PASTURE DECLINE IN THE SOUTHEAST UNITED STATES

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Friday, October 28, 2022

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Chapter 1

Pasture decline overview

Reports of pastures in decline for undetermined reasons are seemingly increasing in the 21st century. Pasture decline for the purpose of this report, represents perennial forage stands that lose productivity and appear thin or weak but without a simple, obvious cause. Pasture decline events have been reported throughout the lower Southeast Coastal Plain. Stand losses can vary among fields, but the end results are often reduced production income and increased investments to help recover productivity and system health.

Grazing pasture and hay systems account for more than 73 million ha in the United States, comprised of introduced and native plants used for livestock grazing and hay. These systems support the livestock industry which has an economic value of over $89 billion (NASS, 2018). In the Southeast United States, pastures and fields are dominated by non-native, warm-season, perennial grasses, including improved varieties of bahiagrass and bermudagrass. However, fall overseeding of cool-season annual grasses and legumes are frequently used to offset the warm-season grass dormant periods. The focus of this report is to address declining warm-season, perennial grass pastures and hay fields, with emphasis on bahiagrass and bermudagrass dominated systems.

Pasture decline should not be confused with seasonal fluctuations in productivity from year to year, due to specific and acute management practices or environmental events but rather, it is more of an overarching decline of a field over time. The degradation of forage production and quality is not often a process quickly perceived, as it may take place over several growing seasons. This can interfere with management decisions as producers may not witness significant decline of forage until corrective practices are no longer economically feasible (Pereira et al., 2018).

Globally, pasture decline has been used to describe a range of different conditions or symptoms across a large spectrum of plant types. It is not easily defined, and the meaning of the term can vary, given different social, economic, and environmental perspectives. It is also known by other terms, including ‘sown pasture rundown’, ‘pasture degradation’, and ‘pasture dieback’. Globally, there has been little consensus on how pasture decline is defined or causes causes and effects. Little research has been reported on specific factors that contribute to the onset of pasture decline, although there are reviews and a few reports that address influencing factors (Boddey et al., 2004, Oliveira et al., 2004, Reeve et al., 2000). While pasture decline was confirmed in Australia, causes and effects were difficult to isolate from one another (Hutchinson and King, 1999). Factors such as drought, nutrient cycling, grazing pressure, and plant disease have all been recognized as contributing to pasture decline.

Some of these factors include abiotic influences such as drought stress or excessive soil moisture, and extreme temperatures. According to Getabalew and Alemneh, (2019), climate change is "altering the global hydrologic cycle and it is expected to have substantial and diverse effects on precipitation patterns in different regions". Precipitation extremes (wet or dry) have an impact on pasture forages. For example, Dahal et al. (2020) reported extreme rain events from hurricanes can intensify soil erosion that contribute to soil and nutrient losses, along with nutrient leaching losses. Pasture decline reports out of Australia from as early as the 1970s attributed a portion of reduced productivity to stress from drought (Kemp and Dowling, 2000).

As opposed to rangelands which are often not seeded, fertilized, irrigated, or harvested for hay, improved pastures require maintenance fertilization. Related soil conditions, such as water infiltration, carbon sequestration and nitrogen use efficiency also interact with soil fertility (Xu et al., 2018). Proper soil pH can provide for increased root growth and more efficient fertilizer and water utilization (Silveira et al., 2014). The optimum range of soil pH for warm-season, perennial grasses is between 5.5 and 6.5. Reduced forage yields may occur as a response to low soil pH, typically associated with Al or Mn toxicity. When soil pH is too high, many micronutrients become less available to the plants. Keeping soil pH within the recommended range will allow for better N, P, and K fertilization efficiency (Silveira et al., 2014). Kemp and Dowling (2000) noted that increasing soil acidity in southern Australia may have had some effects on productivity decline, but it was not considered the dominate cause.

Proper fertilization recommendations using the 4Rs concept of Right rate, Right Time, Right place, and Right source provide guidance on nitrogen, phosphorus, and potassium requirements to help maintain perennial grass productivity and health (Hochmuth et al., 2014). Nitrogen application rates are based on production yields and may vary based on different production goals of grazing or haying systems. According to Silveira et al. (2014), an established pasture typically requires 50-60 kg N per ha^{-1} while intensive hay production system may require up to 80 kg N ha^{-1} $harvest^{-1}$. Phosphorus and potassium application rates are based on the plant available nutrients in the soil and plant nutrient needs. Fertilization recommendations will often be included in most soil fertility reports. Grazing pasture systems have the ability to return nutrients that are removed from grazed foraged through cattle excreta or litter (Vendramini et al., 2007). However, excessive litter of grasses which, can have a relatively high C:N ratio (over 25), may immobilize nutrients in the soil and this lack of nutrient availably to perennial grasses can be a potential cause of pasture decline (Vendramini et al., 2007).

Research from Australia and New Zealand showed that pasture decline was due to a lack of available nutrients, coupled with abiotic stressors, and overstocking rates (Oliveira et al., 2004; Boddey et al., 2004). This caused a decline in overall grass production. Walker and Weston (1990) reported that pastures were vigorous for only about four to 10 years before production began to decline. They attributed this decline mainly to nutrient immobilization due to increased C:N ratios of pasture vegetation. Research from Brazil and the Amazon region focused heavily on N cycling and poor fertility management as major contributors to pasture decline. When forests are converted to pastureland through burning there is an increase of nutrients and for a few years after establishment, pasture productivity is high. Data showed that as overstocking increased, the deposition of nitrogen decreased, lessening available soil N for grass, and a lack of maintenance fertilizers further weakened pasture productivity (Boddey et al. 2004).

Additionally, misapplication of nutrients can negatively affect soil health. According to Krasilnikov et al. (2022), an imbalanced use of chemical fertilizers can acidify soils, contribute to soil crusting, and increase pest attraction. This may result in a decrease in soil organic carbon and beneficial soil microorganisms, leading to reduced plant growth and yield.

Livestock management practices are quite influential on pasture health and decline. Animal stocking rates, grazing pressure, and livestock rotation regimes fall under this category. Livestock can benefit the pasture system through increased livestock inputs of excreta and saliva. Some reports of trampling, if done properly, may improve soil health through increased soil biological activity (Rinehart, 2017).

Grazing period (the time animals are allowed to feed on the pasture) and recovery period (the time needed for that pasture to regrow before allowing livestock to feed again) affects the level of stress imposed on the pasture system. A meta-analysis (Sollenberger et al., 2012) on continuous versus rotational grazing, reported that 85% of the 27 publications reviewed demonstrated that intensive rotational grazing strategies resulted in greater forage efficiency vs. continuous grazing. Since intensive rotational grazing systems involve greater animal densities than continuous grazing, variations in grazing pressure are reduced, thereby, improving the efficiency of forage harvest within any given area (Heitschmidt, 1988).

Many of the aforementioned factors contributing to pasture decline also influence pasture pests. There are several types of grass damaging pests, such as mites, scales, grubs, and nematodes. Disease pressures, including leaf spots and root rots, can impair forage productivity across forage species, and even differences in cultivar susceptibility have been noted. For example, Blount et al. (2002) reported that cultivar selection of bahiagrass played a role in an 2001 outbreak of widespread dollar spot fungus (*Sclerotinia homoeocarpa* F.T.Benn.) that resulted in the decline of several North Florida pastures. Argentine bahiagrass had 15% leaf tissue damage, while Tifton 9 and Pensacola bahiagrass had 45% damage. Early season drought followed by heavy rain and humidity contributed to the outbreak. It is unclear if increased weed pressure initiates pasture decline, but it is likely more often a possible response to weakened stands.

Many of the aforementioned factors can interact with and enhance one another. For example, management decisions can affect biological factors, such as overgrazing pastures can lead to increased weed populations. Vendramini et al., (2007), looked at different grazing management regimes to improve nutrient cycling efficiency and found that short period rotationally grazing at high stocking densities enhanced the uniformity of excretal deposits and reduced greater deposits near congregation (loafing and watering) areas. Hutchinson and King (1999) reported that pasture decline was attributed to stocking rates and overgrazing in their study, but the response was not linear and other factors influenced decline, including fertilization rates and seasonal drought stresses.

Australia and Brazil are among the largest contributors to pasture decline reporting, while publications originating from the Southeast United States are limited. Additionally, related terminology can vary by location and reporting country. Instead of pasture decline, sown pasture rundown is the term often used in Australia, while pasture degradation is used in Brazil and other Amazon regions. Additionally, the dominant grass in the Brazil reports has been *Brachiaria spp*. This tropical perennial may not be an adequate analog for the grasses more representative of Florida, but it is similar to bahiagrass and bermudagrass in that it is a C-4 type, warm-season, perennial forage grass.

More recently, modern imagery and satellite data have been used to assess areas affected by pasture decline in the Amazon regions. Perreira et al. (2018) utilized MODIS NDVI time lapse series to investigate pasture degradation in the Cerrado area. The resulting data suggested that poorest social-economic regions exhibited degraded pastures more often, indicating that little or no management of pasture grass was a contributor to pasture decline. Correlations were also found between low rainfall events and degraded pasture areas.

Is pasture decline a real malady? A publication from the Meat and Livestock Australia Limited issued a review in 2011 on the continued concern of pasture decline in northern Australia. Results from an 80 producer focus group found nutrient cycling, overgrazing, disease, and moisture stress as contributing factors but no single factor was agreed upon as the principal cause of pasture decline, based upon producer responses.

Reeves et al., (2000) focused on producers' perception of pasture management, cases of pasture decline and some of the perceived linking factors of pasture decline using a survey that was issued to livestock producers in 9 regions in Australia. The survey focused on information on pasture decline, grazing management strategies, and financial information. Based on the results, producers were highly concerned about pasture decline and indicated that several factors including drought and weed pressures were potential causes of pasture decline. Interestingly, producers also reported grazing management strategies were not enough to correct pasture decline issues.

This report attempts to address the state of pasture decline in the Southeast United States, through 1) state livestock producers self-reporting by survey and 2) a cursory assessment of plant diagnostic pathology reports, with emphasis on bahiagrass and bermudagrass, in order to assess emerging concerns and build strategies to help foster healthier, more resilient forage systems in the Southeast United States.

