Na concentration was analyzed among forages. Excluding sorghum in sorghum mix and chufa, all forages met or exceeded the proposed requirements of 4 to 6.4 g kg^{-1}(McEwen et al., 1957; Ullrey et al., 1975; Ullrey, 1981) for Ca concentration (Table 43). Soybean Ca concentration was low compared to other forages, yet still exceeded requirements for optimal growth and development. Sunflower in sunflower mix exhibited the greatest Ca levels for warm season forages. These data suggest that Ca will not be a limiting factor if forage is present in sufficient quantity.

Phosphorus requirements for white-tailed deer have been estimated as either 1.2 to 1.8 g ka^{-1} or 2.8 to 5.6 g kg^{-1} (McEwen et al., 1957; Ullrey et al., 1975; Ullrey 1981; Grassman and Hellgren 1993). Forage P levels generally exceeded the lower proposed range and fell within the upper range (Table 44). No trends in forage P concentration were noted except that peanut had consistently less P compared to other forages. All other forages appeared to be randomly distributed with regard to P concentration. Waer et al. (1992) estimated forage P levels for similar forages as being below the 2.8 to 5.6 g ka^{-1} range and attributed this to low soil P. The data suggest that P concentration in forages at the time of sampling was sufficient to meet or exceed requirements for deer if forages are not over browsed.

All forages exceeded the proposed requirements of 0.023 to 0.075 g kg^{-1} (Hellgren and Pitts 1997) for Na concentration (Table 45). Sodium concentration for chicory was greater than all other warm season forages. Since harvest coincided with lactation, it is likely that warm season forages could supply the necessary requirements to meet increased demands during the most stressful physiological season for female white-tailed deer as long as forage yields are sufficient (Grassman and Hellgren 1993; Hellgren and Pitts 1997; Atwood and Weeks 2003).

Fiber Concentration

Since forage quality and therefore digestibility depends extensively on the amount of fiber present, an estimation of forage quality is obtainable from estimates of fiber fraction (Van Soest 1994). Neutral detergent fiber (NDF) is a measure of the insoluble portions of the cell wall which is often referred to as total fiber within the forage. Neutral detergent fiber is composed primarily of hemicellulose, cellulose, and lignin (Van Soest 1994). The acid detergent fiber (ADF) values provide a partitioning of indigestible fibers or cell wall components which are primarily cellulose and lignin. The acid detergent lignin (ADL) values provide a further breakdown into the completely indigestible lignin fraction (Van Soest 1994).

Analyses of variance indicated Site x Forage as significant for NDF and ADF, while ADL was impacted by the interaction of Year x Forage (Table 46). Neutral detergent fiber exhibited little variation in warm season forages, excluding chufa and sorghum in sorghum mix. Neutral detergent fiber values in these forages were greater than all other forages (Table 47). These findings are not surprising and are consistent with those presented by Van Soest (1994) for grain sorghum silage. Information on NDF of chufa above ground growth is not available in the literature, because chufas are valued for their tuber production as opposed to their forage value. Values for soybean NDF were at the high end of those sampled (excluding chufa and sorghum in sorghum mix). Interestingly, sunflower in sunflower mix values were on the low end of NDF measurements suggesting excellent digestibility.

There was generally more variation among ADF values than NDF values (Table 48). As expected, chufa and sorghum in sorghum mix values were greater than those of the other forages. Values for sunnhemp ADF were among the greatest in this study, again excluding chufa and sorghum in sorghum mix, which implies a greater proportion of cellulose and lignin in the fiber fraction than was found in most other forages. Values for no-till forages appeared to be slightly less than those of conventional tillage forages.

The ADL values followed the same trend as NDF and ADF with chufa and sorghum in sorghum mix estimates being greatest (Table 49). Overall, there was little discrepancy with regards to ADL values between forages other than soybean and lablab. Estimates for those forages were greatest in this study, while treatments containing cowpea were the least. This suggests that the lignin portion of soybean and lablab is somewhat above that of treatments containing cowpea.

Deer Feeding Observations

Analysis of variance indicated no effects for warm season feeding observations (Table 50). Interactions could not be considered due to the low number of feeding observations. There were 51 total observations during both warm seasons, 29 of which were feeding, 29 were walking, 12 were standing, and 1 was bedded. Warm season feeding observations did not reflect other data that suggested there was more utilization during the second year. This is likely due to the overall low number of observations during the warm seasons. The low number of observations may be the result of nocturnal activity. Deer are known to be active during the cooler times of day and at night during the summer. Deer were only observed feeding in chufa, cowpea in corn mix, cowpea, cowpea in sorghum mix, soybean, cowpea in sunflower mix, and the alley. The number of feeding observations were converted to observations ha^{-1} to normalize the data for the given forage treatments and alleys. Warm season feeding observation estimates and standard errors can be found in Table 51. As indicated by the lack of effects in the analysis of variance, no differences were found regarding observations ha^{-1}, and forage treatment in which observations occurred. Four of the seven forages where feeding observations occurred during the warm season had cowpea as a component. This suggests that cowpea may have been preferred over non cowpea containing forage treatments. Feeding observations occurring in chufa were likely not the result of deer feeding on chufa. Since chufa is not commonly utilized as a forage, it is possible that individuals were feeding on volunteer vegetation present within the plots rather than chufa since these plots tended to have many weedy forbs present. These same weeds were observed to be browsed when found in the alley.

Summary and Conclusions

Establishment of no-till treatments proved difficult for all warm season forages during both years. It is not recommended that food plots be established via no-till methods without the proper herbicide program. Care must be taken when selecting forages if mixtures are to be planted and volunteer weeds are controlled.

Warm season production and percent DM removed was inconsistent among treatments. The conventional forage legumes (soybean, lablab, and cowpea) tended to have greater production and be the most preferred. Sunnhemp production exceeded that of all other treatments. Due to the management practices chosen, the cool season forages with perceived warm season production had poor yields. Such forages are not recommended unless weed management occurs. In this study, graminaceous weeds choked out nearly all stands of these cool season forages.

Few distinct patterns were seen with regard to tissue N concentration in warm season forages. Although not readily observed as being fed on, sunnhemp estimates of tissue N concentration were similar to that of other legumes suggesting the potential as a good forage. All forages met the proposed N concentration requirement for maintenance.

Warm season forages met or exceeded Ca concentration requirements with the exception of sorghum in sorghum mix and chufa. Few trends were observed concerning P concentration in warm season forages. Forage P levels tended to exceed the lower proposed requirement for white-tailed deer and fell within the range of the upper proposed requirements. Although Na is often limiting in natural systems, Na concentration was adequate for all warm season forages. Chicory had the greatest Na concentration.

Little variation was found with regards to warm season fiber estimates. Fiber values (NDF, ADF, and ADL) for sorghum in sorghum mix and chufa were consistently greater than in all other warm season forages. Overall most forages proved to have low fiber concentration and therefore good digestibility at the time of harvest.

Warm season feeding observations occurred in all treatments containing cowpea, soybean and chufa as well as in the alleys. This proposes a degree of preference for these treatments over the others. Chufa is known to have poor forage quality, therefore it is probable that chufa feeding observations were not actually on chufa, and likely reflected individuals feeding on volunteer vegetation similar to feeding in the alleys.

Based on our findings, there are certain aspects of food plot establishment and management that should be of concern. Warm season food plots should include either soybean, lablab or cowpea. The choice as to which of these is planted should be made based on several factors including management goals, environmental conditions, food plot size and perceived deer densities. A companion forage such as sorghum or sunflower could be beneficial to supply additional nutrition, and increase production over time. The presence of a companion forage will complicate weed management, which may not be feasible for some individuals

Table 26. Analysis of variance probability of greater F (Pr>F) for warm season conventional and no-till single and mixed forage treatment yields.

Effect	Conventional tillage	No-till
	---------------------Pr>F-------------------	
Site	0.1978	0.0003
Forage	0.2464	0.0001
Site x Forage	0.6779	0.0009
Year	0.4846	0.0000
Site x Year	0.4974	0.0000
Year x Forage	0.5943	0.0001
Site x Year x Forage	0.8261	0.0193

Table 27. Lowland dry matter (DM) yield estimates, standard errors, and simulated adjusted pairwise P-values for warm season no-till single and mixed forage treatment species.

Year	Forage[†]	Estimate	StdErr	CP_CO	CP	LL	PE	SO_SO	CP_SO	SB	SU_SU	CP_SU
		---kg DM ha^{-1}---		---Adjusted P---								
2008	CO_CO	7295	857	0.9729	0.0005	0.9116	0.1237	0.0098	1	0.976	0.2524	0.956
	CP_CO	5983	857	‡	0.0001	0.9991	0.4987	0.1491	0.9224	0.6682	0.7287	0.5908
	CP	15327	1632	0.0001	‡	0.0002	<0.0001	<0.0001	0.0075	0.1903	<0.0001	0.23
	LL	4770	1632	0.9991	0.0002	‡	0.9768	0.9345	0.8364	0.5664	0.996	0.5084
	PE	2193	1632	0.4987	<0.0001	0.9768	‡	1	0.1072	0.0547	1	0.0417
	SO_SO	2148	1174	0.1491	<0.0001	0.9345	1	‡	0.0149	0.011	1	0.0083
	CP_SO	7897	1174	0.9224	0.0075	0.8364	0.1072	0.0149	‡	0.9988	0.209	0.9967
	SB	9339	1632	0.6682	0.1903	0.5664	0.0547	0.011	0.9988	‡	0.1115	1
	SU_SU	2795	1632	0.7287	<0.0001	0.996	1	1	0.209	0.1115	‡	0.0919
	CP_SU	9534	1632	0.5908	0.23	0.5084	0.0417	0.0083	0.9967	1	0.0919	‡
2009	CO_CO	212	607	1	0.7025	1	1	0.2726	1	1	1	0.9963
	CP_CO	230	607	‡	0.7127	1	1	0.2829	1	1	1	0.997
	CP	2529	1154	0.7127	‡	0.8444	0.8444	1	0.8871	0.8444	0.8444	0.999
	LL	0	1154	1	0.8444	‡	1	0.6481	1	1	1	0.998
	PE	0	1154	1	0.8444	1	‡	0.6481	1	1	1	0.998
	SO_SO	2650	830	0.2829	1	0.6481	0.6481	‡	0.6366	0.6481	0.6481	0.9926
	CP_SO	468	830	1	0.8871	1	1	0.6366	‡	1	1	0.9998
	SB	0	1154	1	0.8444	1	1	0.6481	1	‡	1	0.998
	SU_SU	0	1154	1	0.8444	1	1	0.6481	1	1	‡	0.998
	CP_SU	1316	1154	0.997	0.999	0.998	0.998	0.9926	0.9998	0.998	0.998	‡

† corn in corn mixture (CO_CO), cowpea in corn mixture (CP_CO), cowpea (CP), lablab (LL), peanut (PE), sorghum in sorghum mixture (SO_SO), cowpea in sorghum mixture (CP_SO), soybean (SB), sunflower in sunflower mixture (SU_SU), cowpea in sunflower mixture (CP_SU)

‡ Indicates a self comparison

Table 28. Upland dry matter (DM) yield estimates, standard errors, and simulated adjusted pairwise P-values for warm season no-till single and mixed forage treatment species.