Chapter 2

Producer perceptions of pasture health and decline

Increased incidences of poor pasture performance and decline in the southeast\ United States and specifically Florida, have yielded little in terms of potential causes. Several popular press, extension articles and bulletins have been posted since 2016 regarding increased cases of pasture decline (Knight, 2021; Mauldin, 2016; Mayo, 2012). There has been research to evaluate the impact of N, P, and K fertilization of bermudagrass and bahiagrass for improving pasture health (Yarborough et al., 2017a; 2017b). However, there is no known published reports addressing the southeast United States on the cause or causes of pasture decline or discussion of potential future trends. In defense, pasture decline has been difficult to define, diagnose, and treat, and producer education is often focused on individual factors, rather than the system. Since pasture decline tends to progress slowly, sometimes over several growing seasons, it is understandable that producers often recognize the signs or symptoms of weakening forage stands when it is often too late to remedy. Pasture decline may be masked by earlier events, such as temporary drought or flooding events or pest infestations.

In 2019, a survey was developed for pasture and hay producers to identify cases of pasture decline and for producers to share their perceptions of pasture health and pasture decline. The intended audience of this survey was agricultural producers who managed grasslands for the purpose of livestock grazing or hay production in the southeastern United States, with Florida as a model for this effort. The objective of the survey was to 1) gather producer perceptions on pasture health and decline and 2) assess producer need for current and future research and extension education.

Materials and methods

The survey contained 12 questions that queried producers in the following broad areas: 1) general practices and noted impacts over past three years, 2) commonly used pasture management practices, 3) producer perceived list of factors that are important to pasture health 4) strategies producers used to address pasture decline, 5) research and education needs on this topic.

Several questions were designed for producers to answer using a rating system of 1-5 (1=Never, 2=Infrequent, 3=Sometimes, 4=Often, and 5=Nearly always). Questions relating to producer general (county) location and on pasture related research and education needs were open-ended. The survey was issued in both, hard-copy form and through a Qualtrics survey that was anonymously submitted.

The survey was initially advertised in 2019 through the July 2019 issue of the Florida Cattleman's Magazine statewide, through the UF-IFAS Forage Team Facebook page, and through a UF/IFAS Extension regional livestock and forages educational event. In early 2020, COVID-19 stalled the implementation of further piloting the survey at in-person meetings of local and regional cattlemen. Additional advertisement of the survey in 2020 was marketed through UF/IFAS Extension social media postings, the October 2020 issue of the Florida Cattleman's Magazine, and through 2 UF/IFAS Extension educational events. With limited responses, 5 UF/IFAS County extension agents assisted with soliciting producer involvement in the survey. Survey distributions were completed in October 2021. A total of 33 surveys were returned through Qualtrics or by mail and compiled. Generalized regions of completed surveys were from northwest, northeast, and south Florida (Figure 1).

Statistical analysis was performed by the University of Florida Statistical Consulting Unit. A one-way ANOVA was used to test for differences among responses. A post hoc ANOM was used to compare individual choice means against the overall mean across all responses.

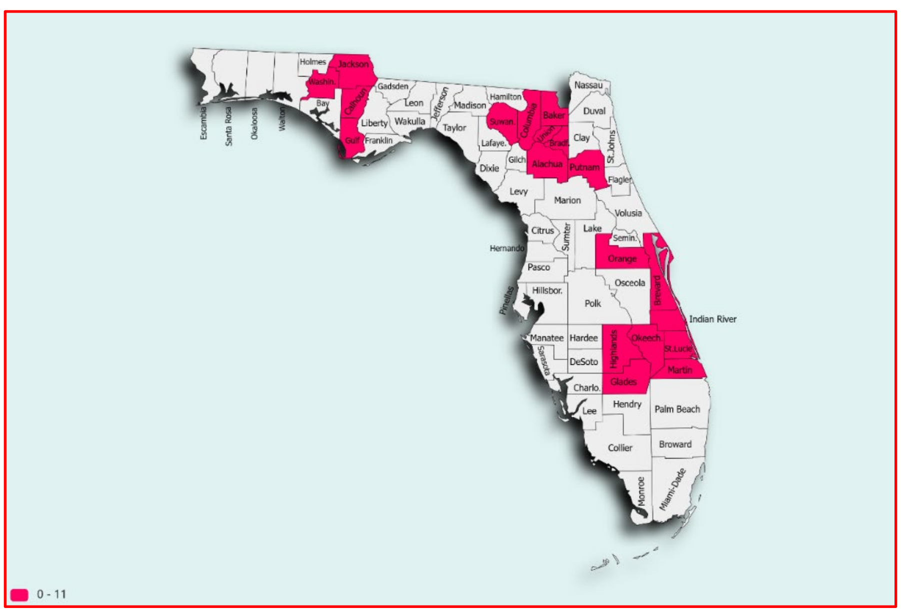

Figure 1: Florida counties where surveys were collected between 2019 and 2021 (highlighted in red).

Results

Factors that impacted a producer’s enterprise over the last 3 year*s*

The following addressed stressors or factors that may had impacted a producer’s pasture during the previous 3 years or roughly 2017 through 2020 (Figure 2). In general, these factors represented the following areas of interest:1) environmental stresses, such as excessive rainfall/excessive drought, 2) lack of variety options, lack of proper equipment, or lack of understanding forage IPM, 3) forage management concerns, such as poor establishment, poor weed management, grazing/forage needs, and 4) soil health concerns, such as soil pH and fertility, and soil health comprehension.

Weed pressure was the only factor that respondents found to be a greater concern (nearly frequent) compared to the mean (sometimes) as it relates to negatively impacting producers’ enterprises over the last 3 years. Even so, management and herbicide options were less of a perceived impact. The need to address weeds is consistent with other producer-driven surveys that have been conducted. In the Reeve et al. (2000) survey, 78% of producers in the Wagga Wagga region of Australia reported concerns over weeds being a major factor in maintaining a healthy pasture. It is interesting to note that there were few ‘Never’ responses to the impact list, Weather related excessive rainfall trended higher than most all other impacts, while lack of information on soil fertility or health management trended below the mean (less perceived issue by producers). Interestingly, drought impact response also fell below the mean rating. More explicit forage species information, such as forage species options/availability or understanding forage IPM/scouting did not appear to be a concern to most respondents.

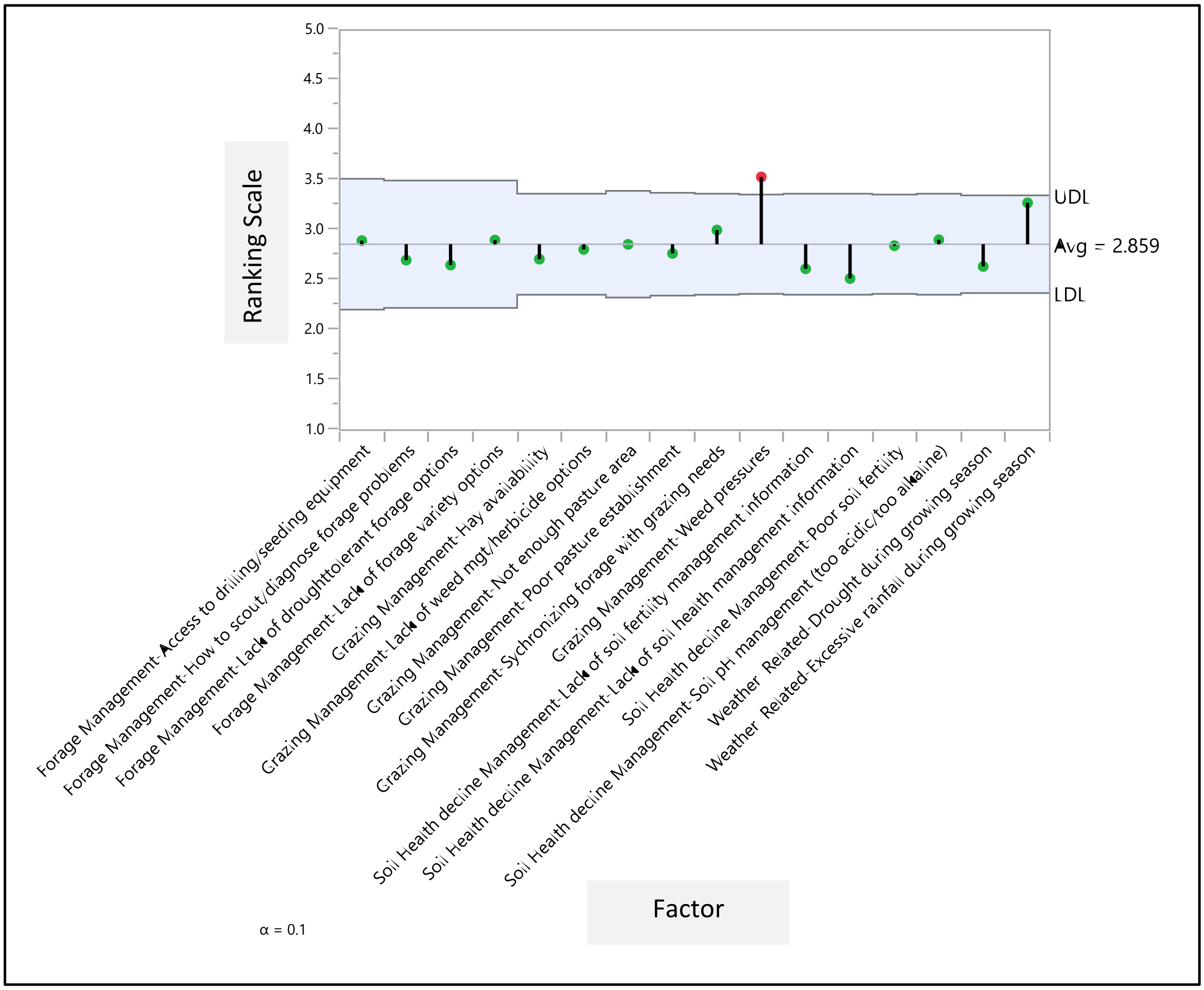

Figure 2: Factors that have negatively impacted producer enterprises within the last 3 years. The y-axis = producer assessed frequency of impact by individual factors (x-axis) from 1 to 5, with 1=Never, 2=Infrequently, 3=Sometimes, 4=Often, and 5=Nearly always. Group mean= 2.859, with green and red symbols indicating individual factor means. Green symbols are within the upper and lower 90% confidence limits and red symbols are outside the upper and lower limits.

<u>Pasture related management practices routinely used by producers</u>

The following addressed pasture management practices applied to producer fields (Figure 3). The responses were rated statistically similar to one another (none were used more or less than another) in terms of frequency, with the mean value landing at “Infrequently applied”. However, based on responses, a few producers utilized soil sampling every 3 years as a practice to gauge soil fertility needs. Interestingly, routine fertilization based on those recommendations landed below “Infrequently”, approaching “Never”. Other practices including livestock rotation, stocking rates, and use of cool-season forages ranked poorly, as well.

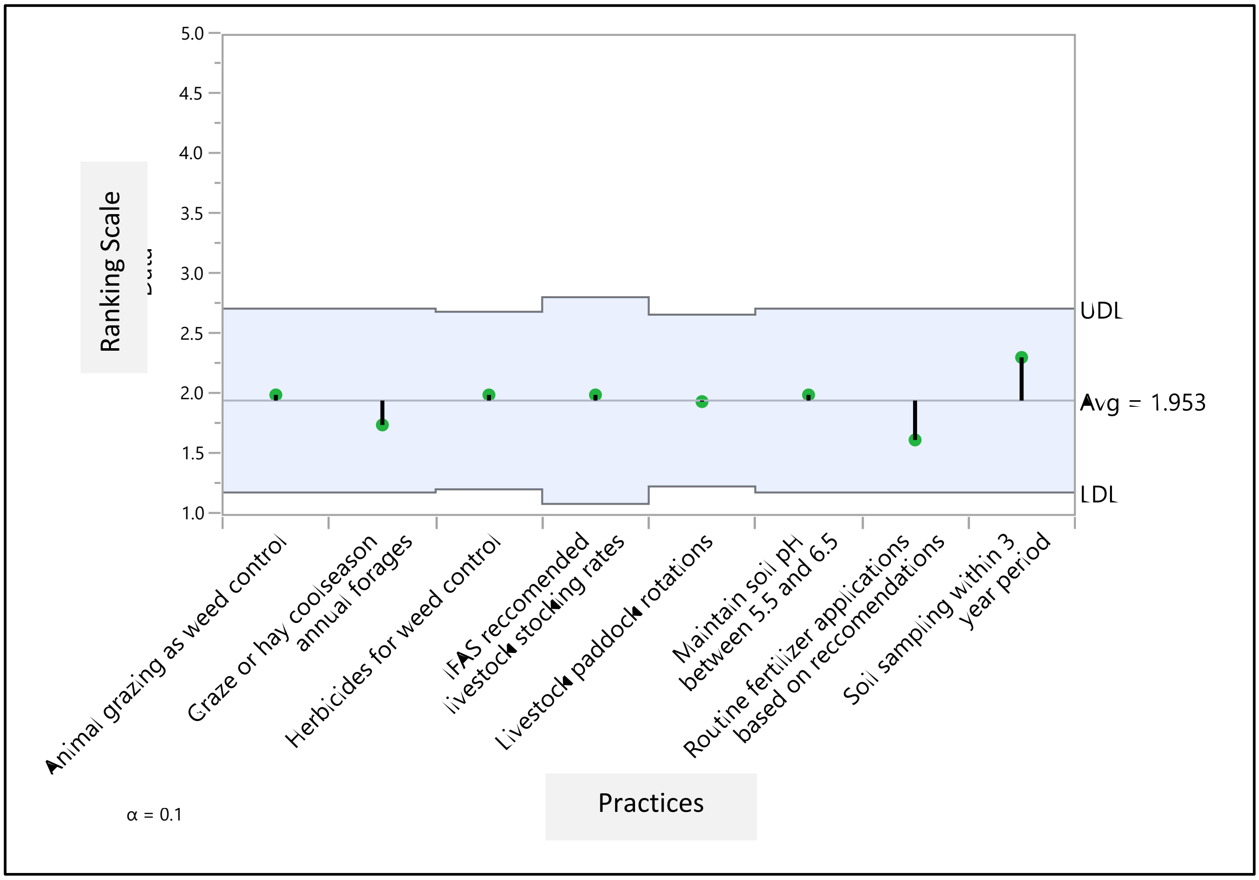

Figure 3: Common pasture management practices implemented by producers. The y-axis = frequency of producer self-reported implementation of a given practice (x-axis) from 1 to 5, with 1=Never, 2=Infrequently, 3=Sometimes, 4=Often, and 5=Nearly always. Group mean= 1.953, with green symbols indicating individual practice means. Green symbols are within the upper and lower 90% confidence limits. Only 22 of the 33 respondents responded to this question.

Factors that producers feel are important to their pasture health

This question asked producers to rate different factors that were important to the health of their own pastures. Based on the results, the mean value landed between moderately to highly important (Figure 4). Those practices that were significantly more important compared to the mean ranking were soil sampling, the application of commercial fertilizers, using grazing/mowing as a weed control method, and using livestock recommended stocking rates.

Significantly less important (somewhat important ranking) were reseeding weakened areas by drill or using soil conditioners/supplements to support soil microbes. Interestingly, overseeding with cool-season forages and incorporating warm-season legumes trended below the mean ranking, as well.

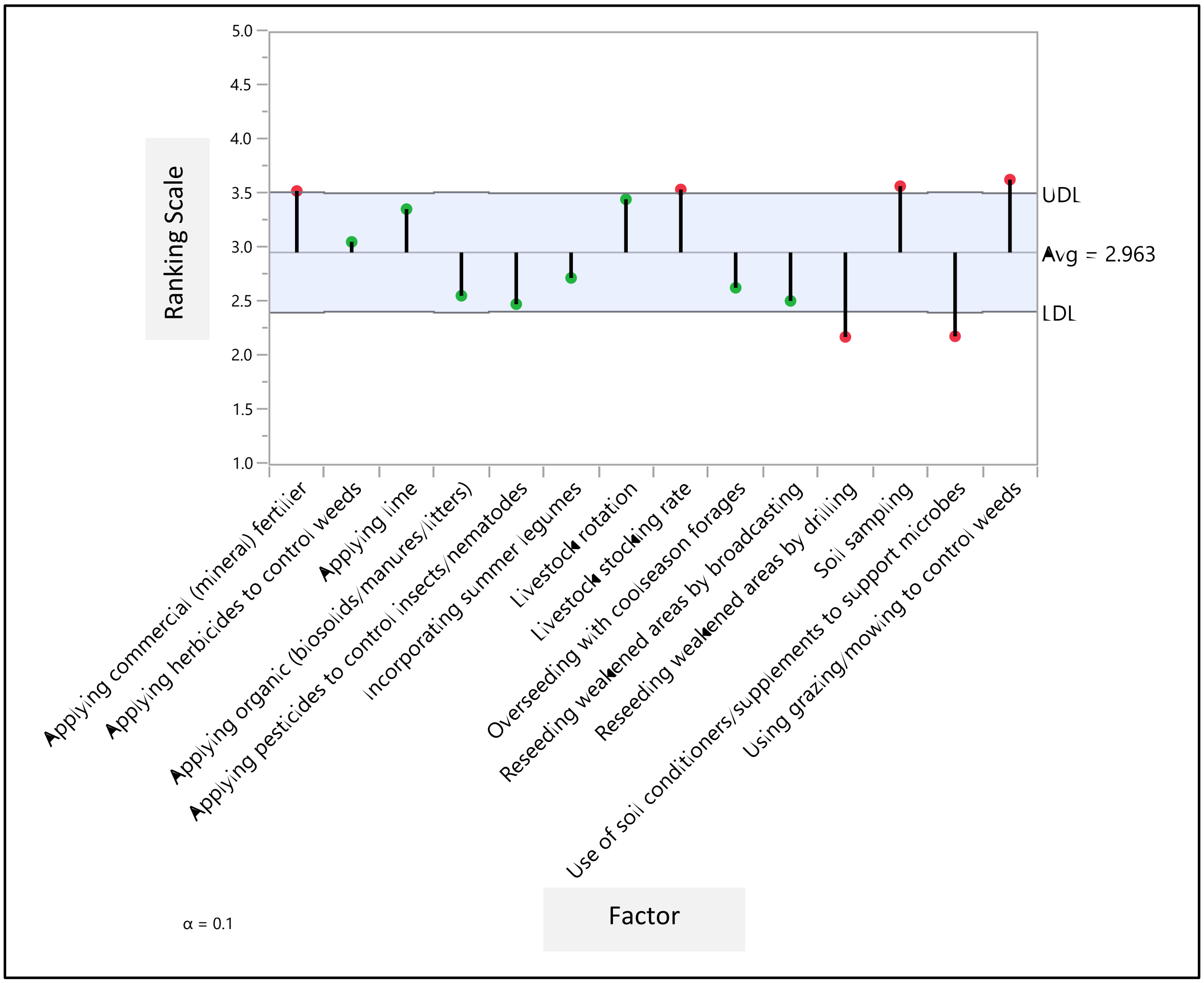

Figure 4: Management practices that producers selected as being important to maintaining their own pasture health. The y-axis = represents degree of importance of the listed practices (x-axis) from 1 to 5, with 1=Not important, 2=Somewhat, 3=Moderately, 4=Highly, and 5=Critical. Average group mean= 2.963, with green and red symbols indicating individual factor means. Green symbols are within the upper and lower 90% confidence limits and red symbols are outside the upper and lower limits.

Cases of pasture decline

This section of the survey focused specifically on producers' experiences with pasture decline. Producers were provided a definition of pasture decline: *"A continual reduction in the forage stand density and performance from year to year that is not easily explained by management practices or weather alone".* They were then asked a Yes/No question if they had experienced pasture decline on their property within the last 5 years. A total of 30 producers responded with 43% (n=13) indicating Yes and 57% (n=17) indicating No. Next, producers who indicated they had experienced a case of pasture decline were asked what tools/practices were used to try to correct the pasture decline (Figure 5).