Year	Forage†	Estimate	StdErr	CP_CO	CP	LL	PE	SO_SO	CP_SO	SB	SU_SU	CP_SU
		----kg DM ha^{-1}----		---Adjusted P---								
2008	CO_CO	3941	857	0.9158	0.5411	0.4959	0.4295	0.7978	0.8349	0.9906	0.4295	0.7759
	CP_CO	2348	857	‡	0.9718	0.9601	0.9378	1	1	0.6537	0.9378	0.9984
	CP	254	1632	0.9718	‡	1	1	0.9998	0.9994	0.3006	1	1
	LL	136	1632	0.9601	1	‡	1	0.9991	0.9987	0.271	1	1
	PE	-35	1632	0.9378	1	1	‡	0.9978	0.9962	0.2332	1	1
	SO_SO	1620	1174	1	0.9998	0.9991	0.9978	‡	1	0.5132	0.9978	1
	CP_SO	1714	1174	1	0.9994	0.9987	0.9962	1	‡	0.5445	0.9962	1
	SB	5743	1632	0.6537	0.3006	0.271	0.2332	0.5132	0.5445	‡	0.2332	0.4797
	SU_SU	-35	1632	0.9378	1	1	1	0.9978	0.9962	0.2332	‡	1
	CP_SU	881	1632	0.9984	1	1	1	1	1	0.4797	1	‡
2009	CO_CO	0	607	1	1	1	1	0.9877	1	0.9944	1	0.9999
	CP_CO	317	607	‡	1	1	1	0.9994	1	0.9995	1	1
	CP	0	1154	1	‡	1	1	0.9992	1	0.9992	1	1
	LL	0	1154	1	1	‡	1	0.9992	1	0.9992	1	1
	PE	0	1154	1	1	1	‡	0.9992	1	0.9992	1	1
	SO_SO	1026	830	0.9994	0.9992	0.9992	0.9992	‡	0.9999	1	0.9992	1
	CP_SO	378	830	1	1	1	1	0.9999	‡	0.9998	1	1
	SB	1188	1154	0.9995	0.9992	0.9992	0.9992	1	0.9998	‡	0.9992	1
	SU_SU	0	1154	1	1	1	1	0.9992	1	0.9992	‡	1
	CP_SU	646	1154	1	1	1	1	1	1	1	1	‡

† corn in corn mixture (CO_CO), cowpea in corn mixture (CP_CO), cowpea (CP), lablab (LL), peanut (PE), sorghum in sorghum mixture (SO_SO), cowpea in sorghum mixture (CP_SO), soybean (SB), sunflower in sunflower mixture (SU_SU), cowpea in sunflower mixture (CP_SU)

‡ Indicates a self comparison

Table 29. Warm season conventional tillage yield estimates and standard errors.

Forage†	Estimate	StdErr
	----------kg DM ha^{-1}----------	
CHU	1060	2371
CO_CO	14012	1418
CP_CO	5303	1418
CP	7733	2371
LL	10162	2371
PE	2617	2371
SO_SO	5443	1795
CP_SO	4173	1795
SB	6374	2371
SU_SU	1006	2371
CP_SU	3003	2371
SH	18441	1555

† chufa (CHU), corn in corn mix (CO_C), cowpea in corn mix (CP_CO), cowpea (CP), lablab (LL), peanut (PE), sorghum in sorghum mix (SO_SO), cowpea in sorghum mix (CP_SO), soybean (SB), sunflower in sunflower mix (SU_SU), cowpea in sunflower mix (CP_SU), sunnhemp (SH)

Table 30. Analysis of variance probability of greater F (Pr>F) for warm season conventional and no-till single and mixed forage treatment percent dry matter removed.

Effect	Conventional tillage	No-till
	-----------------Pr>F-------------------	
Site	0.2252	0.4979
Forage	0.0001	0.1450
Site x Forage	0.2236	0.8062
Year	0.0011	0.3112
Site x Year	0.2724	0.4836
Year x Forage	0.0001	0.7000
Site x Year x Forage	0.4297	0.4622

Table 31. Percent dry matter (DM) removed for 2008 estimates, standard errors, and simulated adjusted pairwise P-values for warm season conventional tillage single and mixed forage treatment species.

Forage†	Estimate	StdErr	CO_CO	CP_CO	CP	LL	PE	SO_SO	CP_SO	SB	SU_SU	CP_SU	SH
	percent DM removed		--Adjusted P---										
CHU	23	29	1	0.7672	1	0.9976	1	0.9842	1	0.9921	0.9975	0.9993	0.9998
CO_CO	3	17	‡	0.8228	0.9993	0.8251	1	0.9993	1	0.7221	1	1	1
CP_CO	-38	16	0.8228	‡	0.58	0.0981	0.9317	1	0.6827	0.0599	1	1	0.9484
CP	32	29	0.9993	0.58	‡	0.9998	1	0.9422	1	0.9991	0.9871	0.9939	0.9955
LL	62	29	0.8251	0.0981	0.9998	‡	0.9811	0.4909	0.9821	1	0.7792	0.8403	0.7339
PE	11	29	1	0.9317	1	0.9811	‡	0.9989	1	0.9606	0.9998	1	1
SO_SO	-23	24	0.9993	1	0.9422	0.4909	0.9989	‡	0.9856	0.3841	1	1	1
CP_SO	17	22	1	0.6827	1	0.9821	1	0.9856	‡	0.9594	0.9987	0.9997	0.9998
SB	67	29	0.7221	0.0599	0.9991	1	0.9606	0.3841	0.9594	‡	0.7027	0.7693	0.6198
SU_SU	-22	35	1	1	0.9871	0.7792	0.9998	1	0.9987	0.7027	‡	1	1
CP_SU	-17	35	1	1	0.9939	0.8403	1	1	0.9997	0.7693	1	‡	1
SH	-3	18	1	0.9484	0.9955	0.7339	1	1	0.9998	0.6198	1	1	‡

† chufa (CHU), corn in corn mixture (CO_CO), cowpea in corn mixture (CP_CO), cowpea (CP), lablab (LL), peanut (PE), sorghum in sorghum mixture (SO_SO), cowpea in sorghum mixture (CP_SO), soybean (SB), sunflower in sunflower mixture (SU_SU), cowpea in sunflower mixture (CP_SU), sunnhemp (SH)

‡ Indicates a self comparison

Table 32. Percent dry matter (DM) removed for 2009 estimates, standard errors, and simulated adjusted pairwise P-values for warm season conventional tillage single and mixed forage treatment species.

Forage[†]	Estimate	StdErr	CO_CO	CP_CO	CP	LL	PE	SO_SO	CP_SO	SB	SU_SU	CP_SU	SH
	percent DM removed		--Adjusted P--										
AE	62	23	0.0121	1	1	0.9999	‡	0.2029	1	0.9997	‡	1	0.1238
CO_CO	-34	12	§	<0.0001	0.0009	0.0006	‡	0.9794	0.0001	0.0255	‡	0.0006	0.9697
CP_CO	69	12	<0.0001	§	1	1	‡	0.0027	1	0.9999	‡	1	0.0001
CP	80	23	0.0009	1	§	1	‡	0.0372	1	1	‡	1	0.0177
LL	82	23	0.0006	1	1	§	‡	0.0309	1	1	‡	1	0.0152
SO_SO	-12	16	0.9794	0.0027	0.0372	0.0309	‡	§	0.022	0.1626	‡	0.0381	1
CP_SO	75	19	0.0001	1	1	1	‡	0.022	§	1	‡	1	0.0072
SB	92	35	0.0255	0.9999	1	1	‡	0.1626	1	§	‡	1	0.1215
CP_SU	76	22	0.0006	1	1	1	‡	0.0381	1	1	‡	§	0.017
SH	-13	12	0.9697	0.0001	0.0177	0.0152	‡	1	0.0072	0.1215	‡	0.017	§

† corn in corn mixture (CO_CO), cowpea in corn mixture (CP_CO), cowpea (CP), lablab (LL), peanut (PE), sorghum in sorghum mixture (SO_SO), cowpea in sorghum mixture (CP_SO), soybean (SB), sunflower in sunflower mixture (SU_SU), cowpea in sunflower mixture (CP_SU), sunnhemp (SH), aeschynomene (AE)

‡ Data not included due to poor stand establishment

§ Indicates a self comparison

Table 33. Analysis of variance probability of greater F (Pr>F) for warm season forage tissue nitrogen concentration.

Effect	
	--Pr>F--
Year	0.0214
Site	0.0001
Year x Site	0.0006
Forage	0.0000
Year x Forage	0.3634
Site x Forage	0.0128
Year x Site x Forage	0.0425
Tillage	0.0831
Year x Tillage	0.9773
Site x Tillage	0.1305
Year x Site x Tillage	0.2080
Tillage x Forage	0.5152
Year x Tillage x Forage	0.0653
Site x Tillage x Forage	0.2111
Year x Site x Tillage x Forage	0.6240

Table 34. Lowland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season single species treatments.

Forage†	Estimate	StdErr	CP	LL	PE	SB	SH
	------g kg^{-1}-------		------------------------Adjusted P----------------------				
CHU	19.0	3.2	<0.0001	0.0677	0.6507	0.0004	<0.0001
CP	43.9	2.0	‡	0.0161	<0.0001	0.7079	1
CP_CO	40.1	1.2	0.8683	0.1372	0.0002	0.9987	0.8141
CP_SO	38.8	1.7	0.6848	0.4836	0.0106	1	0.6171
CP_SU	43.1	2.3	1	0.0507	0.0001	0.8762	1
LL	31.9	2.6	0.0161	‡	0.9598	0.886	0.0114
PE	27.1	2.6	<0.0001	0.9598	‡	0.1384	<0.0001
SO_SO	20.4	1.1	<0.0001	0.0033	0.3817	<0.0001	<0.0001
SB	37.7	2.6	0.7079	0.886	0.1384	‡	0.6653
SU_SU	29.7	2.6	0.0013	1	0.9997	0.5171	0.0006
SH	43.9	1.9	1	0.0114	<0.0001	0.6653	‡

† chufa (CHU), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), peanut (PE), sorghum in sorghum mix (SO_SO), soybean (SB), sunflower in sunflower mix (SU_SU), sunnhemp (SH)

‡ Indicates a self comparison

Table 35. Lowland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season mixed species treatments.

Forage[†]	Estimate	StdErr	CP_CO	CP_SO	CP_SU	SO_SO	SU_SU
	------g kg^{-1}-------		----------------------Adjusted P----------------------				
CHU	19.0	3.2	<0.0001	<0.0001	<0.0001	1	0.2454
CP	43.9	2.0	0.8683	0.6848	1	<0.0001	0.0013
CP_CO	40.1	1.2	‡	1	0.9835	<0.0001	0.0144
CP_SO	38.8	1.7	1	‡	0.9007	<0.0001	0.1233
CP_SU	43.1	2.3	0.9835	0.9007	‡	<0.0001	0.0073
LL	31.9	2.6	0.1372	0.4836	0.0507	0.0033	1
PE	27.1	2.6	0.0002	0.0106	0.0001	0.3817	0.9997
SO_SO	20.4	1.1	<0.0001	<0.0001	<0.0001	‡	0.0409
SB	37.7	2.6	0.9987	1	0.8762	<0.0001	0.5171
SU_SU	29.7	2.6	0.0144	0.1233	0.0073	0.0409	‡
SH	43.9	1.9	0.8141	0.6171	1	<0.0001	0.0006

† chufa (CHU), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), peanut (PE), sorghum in sorghum mix (SO_SO), soybean (SB), sunflower in sunflower mix (SU_SU), sunnhemp (SH)

‡ Indicates a self comparison

Table 36. Upland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season single species treatments.

Forage[†]	Estimate	StdErr	CP	LL	PE	SB	SH
	------g kg^{-1}-------		---------------------------Adjusted P---------------------------				
CHU	18.7	4.5	<0.0001	0.0042	0.0163	<0.0001	<0.0001
CP	50.4	2.6	‡	0.0693	0.0964	0.9993	1
CP_CO	49.1	1.2	1	0.0191	0.0496	1	1
CP_SO	47.2	1.9	0.991	0.2533	0.318	1	0.9957
CP_SU	40.1	2.3	0.0834	1	1	0.4347	0.05
LL	39.1	2.6	0.0693	‡	1	0.3552	0.0446
PE	38.3	3.2	0.0964	1	‡	0.3925	0.08
SB	47.7	2.6	0.9993	0.3552	0.3925	‡	0.9999
SU_SU	50.7	3.2	1	0.1321	0.1546	0.9993	1
SH	49.7	2.0	1	0.0446	0.08	0.9999	‡

† chufa (CHU), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), peanut (PE), soybean (SB), sunflower in sunflower mix (SU_SU), sunnhemp (SH)

‡ Indicates a self comparison

Table 37. Upland, 2008 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season mixed species forage treatments.