It is noteworthy that the use of soil sampling and reducing grazing pressures trended above the mean ranking (between Infrequently to Sometimes). In comparison, the use of disease diagnostics or leaf tissue analysis were rated below the mean ranking for addressing pasture decline. Regardless, the application of any of the listed choices was relatively low. In terms of where producer go to get help with addressing the decline, there seemed to be little difference between obtaining guidance from a professional consultant, chemical/fertilizer suppliers, or university/extension specialists, which also trended towards 'Infrequently' on the scale.

Pasture-related topics that UF/IFAS faculty should focus on

This section was an open-ended question on what topics producers thought UF/IFAS faculty should focus on in terms of pasture management. While responses were open-ended, they were categorized into major topic areas of weed management, fertility management and forage management (Table 1). Lastly, producers who answered yes to experiencing pasture decline were also asked if they were able to solve their case of pasture decline. Of the 13 respondents who stated they had experienced pasture decline, only 3 indicated that they likely corrected the problem.

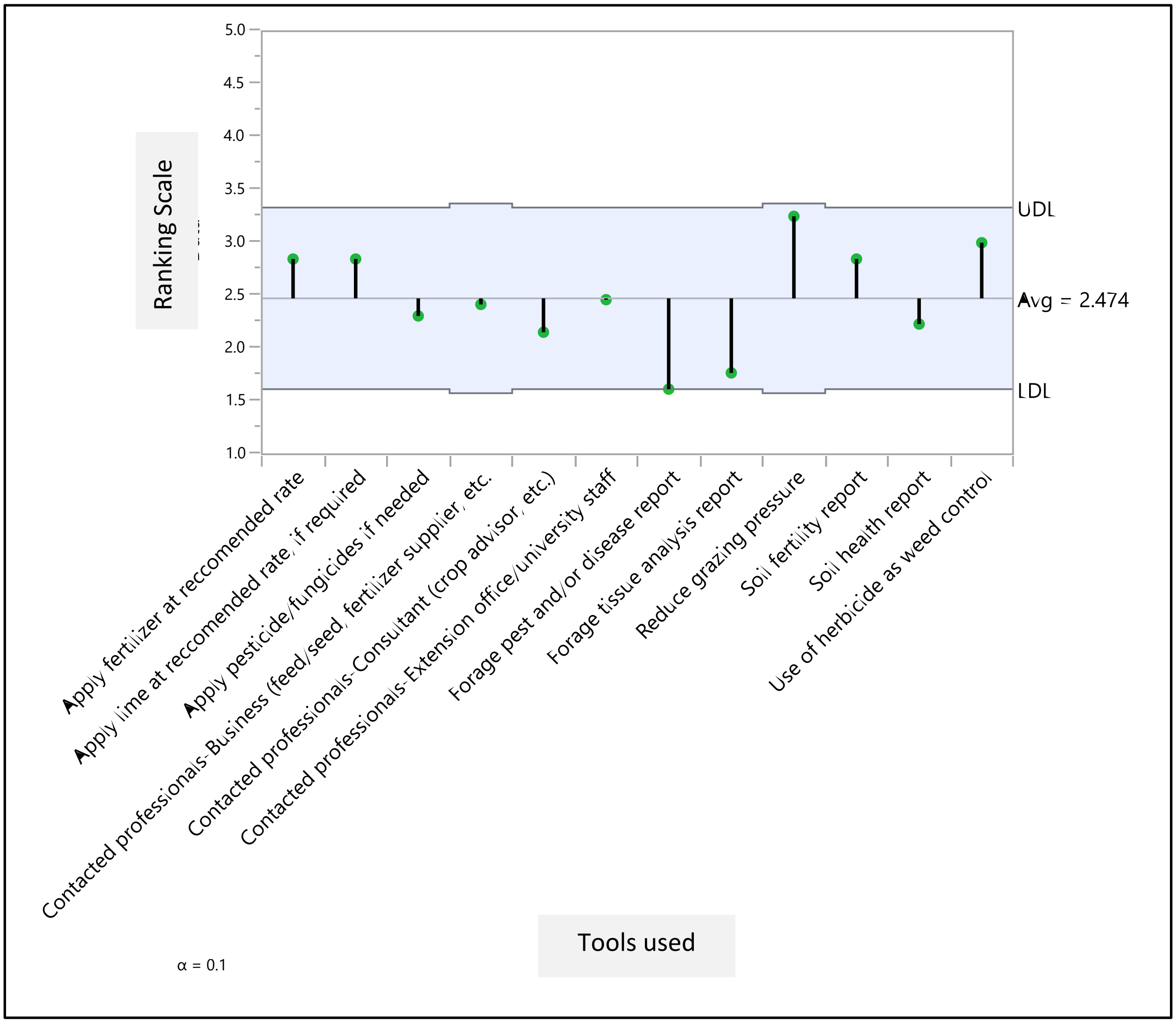

Figure 5: Tools used to address cases of pasture decline in a producer's own field. The y-axis = ranking scale of producer frequency of use of listed practices (x-axis) from 1 to 5, with 1=Never, 2=Infrequently, 3=Sometimes, 4=Often, and 5=Always. The group mean= 2.474, with green symbols indicating individual practice means. Green symbols are within the upper and lower 90% confidence limits.

<u>*Pasture-related topics that producers needed additional training/guidance on*</u>

Producers were asked what pasture-related topics they needed additional training or guidance on. This question was open-ended and summarized into the following major topic areas of weed management, fertility management, and forage management and responses were fairly equally distributed across the three areas (Table 2).

Table 1: Topics UF/IFAS faculty should focus on.

Major Category	Number of Responses	Specific topics
Weed Management	15	General weed control, centipedegrass control, broomsedge control, bahia pasture specific weed control, non-herbicide weed control options
Fertility Management	5	General fertilizer recommendations, pH management
Forage Management	9	Cool season forages and winter grazing, equine grazing management, forage selection and establishment, regenerative agricultural practices, and BMP management

Table 2: Pasture-related topics producers need additional training/guidance on.

Major Category	Number of Responses	Specific topics
Weed Management	7	General weed control, centipedegrass control, invasive weed control, herbicide recommendations
Fertility Management	7	General fertilizer recommendations, pH management, soil improvement, soil testing
Grazing Management	10	Cool season forages and winter grazing, equine grazing management, forage selection and establishment, regenerative agricultural practices, and BMP management

Discussion

With the main objectives of the survey in mind: 1) gather producer perceptions on pasture health and decline and 2) assess producer needs for current and future research and extension education, certain general themes became apparent. Results of this survey suggest that weed management is a major factor that producers reported impacts their enterprises, which also corresponds with the results of Reeeve et al. (2000) survey. However, herbicide use as weed control was not a practice often implemented by producers to reduce weed impacts. Possible explanations might include: 1) producers decided that mowing as a means of weed control was more effective than incurring the higher upfront cost of purchasing herbicides. 2) producers may have decided to live with the problem as it was, 3) the socioecological perceptions of pesticides having a negative impact on the environment/soil may have prevented application of herbicide for weed control. Whatever the reasoning, this is an interesting dilemma, and more information is needed to understand the divide. In relation to pasture decline cases, 43% of respondents stated they experienced cases of pasture decline in the last 5 years but with only 23% of those cases being corrected. Producers mainly used the tactic of reducing grazing pressure, as well as the use of fertilizer, lime, and herbicides to minimize the impact of the decline. What is interesting is that few producers utilized professional services to identify and correct these issues. It might be possible that producers did consult other sources not listed on the survey, including another farmer/rancher, or family members but this is unclear.

In terms of assessing current and future needs, producers viewed weed control in pastures a high priority that UF/IFAS faculty should be addressing. Grazing management, including winter grazing options, forage selection, and regenerative practices were secondary priorities, with fertility management falling below the average rating. Interestingly, even though most producers noted that weed management should be a priority for research and extension faculty to focus on, they did not respond strongly that they needed further training on this topic. However, producers reported more strongly that they needed additional guidance on grazing management practices.

Conclusions

Based on this survey there seems to be opposing perspectives as to what is pasture decline and practices to address it. As expected, pasture decline appears to be multi-faceted and will require further study on factors that contribute to it. Further surveying may be helpful in developing a clearer picture of potential pasture decline factors, such as pests and diseases in terms of them being primary causes or secondary effects in the southeast U.S. There seems to be a disconnect regarding occurrence versus impacts of weeds on pasture health. Weed invasion is a frequent issue in pastures and hayfields, as identified by producers, but other issues such as diseases are not as easily identified and often require additional resources, such as diagnostic labs, that producers may not be willing to utilize.

Chapter 3

Bahiagrass and bermudagrass health trends: utilizing diagnostic records

Grass diseases are not uncommon but the impact of disease and pest pressures on forage grasses as potential links to pasture decline are typically not considered. Typical diseases in the Southeast U.S. include both, leaf spot and root rot types and the degree of damage can vary by forage species and even cultivar. For example, Blount et al. (2002) reported that cases of Dollar Spot fungus (*Sclerotinia homoeocarpa* F.T.Benn) affected cultivars of bahiagrass to different degrees, with Argentine bahiagrass being less susceptible to Dollar Spot compared to Pensacola or Tifton-9 cultivars. However, based on producer responses from the survey in Chapter 2, diseases or other pest pressures are not indicated as major concern with their own production systems.

The purpose of this study was to better understand potential trends in warm-season perennial grass health based on forage sample submissions to plant diagnostic laboratories across the region. The objectives of this study were: 1) Data mine plant diagnostic labs for berumdagrass and bahiagrass sample submissions and their diagnoses, 2) Organize data under categories related to diagnostics, and 3) identify trends among and across categories that are also potentially detrimental to pasture health.

Materials and Methods

Data for this assessment was supplied by the National Plant Diagnostic Network (NPDN) database, through the UF Plant Diagnostic Center at the University of Florida, Gainesville, Florida. Two datasets were compiled: one representing bermudagrass and the other representing bahiagrass. Both sets included all diagnosed samples sent to southern United States plant diagnostic labs within the organization network, from 2005-2020. These data represent AL, FL, GA, LA, MS, SC, and TX. The bermudagrass data set contained 59,380 diagnostic cases, while the bahiagrass set contained 485 diagnostic cases. All were sorted across seven categories: abiotic, algae, bacteria, diseases, insects, nematodes, and undetermined. It should be noted that submitted grass samples were not designated by their use, such as forage or pasture samples. Therefore, many samples (and likely the vast majority of bermudagrass samples), originated from a combination of residential turf, athletic, golf course, and sod production farms, as well as pastures and hay fields. Therefore, the following information is considered solely as a tool to understand potential trends in bermudagrass and bahiagrass health, rather than results that have direct connection to pasture or hay systems.

The categories representing Algae and Bacteria had relatively low numbers of cases and will not be discussed further. The Undetermined category will not be included in the "Likely Causes" discussion, since cause was unknown. Statistical analysis was conducted by the University of Florida Statistical Consulting Unit. The data were analyzed with Clopper-Pearson exact 95% binomial confidence intervals using R (version 4.2.1) to better understand potential trends within and across categories.

Results

The regional sample submission data (Figure 6), shows that there was a major increase in diagnostic submissions for both species of warm-season perennial grasses. The large increase in sample submissions over time might suggest an increase in spatial and temporal distribution of pest and diseases or perhaps more facilities became available to receive samples. Another possibility is an increase awareness of these facilities. Increased research and education on specific pests and diseases and increased marketing of diagnostic services probably had some impact on this trend, but it is likely not the only factor.

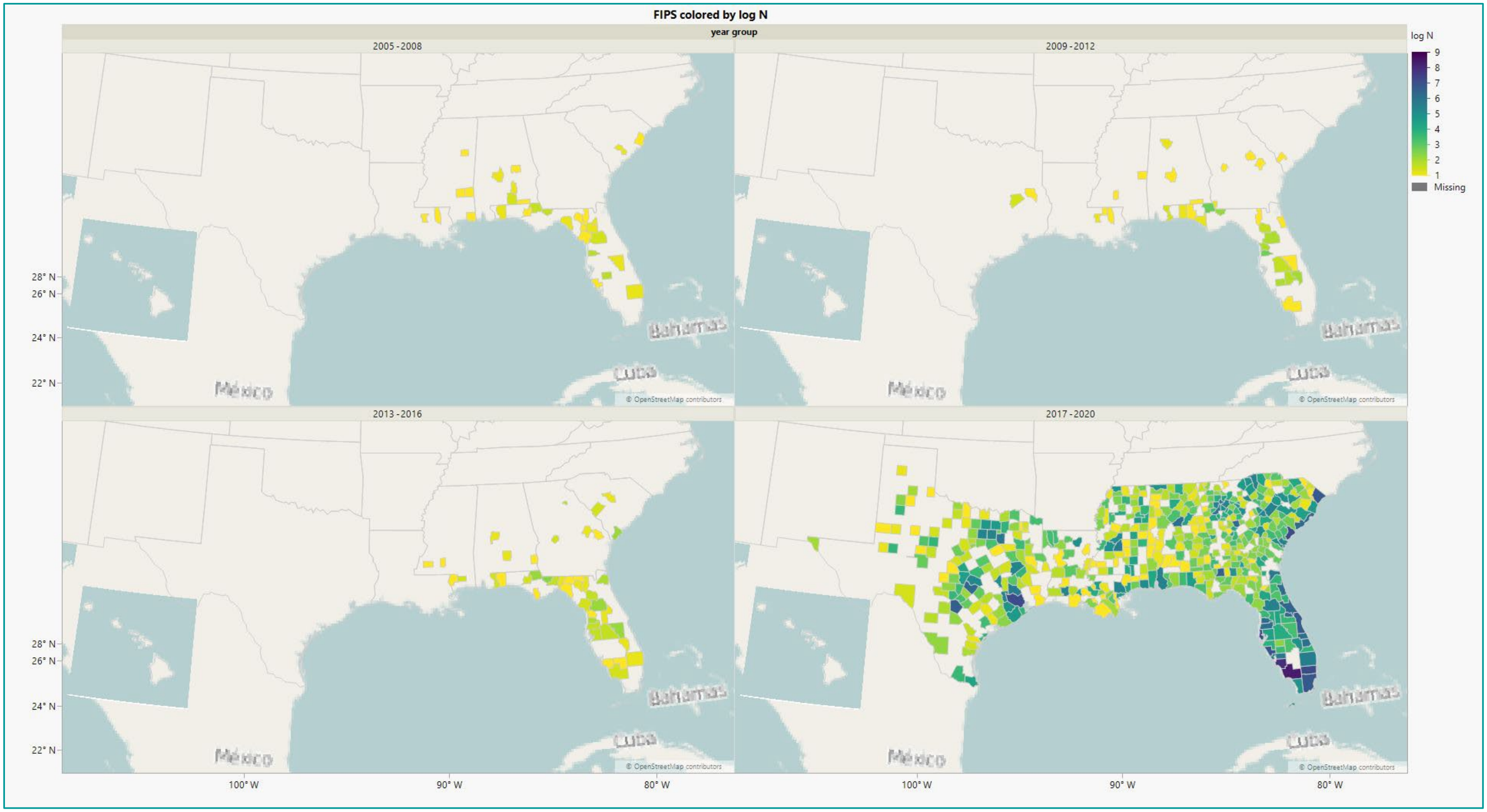

Figure 6: Sample submission locations by state and county across Southeast United States from 2005 through 2008, 2009-2021, 2013-2016, and 2017-2020. Shading indicates number of submissions for that time bracket, increasing in total number of submissions from yellow shade to purple shade.

Bahiagrass and bermudagrass category comparisons were addressed separately (Figure 7). The majority of bahiagrass samples had diseases associated with them, while about a third were categorized as 'Undetermined'. In comparison, nearly three quarters of bermudagrass samples were associated with nematodes and less than 25% were associated with diseases (Fig. 7).

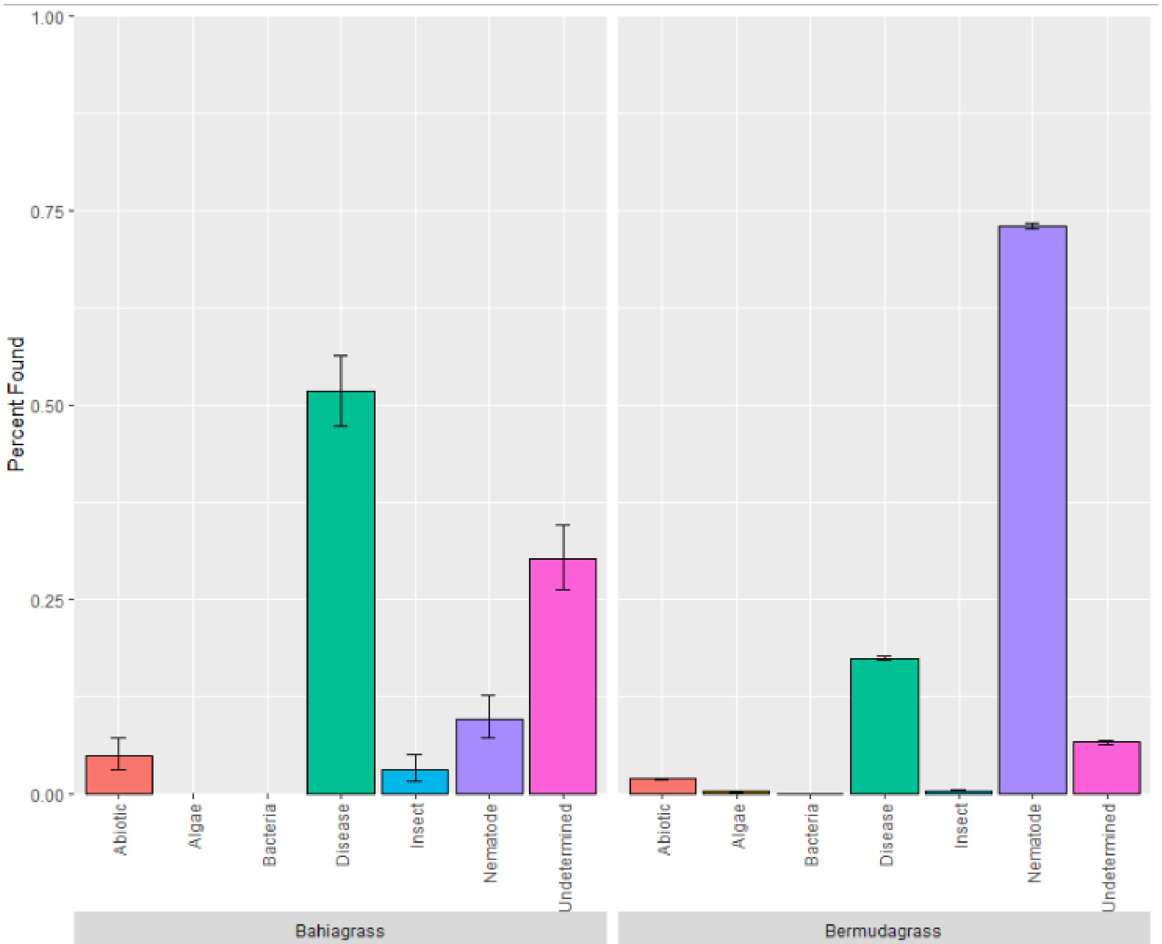

Figure 7: Bahiagrass and Bermudagrass diagnostic categories. y-axis = percent of the categories found within the total diagnostic cases within bahiagrass and bermudagrass datasets, 0.0 = 0% and 1.00 = 100%. x-axis = listed categories of diagnostic cases of abiotic, algae, bacteria, fungal diseases, insects, nematodes, and undetermined. Error bars indicate the 95% exact confidence intervals.