Forage[†]	Estimate	StdErr	CP_CO	CP_SO	CP_SU	SU_SU
	------g kg^{-1}-------		--------------------Adjusted P-----------------			
CHU	18.7	4.5	<0.0001	<0.0001	0.0012	<0.0001
CP	50.4	2.6	1	0.991	0.0834	1
CP_CO	49.1	1.2	‡	0.9966	0.0167	1
CP_SO	47.2	1.9	0.9966	‡	0.3033	0.9947
CP_SU	40.1	2.3	0.0167	0.3033	‡	0.1661
LL	39.1	2.6	0.0191	0.2533	1	0.1321
PE	38.3	3.2	0.0496	0.318	1	0.1546
SB	47.7	2.6	1	1	0.4347	0.9993
SU_SU	50.7	3.2	1	0.9947	0.1661	‡
SH	49.7	2.0	1	0.9957	0.05	1

† chufa (CHU), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), peanut (PE), soybean (SB), sunflower in sunflower mix (SU_SU), sunnhemp (SH)

‡ Indicates a self comparison

Table 38. Lowland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season single species forage treatments.

Forage[†]	Estimate	StdErr	CH	CP	LL	SB	SH
	------g kg^{-1}-------		----------------------------	----------------------------	Adjusted P	----------------------------	----------------------------
AE	40.2	3.2	0.9529	0.999	0.9999	0.9737	0.9269
CH	34.3	3.2	‡	0.3415	0.9929	0.1929	0.0667
CP	42.9	1.7	0.3415	‡	0.6848	0.9998	0.9941
CP_CO	38.2	1.1	0.9794	0.3708	1	0.217	0.0042
CP_SO	43.2	1.4	0.2464	1	0.5023	0.9999	0.9968
CP_SU	40.3	1.9	0.8228	0.9889	0.9973	0.8829	0.5582
LL	38.0	2.0	0.9929	0.6848	‡	0.4324	0.1104
SO_SO	18.3	1.4	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
SB	44.7	2.3	0.1929	0.9998	0.4324	‡	1
SH	44.9	1.3	0.0667	0.9941	0.1104	1	‡

† aeschynomene (AE), chicory (CH), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), sorghum in sorghum mix (SO_SO), soybean (SB), sunnhemp (SH)

‡ Indicates a self comparison

Table 39. Lowland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season mixed species forage treatments.

Forage[†]	Estimate	StdErr	CP_CO	CP_SO	CP_SU	SO_SO
	------g kg^{-1}-------		--------------------Adjusted P------------------			
AE	40.2	3.2	0.9999	0.9967	1	<0.0001
CH	34.3	3.2	0.9794	0.2464	0.8228	0.0002
CP	42.9	1.7	0.3708	1	0.9889	<0.0001
CP_CO	38.2	1.1	‡	0.1413	0.9896	<0.0001
CP_SO	43.2	1.4	0.1413	‡	0.9627	<0.0001
CP_SU	40.3	1.9	0.9896	0.9627	‡	<0.0001
LL	38.0	2.0	1	0.5023	0.9973	<0.0001
SO_SO	18.3	1.4	<0.0001	<0.0001	<0.0001	‡
SB	44.7	2.3	0.217	0.9999	0.8829	<0.0001
SH	44.9	1.3	0.0042	0.9968	0.5582	<0.0001

† aeschynomene (AE), chicory (CH), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), sorghum in sorghum mix (SO_SO), soybean (SB), sunnhemp (SH)

‡ Indicates a self comparison

Table 40. Upland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season single species forage treatments.

Forage[†]	Estimate	StdErr	CH	CP	LL	SB	SH
	------g kg^{-1}-------		--------------------------Adjusted P---------------------------				
AE	36.6	2.3	0.0528	0.3786	1	1	0.0112
CH	26.5	2.3	‡	<0.0001	0.2056	0.2235	<0.0001
CP	44.5	2.6	<0.0001	‡	0.2913	0.6316	0.9998
CP_CO	41.7	1.0	<0.0001	0.9909	0.4273	0.8634	0.177
CP_SO	42.4	1.4	<0.0001	0.9992	0.3472	0.7912	0.5939
CP_SU	42.1	2.0	<0.0001	0.9991	0.5809	0.8934	0.7959
LL	35.5	2.6	0.2056	0.2913	‡	1	0.0117
SO_SO	17.9	1.4	0.0443	<0.0001	<0.0001	<0.0001	<0.0001
SB	36.6	3.2	0.2235	0.6316	1	‡	0.144
SH	46.2	1.3	<0.0001	0.9998	0.0117	0.144	‡

† aeschynomene (AE), chicory (CH), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), sorghum in sorghum mix (SO_SO), soybean (SB), sunnhemp (SH)

‡ Indicates a self comparison

Table 41. Upland, 2009 tissue nitrogen concentration estimates, standard errors, and simulated adjusted pairwise P-values for warm season mixed species forage treatments.

Forage[†]	Estimate	StdErr	CP_CO	CP_SO	CP_SU	SO_SO
	------g kg^{-1}-------		----------------Adjusted P---------------------			
AE	36.6	2.3	0.5376	0.4458	0.7089	<0.0001
CH	26.5	2.6	<0.0001	<0.0001	<0.0001	0.0443
CP	44.5	2.6	0.9909	0.9992	0.9991	<0.0001
CP_CO	41.7	1.0	‡	1	1	<0.0001
CP_SO	42.4	1.4	1	‡	1	<0.0001
CP_SU	42.1	2.0	1	1	‡	<0.0001
LL	35.5	2.6	0.4273	0.3472	0.5809	<0.0001
SO_SO	17.9	1.4	<0.0001	<0.0001	<0.0001	‡
SB	36.6	3.2	0.8634	0.7912	0.8934	<0.0001
SH	46.2	1.3	0.177	0.5939	0.7959	<0.0001

† aeschynomene (AE), chicory (CH), cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), lablab (LL), sorghum in sorghum mix (SO_SO), soybean (SB), sunnhemp (SH)

‡ Indicates a self comparison

Table 42. Analysis of variance probability of greater F (Pr>F) for warm season forage calcium (Ca), sodium (Na), and phosphorus (P) elemental concentration.

Effect	Ca	Na	P
	----------------Pr > F---------------		
Year	0.7161	0.0269	<0.0001
Site	0.3630	0.0014	0.1643
Year x Site	0.0001	0.0256	0.7132
Forage	<0.0001	0.0318	<0.0001
Year x Forage	0.0386	0.7747	0.0182
Site x Forage	0.0005	0.8603	0.0459
Year x Site x Forage	0.0260	0.8875	0.7021
Tillage	0.3623	0.5428	0.0046
Year x Tillage	0.2006	0.2637	0.2543
Site x Tillage	0.0007	0.0910	0.1681
Year x Site x Tillage	0.0406	0.1114	0.7371
Tillage x Forage	<0.0001	0.9465	0.9605
Year x Tillage x Forage	<0.0001	0.6030	0.3271
Site x Tillage x Forage	<0.0001	0.4843	0.9116
Year x Site x Tillage x Forage	0.0001	0.5784	0.0188

Table 43. Least square means comparisons of warm season forage calcium concentration.

Year x Site x Tillage[†]	Forage[‡]	Estimate						
		--g kg^{-1}--						
2008 x Upland x CT	SU_SU	37.5				A[§]		
2008 x Lowland x NT	SU_SU	33.6		B		A		
2009 x Lowland x CT	CP_SU	31.0		B		A		
2009 x Lowland x CT	CP	28.8		B		A	C	
2008 x Upland x CT	CP	28.7		B	D	A	C	
2008 x Lowland x CT	SU_SU	28.1		B	D	A	C	
2008 x Upland x NT	CP_SO	27.7		B	D		C	
2009 x Lowland x CT	CP_CO	27.1		B	D		C	
2008 x Upland x NT	CP	26.6		B	D	E	C	
2009 x Upland x CT	LL	26.5		B	D	E	C	
2008 x Upland x CT	CP_SU	26.5		B	D	E	C	
2008 x Upland x NT	CP_SU	26.4		B	D	E	C	
2009 x Lowland x NT	CH	26.3		B	D	E	C	
2009 x Lowland x NT	CP_CO	26.2		B	D	E	C	
2009 x Upland x NT	CP	25.8	F	B	D	E	C	
2009 x Lowland x CT	CP_SO	24.9	F		D	E	C	
2009 x Lowland x CT	LL	24.5	F		D	E	C	
2009 x Lowland x NT	LL	24.4	F		D	E	C	
2008 x Lowland x NT	CP_CO	23.3	F		D	E	C	
2008 x Lowland x CT	CP_CO	23.1	F		D	E	C	
2008 x Upland x CT	CP_CO	22.8	F		D	E	C	
2008 x Lowland x CT	CP_SU	22.7	F	G	D	E	C	
2008 x Lowland x CT	CP_SO	22.5	F	G	D	E	C	
2009 x Upland x CT	CP_SO	22.4	F	G	D	E	C	
2009 x Lowland x NT	CP_SU	22.0	F	G	D	E	C	
2008 x Upland x NT	LL	21.9	F	G	D	E	C	H
2008 x Lowland x NT	CP_SU	21.6	F	G	D	E	C	H
2008 x Lowland x CT	CP	21.6	F	G	D	E	C	H
2009 x Upland x CT	CP_SU	21.4	F	G	D	E		H
2008 x Upland x CT	CP_SO	20.1	F	G	D	E		H
2008 x Lowland x NT	LL	19.2	F	G	D	E	I	H
2009 x Upland x NT	CP_CO	18.7	F	G		E	I	H
2009 x Upland x CT	CP_CO	18.7	F	G		E	I	H

† Conventional tillage (CT), no-till (NT)

‡ cowpea (CP), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), sunflower in sunflower mix (SU_SU), lablab (LL)

§ Entries with the same letter are not significantly different (α = 0.05)

Table 43. continued.