<u>*Bermudagrass*</u>

Samples from the 'Likely Cause' under the 'Abiotic' category included Abiotic, Black layer, Drought, Fertility, Homoptera, Shade, Thatch, Unknown, Weeds, and Wet soil (Figure 7). Due to lack of diagnostic success, many samples were simply identified as an abiotic issue and the cause of the abiotic stressor was not determined. These samples more fittingly should be placed under the 'Unknown' label. However, among the remaining causes, fertility issues dominated these samples.

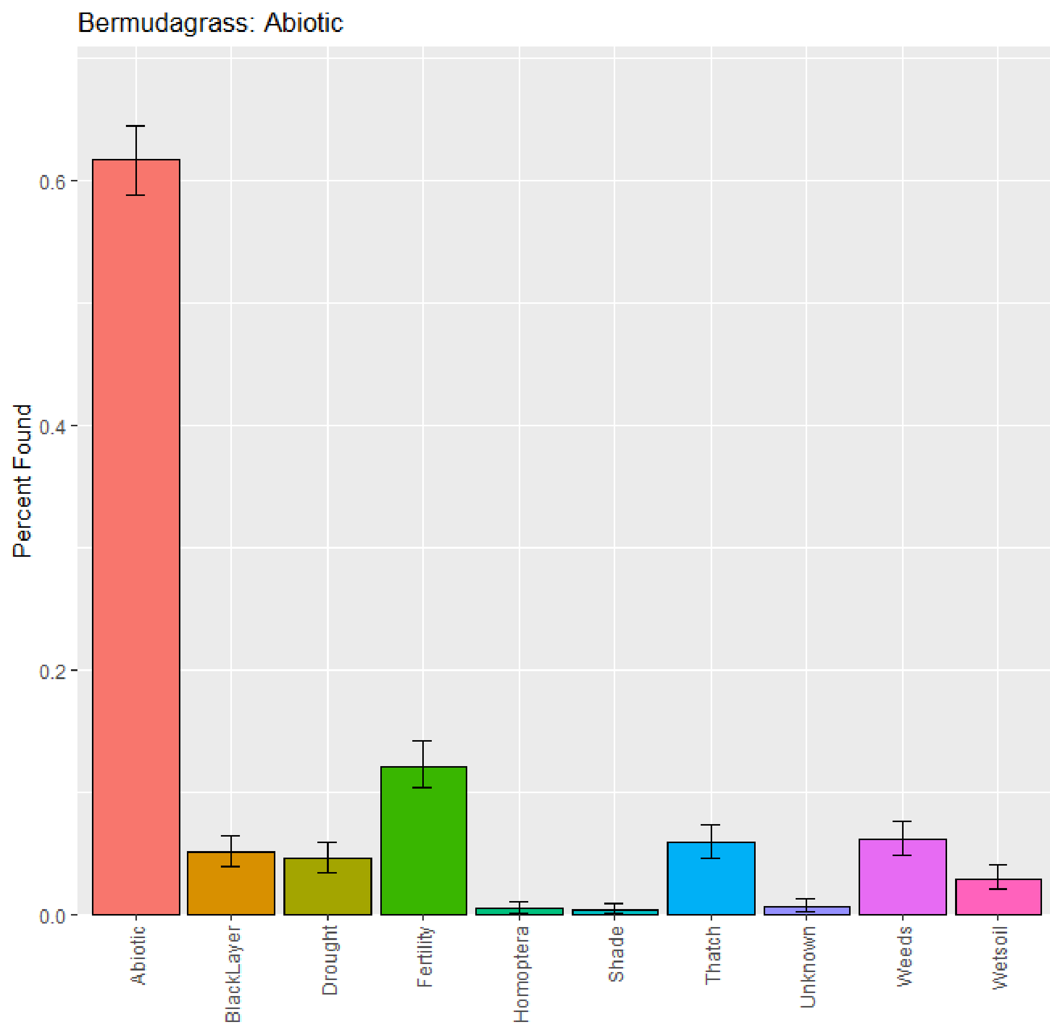

Figure 8: Abiotic cases of bermudagrass sample. y-axis = percent of the categories found within the total bermudagrass diagnostic cases identified as abiotic causes, with 0.0 = 0% and 0.6 = 60%. x-axis = listed categories of abiotic causes of diagnostic cases. Error bars indicate the 95% exact confidence intervals.

Samples within the 'Insect' category for bermudagrass were separated into 30 different species categories (Figure 9). By far, most samples with insect diagnoses were those of the *Odonaspis* *ruthae*, bermudagrass scale, followed by *Antonina graminis*, Rhodes grass scale, and *Eriophyes cynodoniensis*, Bermudagrass mite. These insects have either piercing-sucking mouthparts or chewing mouth parts that can stunt and stress grasses. Other lesser insect diagnoses included *Blissus* (chinch bugs) and army worms, which are both familiar insect pests of bermudagrass.

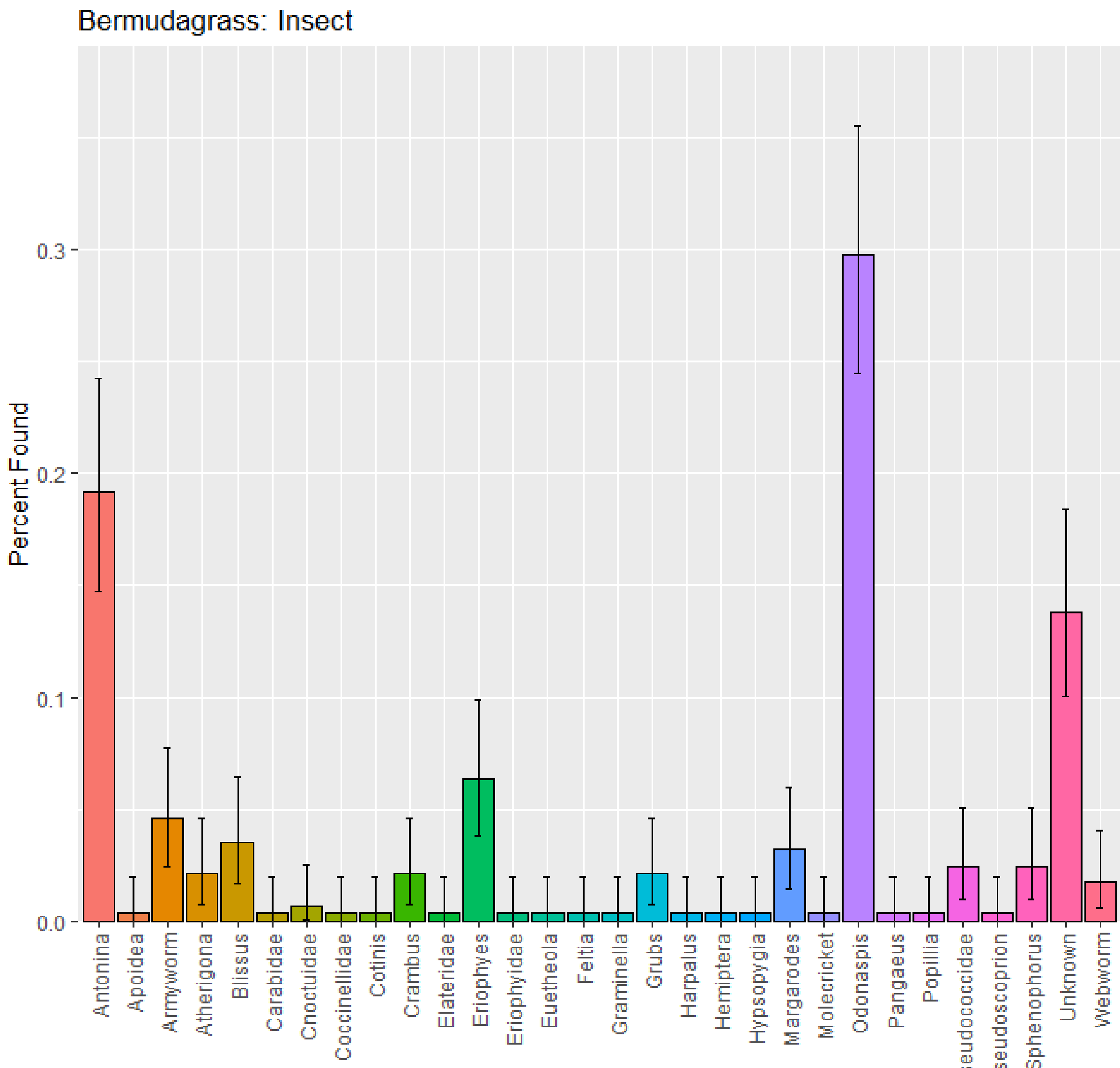

Figure 9: Bermudagrass Insect cases with. y-axis = percent (0 to 0.4 = 0 to 40%) of the categories identified within the total cases identified as insect causes. Error bars represent 95% confidence intervals.

Nematode samples were by far, the majority of identified cases from the entire bermudagrass set. Over 70% of the samples listed nematode as the causal agent. The following two species of nematode *Hoplolaimus sp./spp*. (Lance nematode) and *Mesocriconema sp./spp*. (Ring nematode) were the most common 'Likely Cause' (Figure 10), with *Meloidogyne sp./spp*. (Root knot nematode) and *Belonolaimus sp./spp*. (Sting nematode) representing a similar proportion of samples.