Year x Site x Tillage†	Forage‡	Estimate						
		--g kg^{-1}--						
2009 x Upland x NT	CP_SO	18.0	F§	G		E	I	H
2008 x Upland x CT	LL	18.0	F	G		E	I	H
2009 x Lowland x NT	CP	17.9	F	G		E	I	H
2008 x Upland x CT	PE	17.8	F	G	J	E	I	H
2008 x Upland x NT	CP_CO	17.2	F	G	J		I	H
2008 x Lowland x NT	CP_SO	16.6	F	G	J		I	H
2009 x Lowland x NT	CP_SO	16.5	F	G	J		I	H
2009 x Upland x NT	CH	16.5	F	G	J		I	H
2008 x Lowland x CT	LL	16.3	F	G	J	K	I	H
2008 x Lowland x NT	CP	15.8	F	G	J	K	I	H
2009 x Upland x NT	CP_SU	15.7		G	J	K	I	H
2008 x Upland x CT	SB	15.4		G	J	K	I	H
2008 x Lowland x CT	PE	15.1		G	J	K	I	H
2009 x Upland x CT	CP	14.9		G	J	K	I	H
2008 x Upland x CT	SH	14.8		G	J	K	I	H
2008 x Lowland x NT	PE	14.5		G	J	K	I	H
2009 x Lowland x CT	SB	12.3			J	K	I	H
2009 x Upland x CT	SB	12.1		L	J	K	I	H
2008 x Upland x NT	SB	12.0		L	J	K	I	
2009 x Upland x NT	SB	10.6		L	J	K	I	
2008 x Lowland x CT	SH	10.4		L	J	K	I	
2008 x Lowland x NT	SB	10.4		L	J	K	I	
2009 x Upland x CT	AE	10.2		L	J	K	I	
2009 x Upland x CT	SH	9.4		L	J	K		
2008 x Lowland x CT	SB	8.5		L	J	K		
2009 x Lowland x CT	SH	7.8		L	J	K		
2009 x Lowland x CT	AE	7.7		L	J	K	M	
2008 x Upland x CT	CHU	4.7		L		K	M	
2008 x Lowland x NT	SO_SO	2.7		L			M	
2008 x Lowland x CT	CHU	2.7		L			M	
2009 x Lowland x CT	SO_SO	1.2					M	
2009 x Lowland x NT	SO_SO	1.2					M	
2009 x Upland x CT	SO_SO	1.0					M	
2009 x Upland x NT	SO_SO	0.9					M	
2008 x Lowland x CT	SO_SO	0.7					M	

† Conventional tillage (CT), no-till (NT)

‡ cowpea (CP), chufa (CHU), chicory (CH), aeschynomene (AE), cowpea in corn mix (CP_CO), cowpea in sorghum mix (CP_SO), cowpea in sunflower mix (CP_SU), sorghum in sorghum mix (SO_SO), soybean (SB), peanut (PE), sunnhemp (SH), lablab (LL)

§ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 44. Least square means comparisons of warm season forage phosphorus concentration.

Year x Site x Tillage[†]	Forage[‡]	Estimate							
		--g kg^{-1}--							
2009 x Upland x NT	CH	3.7				A[§]			
2009 x Upland x CT	CP_SO	3.7				A			
2009 x Upland x CT	SH	3.6				A			
2009 x Lowland x CT	SH	3.6				A			
2009 x Upland x NT	CP_SU	3.6		B		A			
2009 x Lowland x CT	SO_SO	3.5		B		A			
2009 x Lowland x NT	SO_SO	3.5		B		A			
2009 x Upland x CT	CP	3.5		B		A			
2008 x Upland x CT	CP_SU	3.4		B		A			
2009 x Upland x NT	CP_SO	3.4		B		A			
2008 x Lowland x CT	CP	3.3		B		A			
2009 x Lowland x NT	CH	3.2		B		A			
2009 x Lowland x CT	CP_SO	3.2		B		A			
2008 x Lowland x CT	SO_SO	3.2		B		A			
2009 x Lowland x NT	CP	3.2		B		A			
2009 x Lowland x NT	CP_SO	3.2		B		A			
2008 x Lowland x CT	SU_SU	3.1		B		A		C	
2009 x Upland x CT	SO_SO	3.1		B		A		C	
2008 x Upland x CT	CP_SO	3.1		B		A		C	
2009 x Upland x CT	CP_CO	3.1		B		A		C	
2009 x Upland x CT	CP_SU	3.0		B		A		C	
2009 x Upland x NT	SO_SO	3.0		B		A		C	
2009 x Upland x NT	CP_CO	3.0		B	D	A		C	
2008 x Lowland x NT	SO_SO	3.0	E	B	D	A		C	
2008 x Lowland x CT	CP_SU	2.9	E	B	D	A		C	F
2009 x Lowland x NT	CP_SU	2.9	E	B	D	A		C	F
2009 x Lowland x CT	CP	2.9	E	B	D	A		C	F
2009 x Lowland x CT	CP_SU	2.9	E	B	D	A		C	F
2009 x Lowland x CT	LL	2.9	E	B	D	A		C	F
2009 x Lowland x NT	CP_CO	2.9	E	B	D	A	G	C	F
2009 x Lowland x CT	SB	2.9	E	B	D	A	G	C	F
2008 x Lowland x NT	CP_SU	2.7	E	B	D	A	G	C	F

† Conventional tillage (CT), no-till (NT)

‡ chicory (CH), cowpea in sorghum mix (CP_SO), sunnhemp (SH), cowpea in sunflower (CP_SU), sorghum in sorghum mix (SO_SO), cowpea (CP), sunflower in sunflower mix (SU_SU), lablab (LL), soybean (SB)

§ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 44. continued.

Year x Site x Tillage[†]	Forage[‡]	Estimate								
		--g kg^{-1}--								
2009 x Lowland x NT	LL	2.7	E[§]	B	D	H	A	G	C	F
2009 x Upland x CT	LL	2.7	E	B	D	H		G	C	F
2009 x Lowland x CT	AE	2.7	E	B	D	H		G	C	F
2009 x Lowland x CT	CP_CO	2.6	E	B	D	H		G	C	F
2008 x Upland x CT	CP_CO	2.6	E	B	D	H		G	C	F
2008 x Lowland x CT	CP_SO	2.6	E	B	D	H		G	C	F
2008 x Upland x CT	SH	2.6	E	B	D	H		G	C	F
2008 x Lowland x NT	CP_SO	2.5	E	B	D	H		G	C	F
2008 x Lowland x NT	CP	2.5	E	B	D	H		G	C	F
2008 x Lowland x CT	SH	2.5	E	B	D	H		G	C	F
2008 x Lowland x NT	SU_SU	2.5	E	B	D	H	I	G	C	F
2008 x Upland x CT	LL	2.5	E	B	D	H	I	G	C	F
2008 x Upland x CT	CP_SO	2.5	E	B	D	H	I	G	C	F
2009 x Upland x CT	SB	2.4	E	B	D	H	I	G	C	F
2008 x Lowland x CT	CP_CO	2.4	E	B	D	H	I	G	C	F
2008 x Upland x CT	LL	2.4	E	B	D	H	I	G	C	F
2008 x Upland x CT	CP_SU	2.4	E	B	D	H	I	G	C	F
2009 x Upland x CT	AE	2.3	E	B	D	H	I	G	C	F
2008 x Lowland x CT	SB	2.3	E	B	D	H	I	G	C	F
2008 x Upland x CT	CP	2.3	E	B	D	H	I	G	C	F
2008 x Upland x CT	CP	2.3	E	B	D	H	I	G	C	F
2008 x Upland x CT	SU_SU	2.3	E		D	H	I	G	C	F
2008 x Upland x CT	SB	2.2	E		D	H	I	G		F
2008 x Lowland x CT	LL	2.1	E		D	H	I	G		F
2008 x Lowland x NT	CP_CO	2.1	E		D	H	I	G		F
2008 x Lowland x NT	SB	2.0	E	J	D	H	I	G		F
2009 x Upland x NT	SB	2.0	E	J	D	H	I	G		F
2008 x Lowland x NT	LL	1.9	E	J		H	I	G		F
2008 x Lowland x CT	CHU	1.9		J		H	I	G		F
2008 x Upland x CT	SB	1.9		J		H	I	G		F
2009 x Upland x NT	CP	1.7		J		H	I	G		

[†] Conventional tillage (CT), no-till (NT)

[‡] lablab (LL), aeschynomene (AE), cowpea in corn mix (CP_CO), sunnhemp (SH), cowpea in sorghum mix (CP_SO), soybean (SB), cowpea (CP), sunflower in sunflower mix (SU_SU), chufa (CHU)

[§] Entries with the same letter are not significantly different (α = 0.05)

Table 44. continued.

Year x Site x Tillage[†]	Forage[‡]	Estimate			
		--g kg^{-1}--			
2008 x Upland x CT	PE	1.7	J[§]	H	I
2008 x Lowland x CT	PE	1.5	J		I
2008 x Upland x CT	CP_CO	1.5	J		I
2008 x Lowland x NT	PE	1.3	J		I
2008 x Upland x CT	CHU	0.9	J		

† Conventional tillage (CT), no-till (NT)

‡ peanut (PE), cowpea in corn mix (CP_CO), chufa (CHU)

§ Entries with the same letter are not significantly different (α = 0.05)

Table 45. Least square means comparisons of warm season forage sodium concentration

Forage[†]	Estimate			
	--g kg^{-1}--			
CH	1.2		A[‡]	
AE	0.8	B	A	
CP	0.7	B	A	
SB	0.7	B	A	
SH	0.7	B	A	
CP_SO	0.6	B	A	
CP_CO	0.6	B	A	
CP_SU	0.6	B	A	
LL	0.5	B	A	C
SU_SU	0.3	B	A	C
CHU	0.3	B	A	C
PE	0.2	B		C
SO_SO	0.2			C

† chicory (CH), aeschynomene (AE), cowpea (CP), soybean (SB), sunnhemp (SH), cowpea in sorghum mix (CP_SO), cowpea in corn mix (CP_CO), cowpea in sunflower mix (CP_SU), lablab (LL), sunflower in sunflower mix (SU_SU), chufa (CHU), peanut (PE), sorghum in sorghum mix (SO_SO)

‡ Entries with the same letter are not significantly different (α = 0.05)

Table 46. Analysis of variance probability of greater F (Pr>F) for warm season forage natural detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) concentration.

Effect	NDF	ADF	ADL
		-------------Pr>F--------------	
Year	0.0277	0.0007	0.0722
Site	0.7674	0.3821	0.6936
Year x Site	0.5759	0.0232	0.0435
Forage	0.0000	0.0000	0.0000
Year x Forage	0.0000	0.0000	0.0297
Site x Forage	0.0025	0.0005	0.0723
Year x Site x Forage	0.9809	0.8052	0.2500
Tillage	0.4932	0.0067	0.3496
Year x Tillage	0.7514	0.0637	0.0764
Site x Tillage	0.8051	0.2539	0.3342
Year x Site x Tillage	0.0676	0.5937	0.3211
Tillage x Forage	0.8899	0.0586	0.6072
Year x Tillage x Forage	0.7290	0.0857	0.2577
Site x Tillage x Forage	0.9635	0.2296	0.9413
Year x Site x Tillage x Forage	0.4266	0.8793	0.7798

Table 47. Least square means comparisons of warm season forage neutral detergent fiber concentration.

Site	Forage†	Estimate		
		------g kg^{-1}-------		
Upland	CHU	642		A‡
Lowland	CHU	589	B	A
Upland	SO_SO	518	B	C
Lowland	SO_SO	482		C
Upland	AE	305		D
Upland	SB	297		D
Lowland	LL	295		D
Lowland	AE	286	E	D
Lowland	SB	272	E	D
Lowland	SH	269	E	D
Upland	LL	268	E	D
Upland	SH	265	E	D
Upland	CP_CO	264	E	D
Upland	CP	262	E	D
Lowland	CP_SU	251	E	D
Upland	CP_SO	242	E	D
Upland	PE	239	E	D
Upland	CP_SU	231	E	D
Lowland	CP_SO	227	E	D
Lowland	SU_SU	225	E	D
Lowland	CP	222	E	
Lowland	CP_CO	221	E	
Lowland	PE	212	E	
Upland	SU_SU	203	E	

† chufa (CHU), sorghum in sorghum mix (SO_SO), aeschynomene (AE), soybean (SB), lablab (LL), sunnhemp (SH), cowpea in corn mix (CP_CO), cowpea (CP), peanut (PE), cowpea in sunflower mix (CP_SU), cowpea in sorghum mix (CP_SO), sunflower in sunflower mix (SU_SU)

‡ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 48. Least square means comparisons of swarm season forage acid detergent fiber concentration.

Site	Forage[†]	Estimate			
		------$g\ kg^{-1}$-------			
		Conventional Tillage			
Lowland	CHU	317		A[‡]	
Upland	CHU	299		A	
Upland	SO_SO	284		A	
Lowland	SO_SO	282		A	
Lowland	SH	209		B	
Upland	PE	203	C	B	
Upland	SH	202	C	B	
Upland	SB	189	C	B	D
Upland	AE	187	C	B	D
Lowland	SB	182	C	B	D
Lowland	PE	181	C	B	D
Lowland	LL	174	C		D
Upland	LL	171	C		D
Upland	CP	158	C	E	D
Lowland	AE	154	C	E	D
Lowland	CP_SU	154		E	D
Upland	SU_SU	151		E	D
Upland	CP_CO	148		E	D
Lowland	SU_SU	144		E	D
Upland	CP_SO	140		E	
Lowland	CP	137		E	
Upland	CP_SU	136		E	
Lowland	CP_SO	135		E	
Lowland	CP_CO	134		E	
		No-till			
Lowland	SO_SO	251		A	
Upland	SO_SO	229	B	A	
Upland	SB	184	B	C	
Lowland	SB	183	B	C	

† chufa (CHU), sorghum in sorghum mix (SO_SO), aeschynomene (AE), soybean (SB), lablab (LL), sunnhemp (SH), cowpea in corn mix (CP_CO), cowpea (CP), peanut (PE), cowpea in sunflower mix (CP_SU), cowpea in sorghum mix (CP_SO), sunflower in sunflower mix (SU_SU), chicory (CH)

‡ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 48. continued.

Site	Forage[†]	Estimate			
		------g kg^{-1}-------			
Lowland	SU_SU	167	B[‡]	C	D
Lowland	LL	166	B	C	D
Lowland	CH	162	B	C	D
Lowland	CP_CO	154		C	D
Lowland	CP_SU	153		C	D
Upland	CP_CO	147		C	D
Upland	LL	146		C	D
Upland	CP_SU	146		C	D
Upland	CP	143		C	D
Upland	CP_SO	134		C	D
Lowland	CP_SO	132		C	D
Lowland	PE	131		C	D
Lowland	CP	122			D

† chufa (CHU), sorghum in sorghum mix (SO_SO), aeschynomene (AE), soybean (SB), lablab (LL), sunnhemp (SH), cowpea in corn mix (CP_CO), cowpea (CP), peanut (PE), cowpea in sunflower mix (CP_SU), cowpea in sorghum mix (CP_SO), sunflower in sunflower mix (SU_SU), chicory (CH)

‡ Entries with the same letter are not significantly different ($\alpha = 0.05$)

Table 49. Least square means comparisons of warm season forage acid detergent lignin concentration.

Year	Forage†	Estimate				
		------g kg^{-1}-------				
2009	SO_SO	74			A‡	
2009	CH	72	B		A	
2008	SO_SO	67	B		A	
2008	CHU	62	B		A	
2009	SB	51	B		C	
2008	CP_SU	47			C	
2009	LL	47	D		C	
2009	AE	44	D		C	E
2008	LL	41	D		C	E
2008	SB	40	D		C	E
2008	SU_SU	39	D	F	C	E
2008	SH	37	D	F		E
2009	SH	37		F		E
2009	CP_SO	37		F		E
2009	CP_CO	36		F		E
2009	CP_SU	35		F		E
2008	CP_SO	34		F		E
2009	CP	34		F		E
2008	CP_CO	33		F		E
2008	CP	33		F		E
2008	PE	27		F		

† chufa (CHU), sorghum in sorghum mix (SO_SO), aeschynomene (AE), soybean (SB), lablab (LL), sunnhemp (SH), cowpea in corn mix (CP_CO), cowpea (CP), peanut (PE), cowpea in sunflower mix (CP_SU), cowpea in sorghum mix (CP_SO), sunflower in sunflower mix (SU_SU), chicory (CH)

‡ Entries with the same letter are not significantly different (α = 0.05)

Table 50. Analysis of variance probability of greater F (Pr>F) for warm season feeding observations.

Effect	--Pr>F--
Forage	0.3984
Year	0.3155
Site	0.5603

Table 51. Estimates and standard errors for log transformed warm season observations.

Forage[†]	Estimate [‡]	Estimate	StdErr
	--observations ha^{-1}--	-log observations ha^{-1}-	
CHU	75	1.8	0.32
CO_CP	17	1.2	0.16
CP	53	1.7	0.23
SO_CP	37	1.5	0.32
SB	37	1.5	0.32
SU_CP	53	1.7	0.23
Alley	8	0.9	0.23

[†] Chufa (CHU), corn and cowpea mix (CO_CP), cowpea (CP), sorghum and cowpea mix (SO_SP), soybean (SB), sunflower and cowpea mix (SU_CP), non planted borders and alleys (Alley)

[‡] Estimates were back-transformed to observations ha^{-1} for interpretation

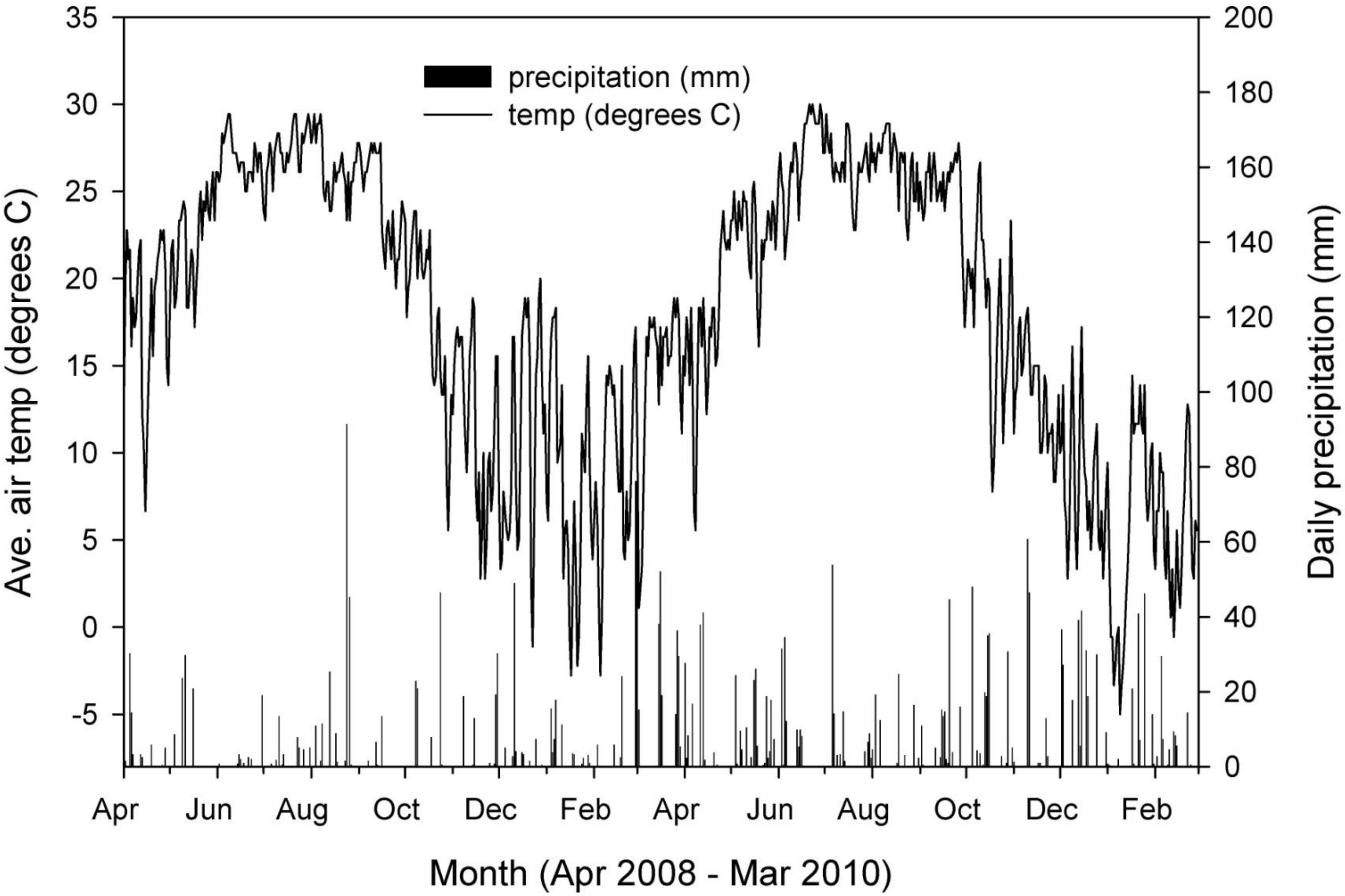


Figure 2. Average air temperature at 2 m and daily precipitation in Auburn, AL over the study period.

III. Chufa Response to Nutrient Additions

Abstract

Chufas (*Cyperus esculentus* L. var.*sativus* Boeck) are a common wildlife planting in the Southeast, and are a preferred food of the wild turkey (*Meleagris gallopavo*). However, published information regarding fertilization of chufa is inconclusive. During the summer of 2009 a greenhouse experiment was conducted to determine chufa response to fertilization. Chufas were planted in 11-L pots, thinned to 4 plants per pot and fertilized with either nitrogen (N), phosphorus (P), or potassium (K). Nitrogen and K rates were 0, 50, 100, 200, 300, 400, or 800 kg ha^{-1} and P rates were 0, 20, 40, 80, 160, 320, 640 kg ha^{-1}. Each treatment received a standard rate of micronutrient solution, N, P, or K as needed. Above ground growth and tubers were harvested, weighed, and analyzed for nutrient uptake. Chufa exhibited an above ground yield response to N fertilization but not P or K. Nitrogen, P, and K uptake increased in above ground growth with nutrient application. Tuber weight did not respond to the treatments, while tuber count increased with N addition. No response was observed in tuber count owing to P or K addition. Tubers had no increase in either N, P, or K uptake owing to fertilization. Results suggest that limited response to nutrient application of chufa tubers can be expected. However, field studies are warranted to verify these results.

Introduction

Chufa is a popular wildlife crop in the southeastern U.S. that is primarily planted for wild turkey (*Meleagris gallopavo*) or in moist soil impoundments for waterfowl (Martin and Uhler, 1939; Mitchell and Martin, 1986; Kelley and Frederickson, 1991).

Chufa plants produce tuber like growths below ground that provide an excellent source of carbohydrates for wildlife (Billingsley and Arner, 1970; Mitchell and Martin, 1986; and Kelley and Frederickson, 1991) and serve as the cornerstone for their use in wildlife plantings.

Management practices for chufa such as cultivation, flooding, and stand establishment have been well described (Reid et al., 1989; Kelley, 1990; Kelley and Frederickson, 1991; Peters and Afton, 1993; Taylor and Smith, 2003; Taylor and Smith 2005). Chufa use in moist soil systems stems from its ability to tolerate periods of flooding without reducing tuber production (Kelley and Frederickson, 1991; Peters and Afton, 1993; Taylor and Smith, 2003; and Taylor and Smith 2005). Since reproduction occurs predominately from the tubers, cultivation is often used to redistribute tubers and increase established stands (Tumbleson and Kommedahl, 1962; Taylorson, 1967; Sanchez Tames and Vieitez, 1970; Thullen and Keeley, 1980; Taylor and Smith, 2003).

Information regarding chufa fertilization is scarce in the published literature, and available recommendations regarding fertilization of chufa are variable (Killinger and Stokes, 1951; Maroto et al., 1986; and Pascual et al., 2000). Recommendations range from 560 kg ha^{-1} of 10-10-10 fertilizer to no fertilizer application (Killinger and Stokes, 1951; Yarrow and Yarrow, 2005; and Mitchell and Martin, 1986). The objectives of this study were to examine chufa response to nutrient additions in a greenhouse setting.