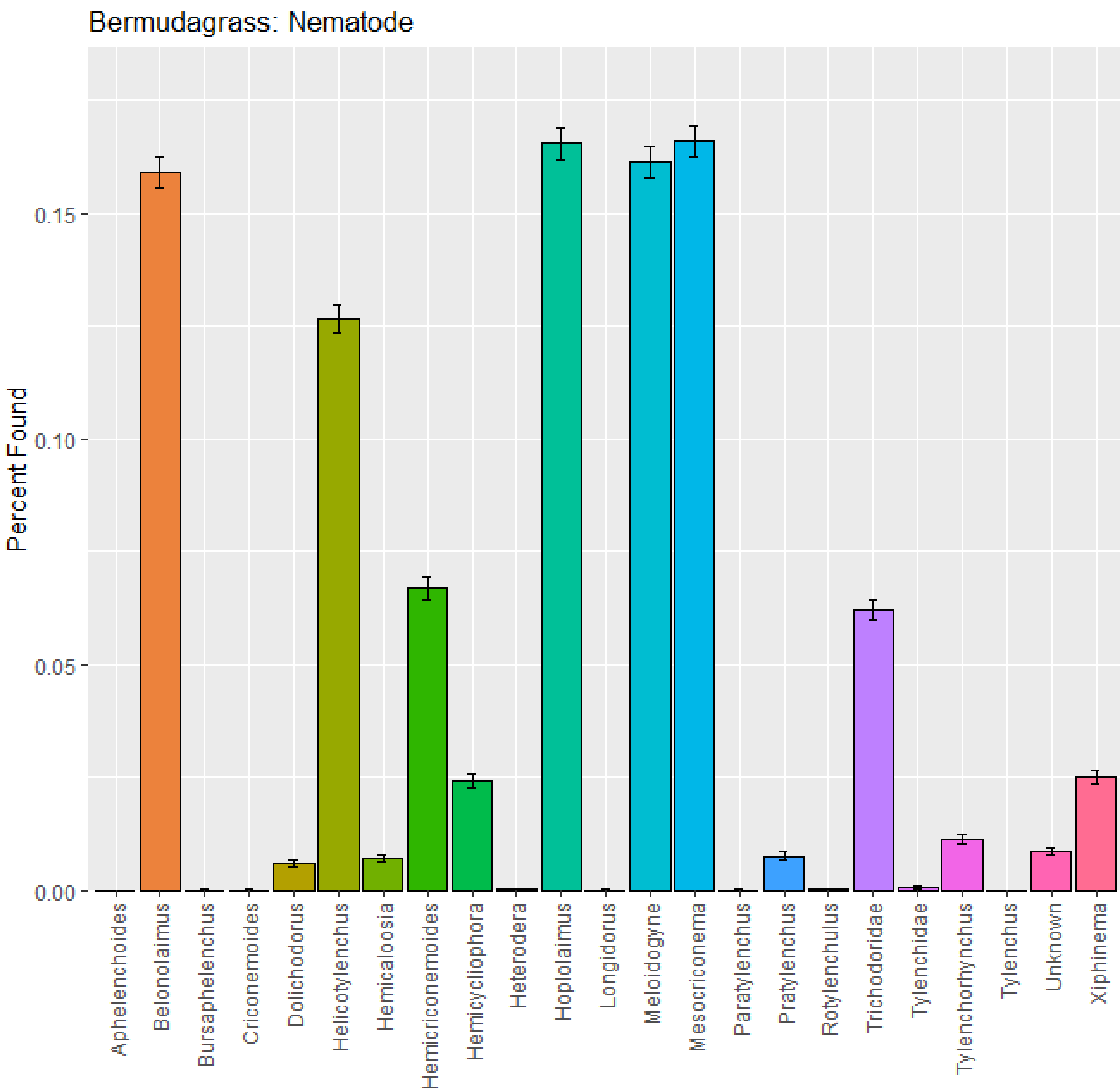

Figure 10: Bermudagrass Nematode cases, with. y-axis = percent (0 to 0.16 = 0 to 16%) of the categories identified within the total cases identified as Nematode causes. Error bars represent 95% confidence intervals.

Over 40 different fungal diseases were identified in the bermudagrass data set, which also represented the second largest category, next to nematodes (Figure 11). *Pythium* sp./spp. was identified most often, followed by *Gaeumannomyces graminis var. graminis,* or Take-All Root Rot (TARR). *Bipolaris cynodontis* and *Rhizoctonia zeae* diseases occurred less frequently. It should be noted that the two fungal diseases that were identified most often, pythium and TARR, both affect the root systems of grasses.

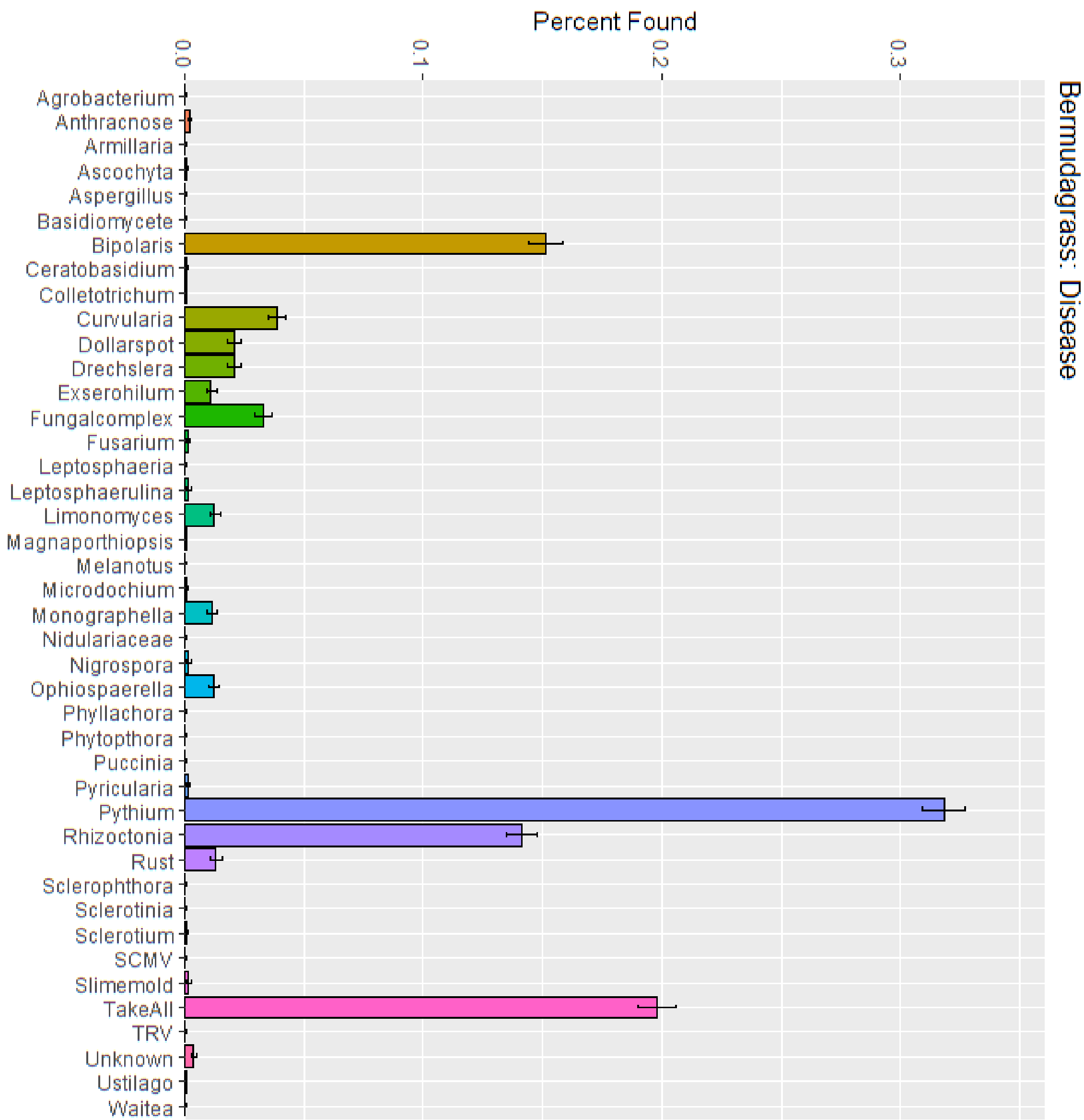

Figure 11: Bermudagrass Disease cases, with. x-axis = percent (0 to 0.35 = 0 to 35%) of the categories identified within the total cases identified as Disease causes. Error bars represent 95% confidence intervals.

Bahiagrass

This was a much smaller number of cases compared to bermudagrass. However, as bermudagrass is more commonly used in turf systems, including golf courses and athletic fields, this was not unexpected. Likely abiotic causes ranged from abiotic, drought, fertility, and non abiotic (NA) (Figure 12). Likely causes for those outside the abiotic category, fertility was proportionally similar to bermudagrass abiotic causes, and stands out as a concern for both grass species.

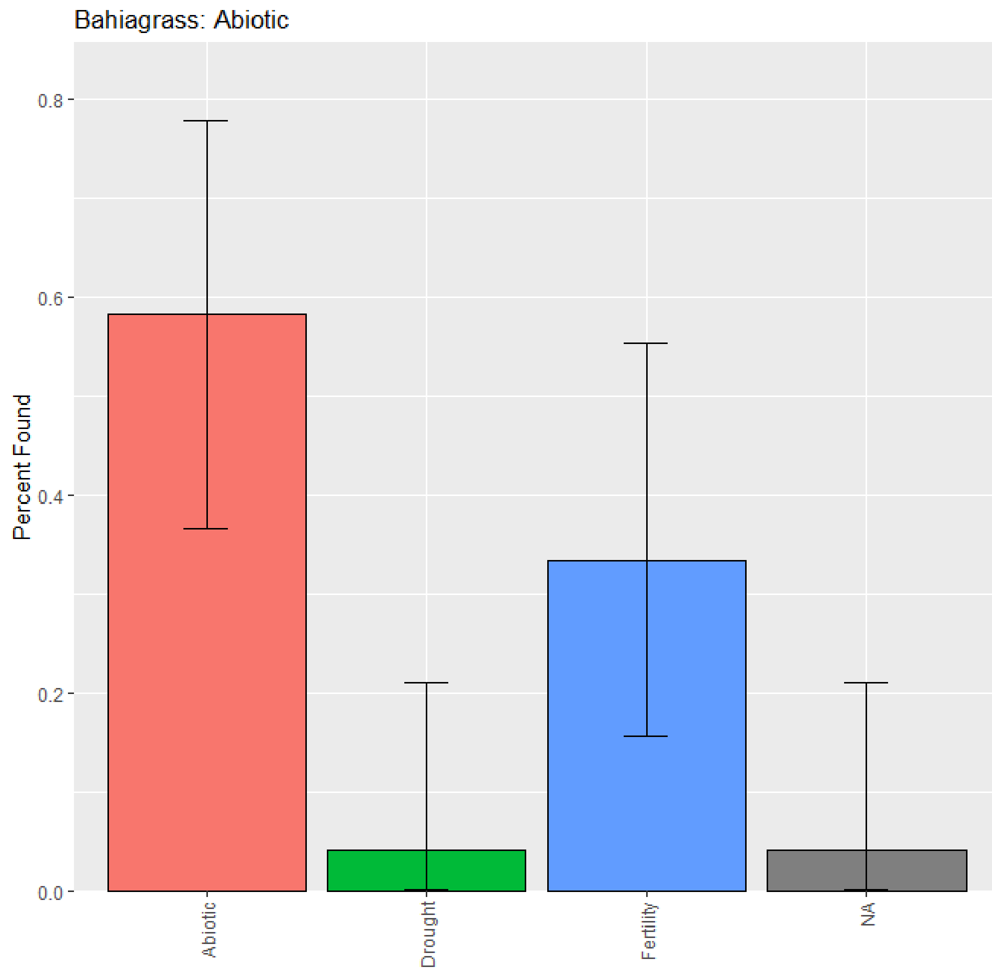

Figure 12: Bahiagrass Abiotic cases, with. y-axis = percent (0 to 0.8 = 0 to 80%) of the categories identified within the total cases identified as Abiotic causes. Error bars represent 95% confidence intervals.