Materials and Methods

Three fertilization studies were conducted from April to September 2009 at the Plant Science Research Center Greenhouse in Auburn, Alabama to examine chufa response to N, P, and K additions. Principle guidelines for these experiments were followed from those published by Tennessee Valley Authority National Fertilizer Development Center, Muscle Shoals, Al (Allen et al., 1976). The potting medium was fritted clay, which is suitable for greenhouse experiments due to its retention of plant-available water, ease of removal from roots, and lack of nutrients (van Bavel et al., 1978; Biondini et al., 1988). The medium had an initial pH of 9.0 to 13.0 and was washed with water until a pH between 6.0 and 6.5 was obtained. The pH was monitored with each rinsing cycle to prevent over-washing the potting medium, which would result in pH less than desirable. Garden fabric was placed in the bottom of 11.3 L pots into which the potting medium was placed.

National Wild Turkey Federation, Turkey Gold chufas were acquired from a local farm supply store. A germination test was performed using a Pro-Grow Propagation Chamber Model PC-70 dual zone from Pro Gro Supply (Brookfield, Wisconsin) and results indicated 97% germination. The pots were planted on 29 May 2009 with germination and emergence occurring within one week. Upon reaching 5 cm in height, all pots were thinned to 4 plants per pot and fertilized with a micronutrient solution and a half rate of macronutrient solution. The micronutrient solution was made with reagent grade magnesium sulfate ($MgSO_4$), iron sulfate ($FeSO_4$), manganese sulfate ($MnSO_4$), zinc sulfate ($ZnS0_4$), copper sulfate ($CuSO_4$), and sodium borate ($Na_2B_4O_7$) to supply 14 mg, 14 mg, 11 mg, 12 mg, 4 mg, 1.4 mg, and 38 mg of magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), and sulfur (S), respectively, per 100 ml of solution.

For the N experiment, a N solution was made with reagent grade ammonium nitrate (NH_4NO_3) to a concentration of 15.3 g NH_4NO_3 L^{-1}. A 31.25 ml aliquot of solution was equal to a rate of 50 kg N ha^{-1} while 500 ml of solution was equal to 800 kg N ha^{-1}. For the P experiment, the treatment solution was made with reagent grade monocalcium phosphate ($Ca(H_2PO_4)_2$) to a concentration of 34.89 g $Ca(H_2PO_4)_2$ L^{-1}. A 15.625 ml aliquot of solution was equal to 20 kg P ha^{-1} while 500 ml of solution was equal to 640 kg P ha^{-1}. The K treatment solution was made with reagent grade potassium chloride (KCl) to a concentration of 10.24 g KCl L^{-1}. A 31.25 ml aliquot of solution equaled 50 kg K ha^{-1} rate while 500 ml of solution was equal to 800 kg K ha^{-1}. The N experiment received. Standard rates of 44 kg P ha^{-1} and 44 kg K ha^{-1} from each solution respectively. The P experiment received standard rates of 134 kg N ha^{-1}, and 44 kg K ha^{-1}. The K experiment received 134 kg N ha^{-1}, and 44 kg P ha^{-1}. Fertilizer solutions were measured in graduated cylinders to ensure accurate solution aliquots were dispensed for each pot. The second split rate application was applied on June 26 following the previously described rates and methods.

Harvest and Analysis

Above ground growth of chufa was harvested by clipping plants 1.2 cm above the soil level. Chufa tops were dried at 55° C to a common moisture content and weighed to determine dry matter production. The samples were then ground to pass a 1 mm screen using a Wiley mill and analyzed for total N concentration by dry combustion using a LECO TruSpec CN (Leco Corp, St. Joseph, MI). Phosphorus and K concentrations were determined according to Hue and Evans (1986) via inductively coupled argon plasma spectrophotometry (ICAP), (SPECTROCIROS CCD, Side-on plasma. Germany). Chufa tubers were harvested within one week after top growth harvest by washing roots over a 3 mm screen to prevent washing off loose tubers. The tubers were removed from the roots, washed, counted, dried at 55° C to a common moisture content and ground with a coffee grinder. Ground tubers were analyzed following the same method as for the above ground growth. Nutrient uptake was calculated as the product of nutrient concentration and dry matter yield (DMY) of chufa tops or tubers.

Data were analyzed using linear regression in PROC MIXED provided by Statistical Analysis Systems (SAS, 2003). Effects and interactions were determined using F-tests, and R^2 values resulting from regression analyses were calculated with PROC GLM (SAS, 2003).

Results and Discussion

Application of N fertilizer increased above ground dry matter yield in a curvilinear fashion (Table 52, Figure 3). Fertilizer requirement for maximum agronomic above ground yield was calculated as 568 kg N ha^{-1}, resulting in a dry matter yield of 139 g pot^{-1}. Dry matter yield increased from 72 to 133 g pot^{-1} with the addition of N rates from 0 to 800 kg N ha^{-1}. These findings contradict findings of Maroto et al., (1986) and Pascual et al., (2000) that indicate there is no relationship between N fertilization rate and chufa above ground production. Chufa above ground growth did not respond to addition of P or K. Tuber dry matter yield did not respond to application of N, P, or K. Tuber count increased with application of N fertilizer (Figure 4). The N requirement for maximum tuber count was calculated as 568 kg N ha^{-1}. Again, these findings contradict previous findings that imply there is no response in tuber production with N application (Maroto et al., 1986). The lack of response in tuber yield along with the response in tuber count suggests an inverse relationship exists between tuber weight and tuber count as N application rates increase. Neither P, nor K influenced tuber count.

Chufa above ground growth exhibited a response in N uptake to N application. Nitrogen uptake in above ground growth increased with N fertilization rate from 488 to 2921 mg pot^{-1} with a maximum N uptake calculated at 743 kg N ha^{-1}(Figure 5). This finding is explained by the direct response in above ground yield to increased N rate. Uptake of both P and K exhibited a linear response as their fertilization rates increased (Figure 6 and Figure 7). Response in P and K uptake in above ground growth ranged from 117 to 176 mg P pot^{-1} and 2940 to 3502 mg K pot^{-1} ,respectively. This suggests luxury uptake of P and K for above ground growth in chufa because no yield increases owing to P or K additions were observed. The application of N increased N uptake in chufa tubers from 179 to 558 mg N pot^{-1} (Figure 8). This is partially due to an increase in N concentration as rate increased (Figure 9). Neither P nor K fertilizer rates influenced uptake in chufa tubers.

Summary and Conclusions

Overall, chufa exhibited little practical response to nutrient additions. Chufa above ground growth responded to N fertilization while no response to P or K additions was observed. While tuber count had a response to N fertilization, no response was shown in tuber weight to either N, P, or K suggesting an inverse relationship between count and weight under N application. A response in tuber weight may be recognized under field conditions where plants may be more spread out (Taylor and Smith, 2003).

Tuber count did not respond to either P or K addition. Uptake of N, P, and K in above ground growth was found to increase with application of nutrients. N uptake increased in tubers with addition of N fertilizer. Neither P nor K uptake was influenced by fertilizer additions. Since tuber production and not above ground growth is the primary concern for planting of chufa, application of fertilizer may not be necessary. However, differences may be found in non-greenhouse settings. In conclusion, our results indicate that little practical response to N, P, or K fertilization is realized for chufa production. However, field studies to verify these results are warranted.

Table 52. Analysis of variance probability of greater F (Pr>F) values for the effect of fertilizer on dry matter yield (DMY) and nutrient uptake of chufa above ground growth (tops), tubers, and tuber count.

		Tops		Tubers		Tuber count
		DMY	Uptake	DMY	Uptake	
Element	Effect			--Pr> F--		
N	Rate	0.0057	<.0001	0.5541	0.0026	0.0879
	Rate*Rate	0.0121	<.0001	0.7600	0.0320	0.1709
P	Rate	0.1314	0.7170	0.9239	0.1037	0.7426
	Rate*Rate	0.1243	0.5392	0.9045	0.2509	0.9673
K	Rate	0.1779	0.0471	0.4256	0.4244	0.7235
	Rate*Rate	0.2349	0.1945	0.5533	0.6201	0.6341

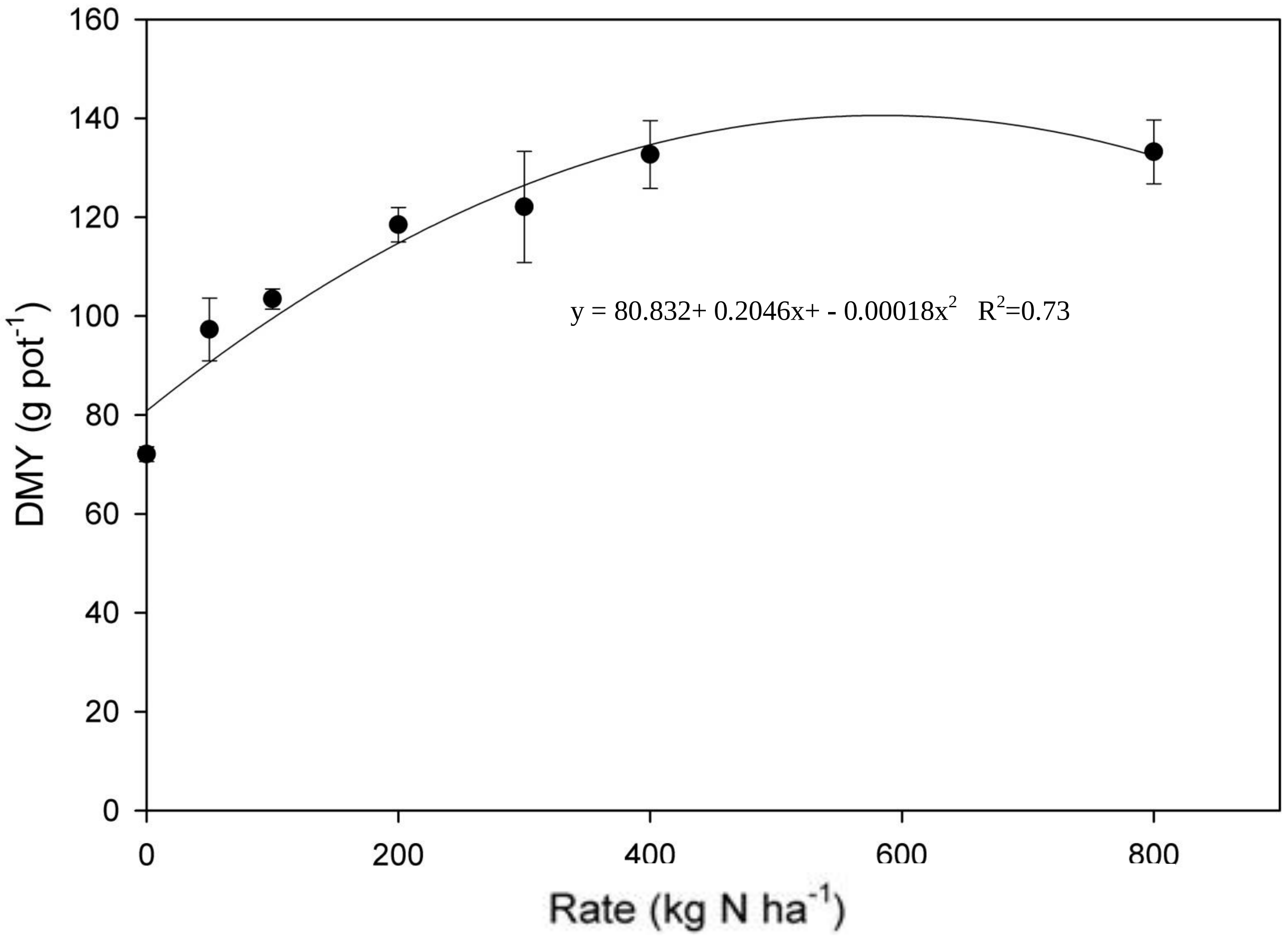


Figure 3. Chufa above ground dry matter yield (DMY) as a function of N rate. Bars are standard errors of means.

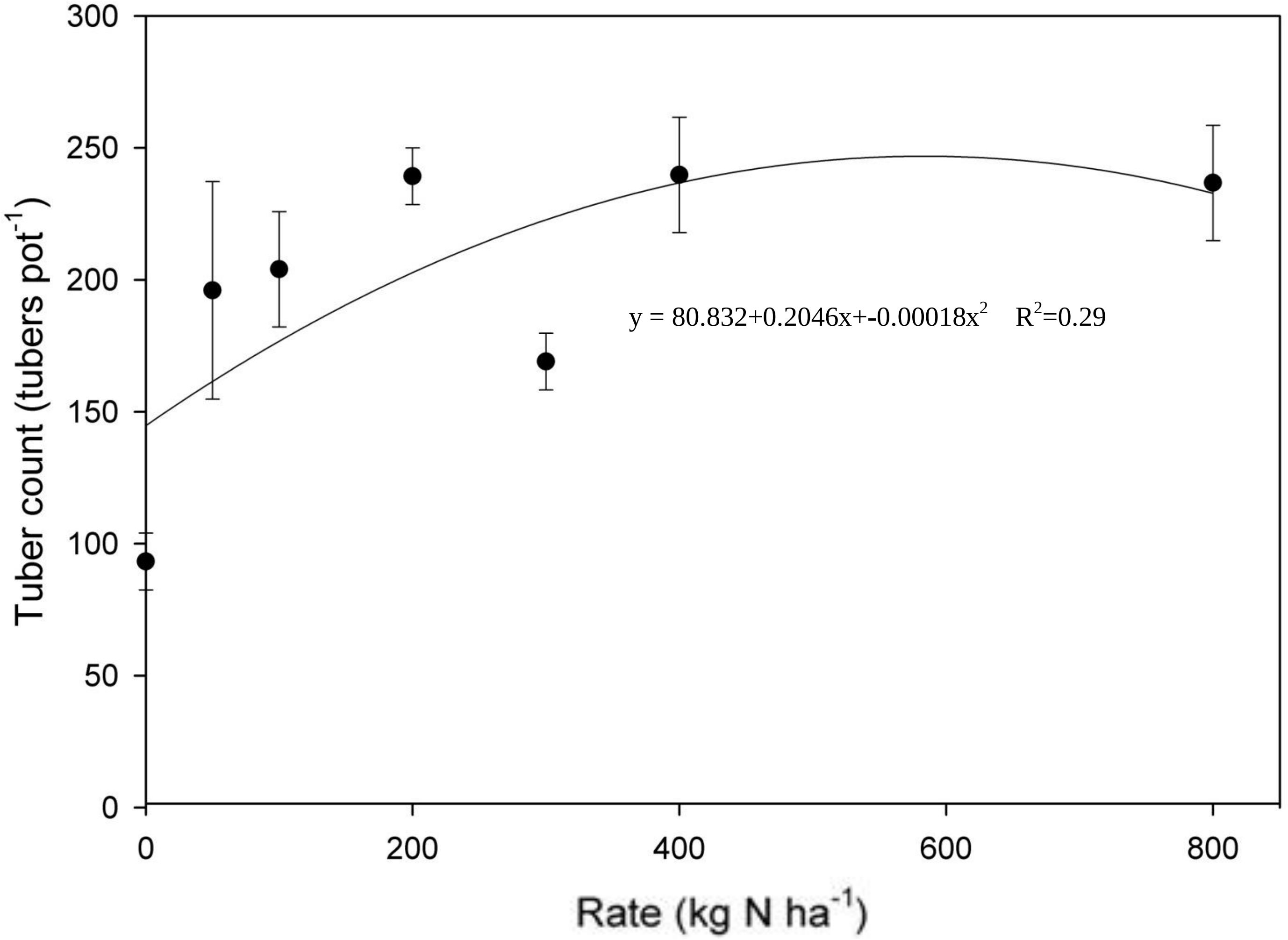


Figure 4. Chufa tuber count as a function of N rate. Bars are standard errors of means.

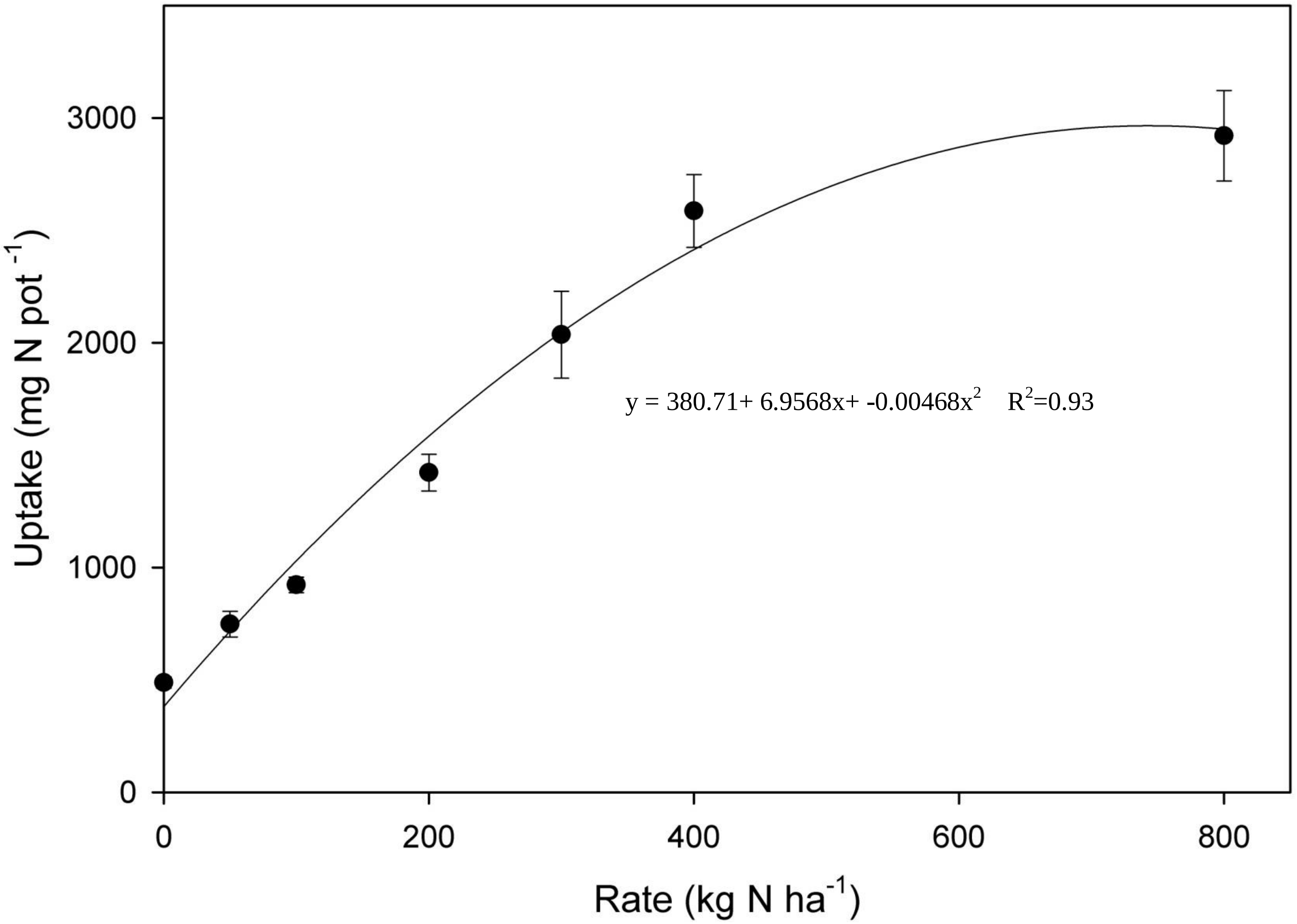


Figure 5. Chufa above ground nitrogen (N) uptake as a function of N rate. Bars are standard errors of means.

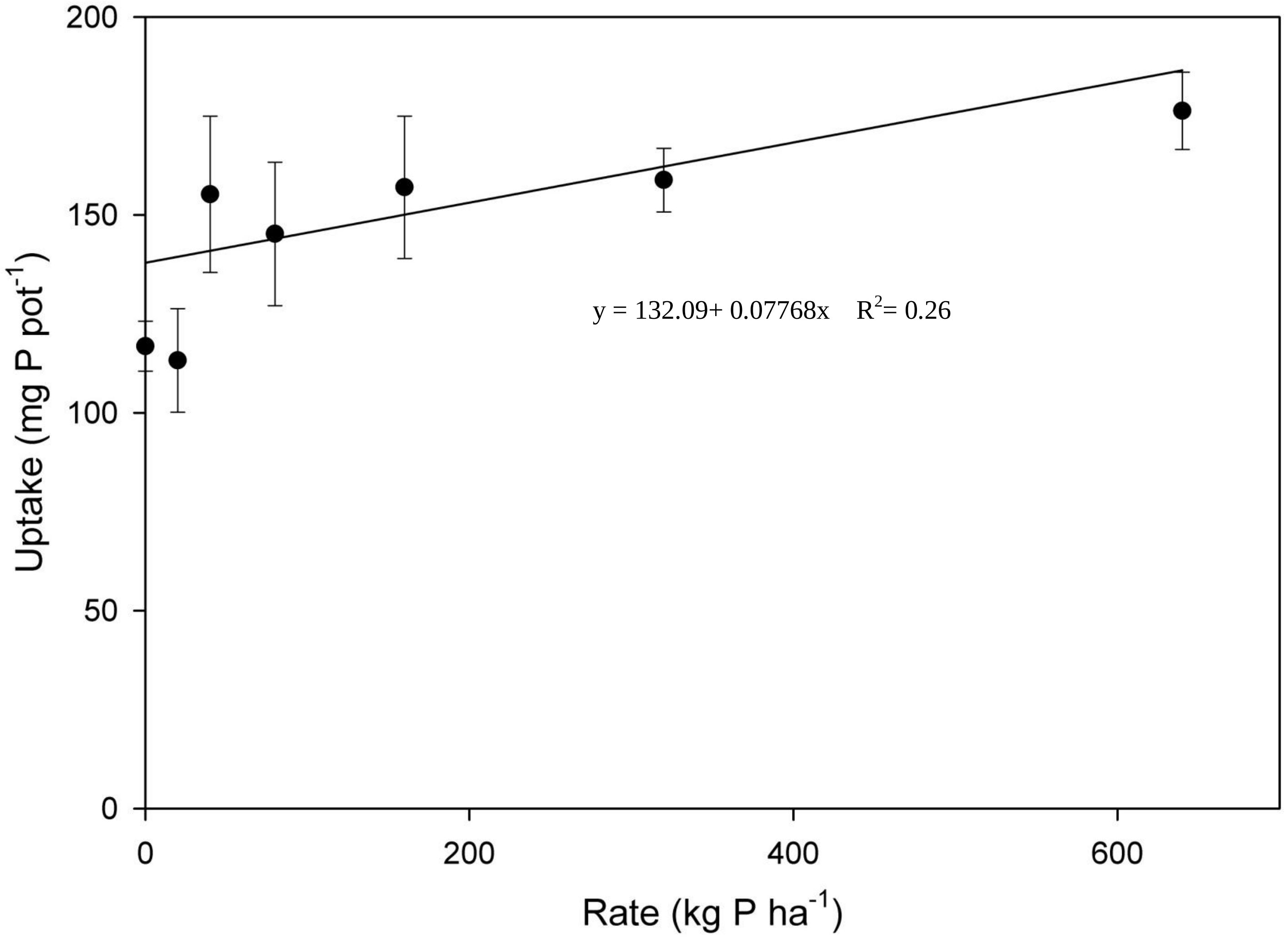


Figure 6. Chufa above ground phosphorus (P) uptake as a function of P rate. Bars are standard errors of means.

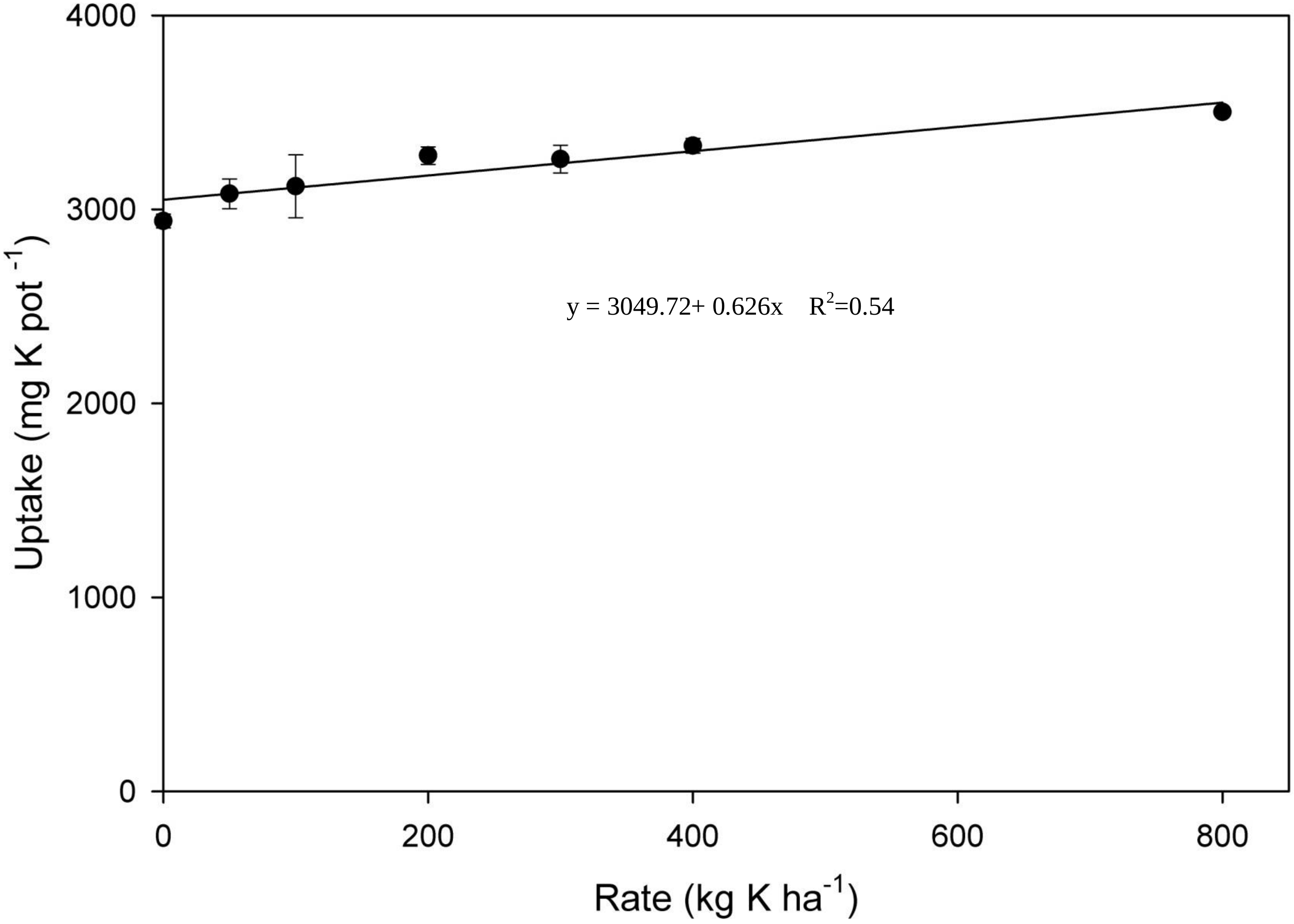


Figure 7. Chufa above ground potassium (K) uptake as a function of K rate. Bars are standard errors of means.

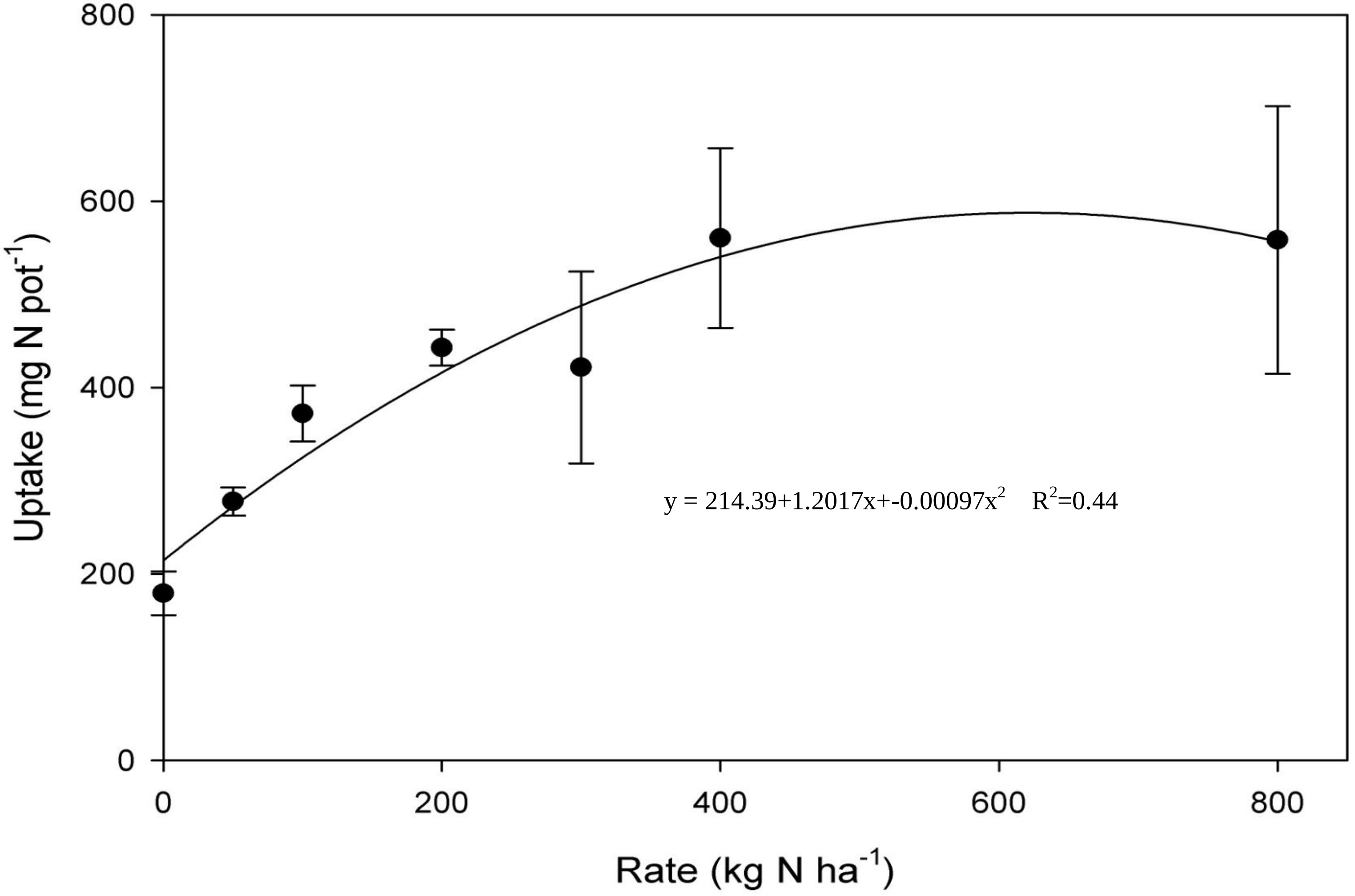


Figure 8. Chufa tuber nitrogen (N) uptake as a function of N rate. Bars are standard errors of means.

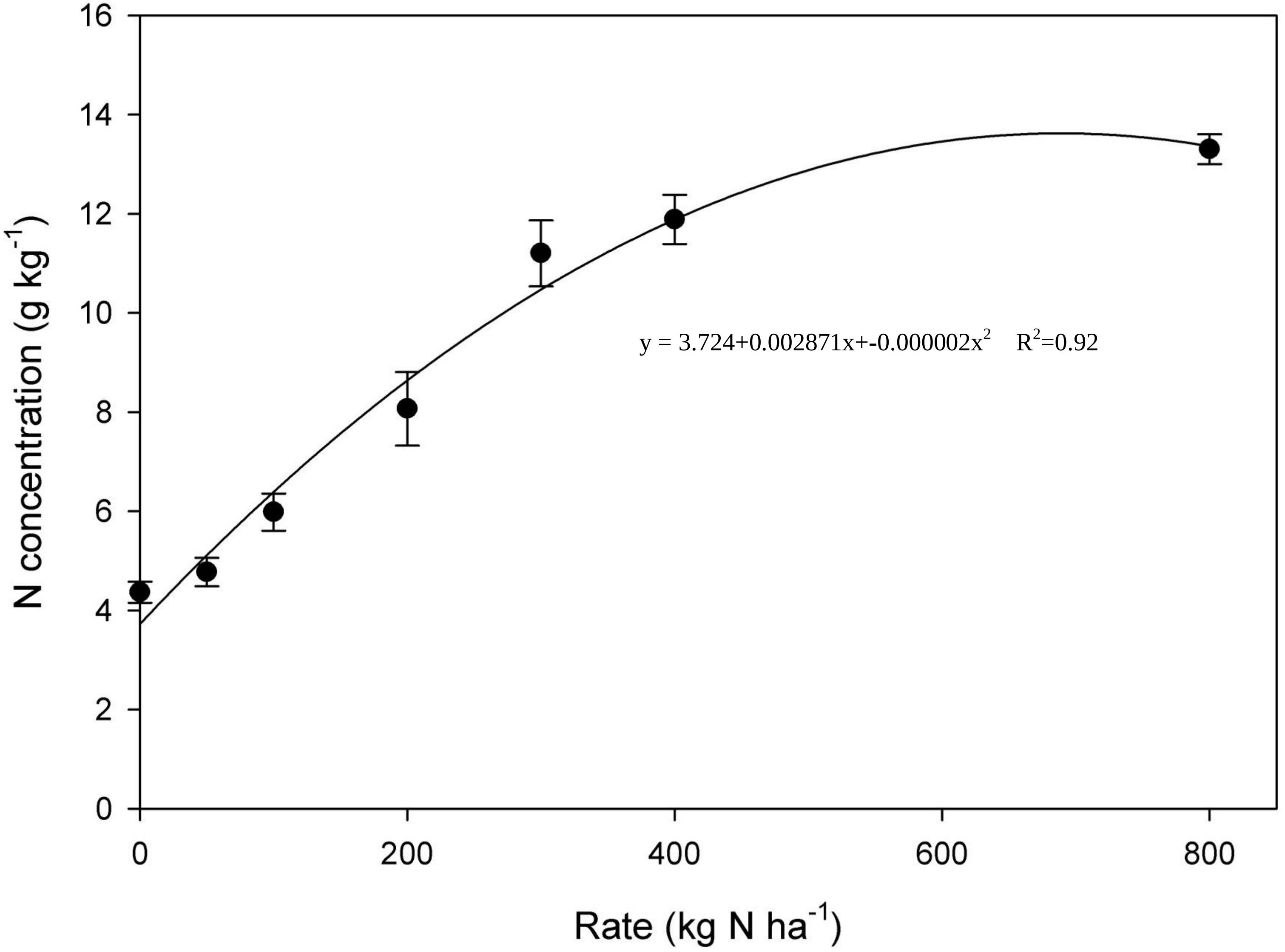


Figure 9. Chufa tuber nitrogen (N) concentration as a function of N rate. Bars are standard errors of means.

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