Samples with insect diagnosis were seperated into the following cateogiries of Blissus, Cruptolestes, Grubs, Insect, June Bettles, Paracoccis, Phyllids, Pseudaletia, Scapteriscus, Scolidwaps, and Trionymus (Figure 13). As with abiotic causes, a general insect cateogory 'Insect' was often used to when the insect species could not be identified but its impact suggested insect damage.. The genus *Blissus*, commonly refered to as a chinch bug and *Pseudaletia*, commonly known as army worms, were the most prevelant pests reported for bahiagrass.

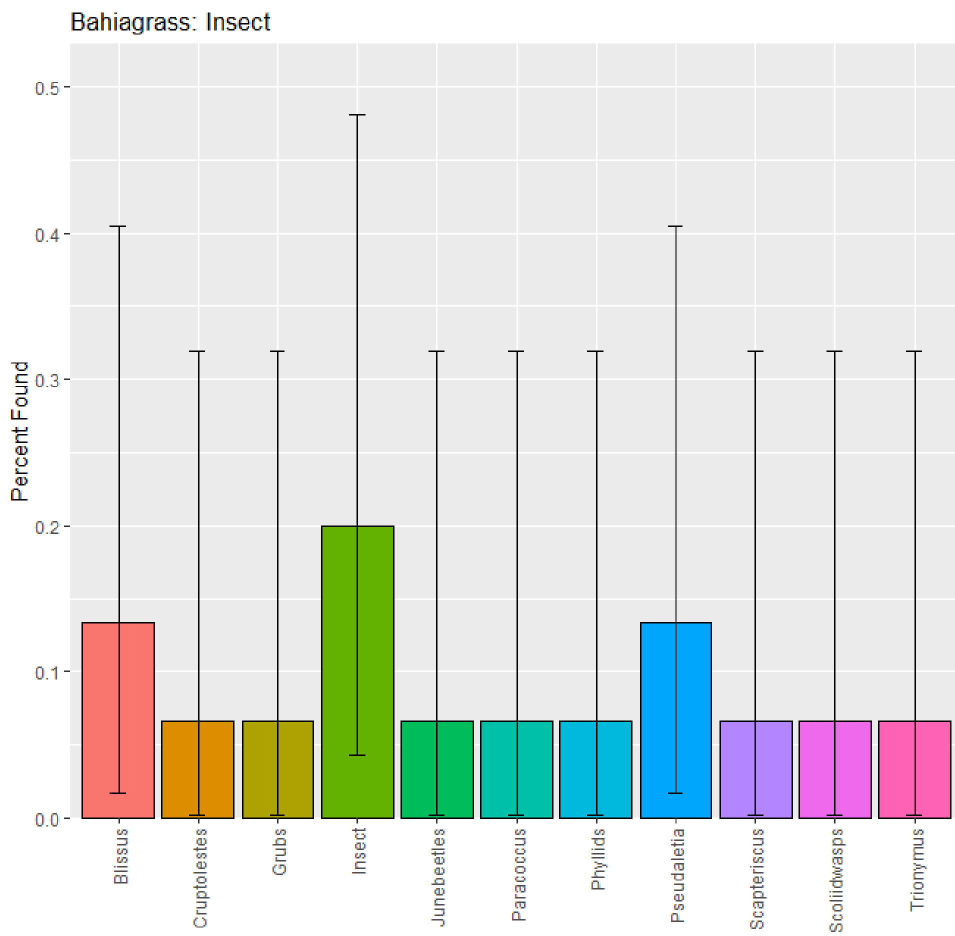

Figure 13: Bahiagrass Insect cases with. y-axis = percent (0 to 0.5 = 0 to 50%) of the categories identified within the total cases identified as insect causes. Error bars represent 95% confidence intervals.

Unlike bermudagrass, nematode submissions were not as prevalent in the bahiagrass samples, representing less than 10% of the total samples submitted (Figure 14). The following nematode species included *Mesocriconema sp./spp*. (Ring nematode), *Helicotylenchus sp./spp.* (Spiral nematode), and *Meloidogyne sp./spp*. (Root knot nematodeInterestingly, *Hoplolaimus sp./spp*. (Lance nematode), which was a major representative of nematode cases in bermudagrass, was less than 15% of the total identifiable nematode samples.

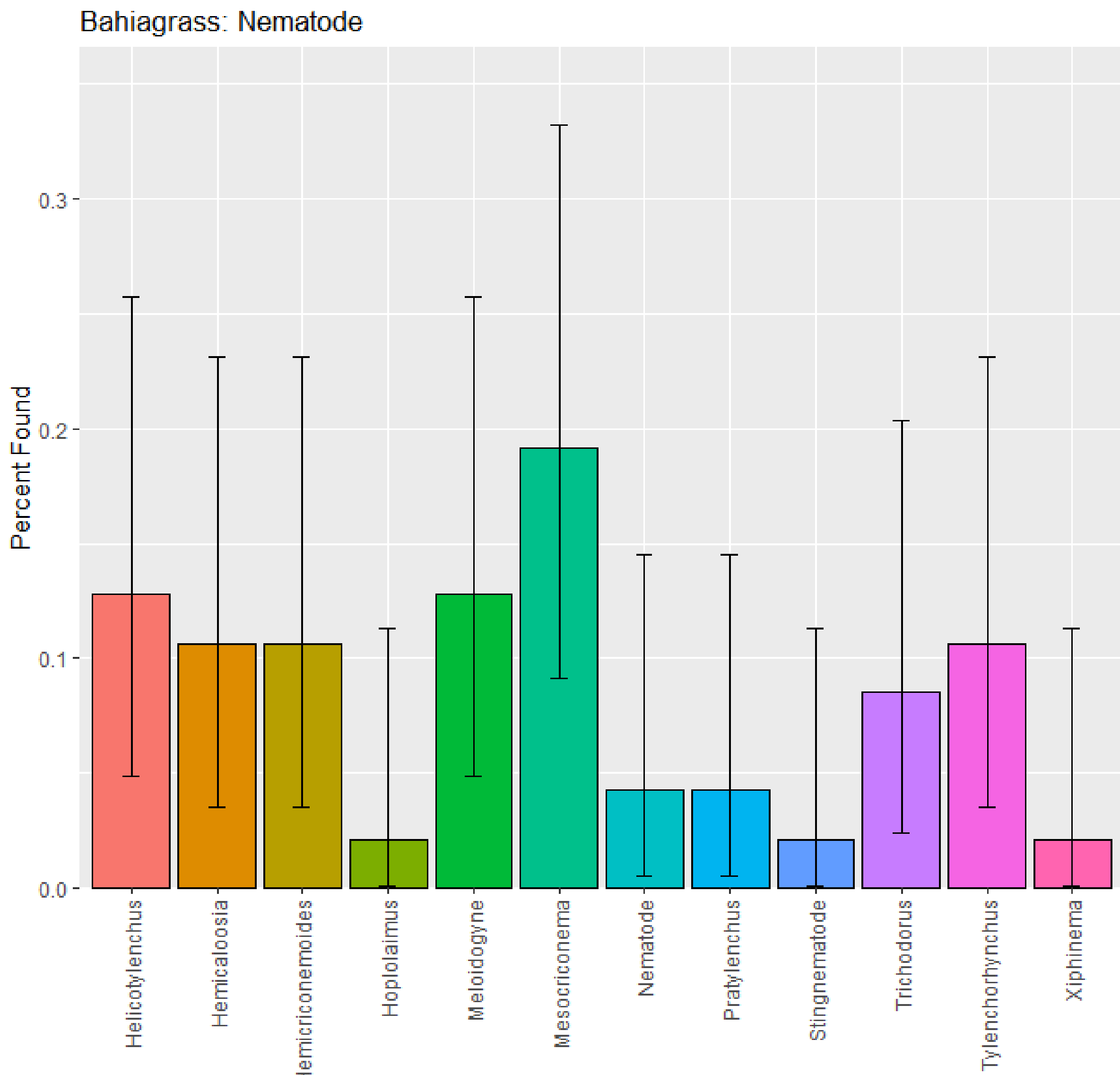

Figure 14: Bahiagrass Nematode cases, with. y-axis = percent (0 to 0.35 = 0 to 35%) of the categories identified within the total cases identified as Nematode causes. Error bars represent 95% confidence intervals.

Diseases consisted of over 50% of all bahiagrass samples, with 24 different diseases being identified as the likely cause (Figure 15). Of these, *Bipolaris cynodontis* was identified the most, followed by *Gaeumannomyces graminis var. graminis,* orTARR. and *Rhizoctonia zeae* diseases. While *Pythium* sp.spp. was a major factor in bermudagrass samples, it was much less prevalent in bahiagrass samples. Interestingly, Dollar Spot was not reported as often as Bipolaris.

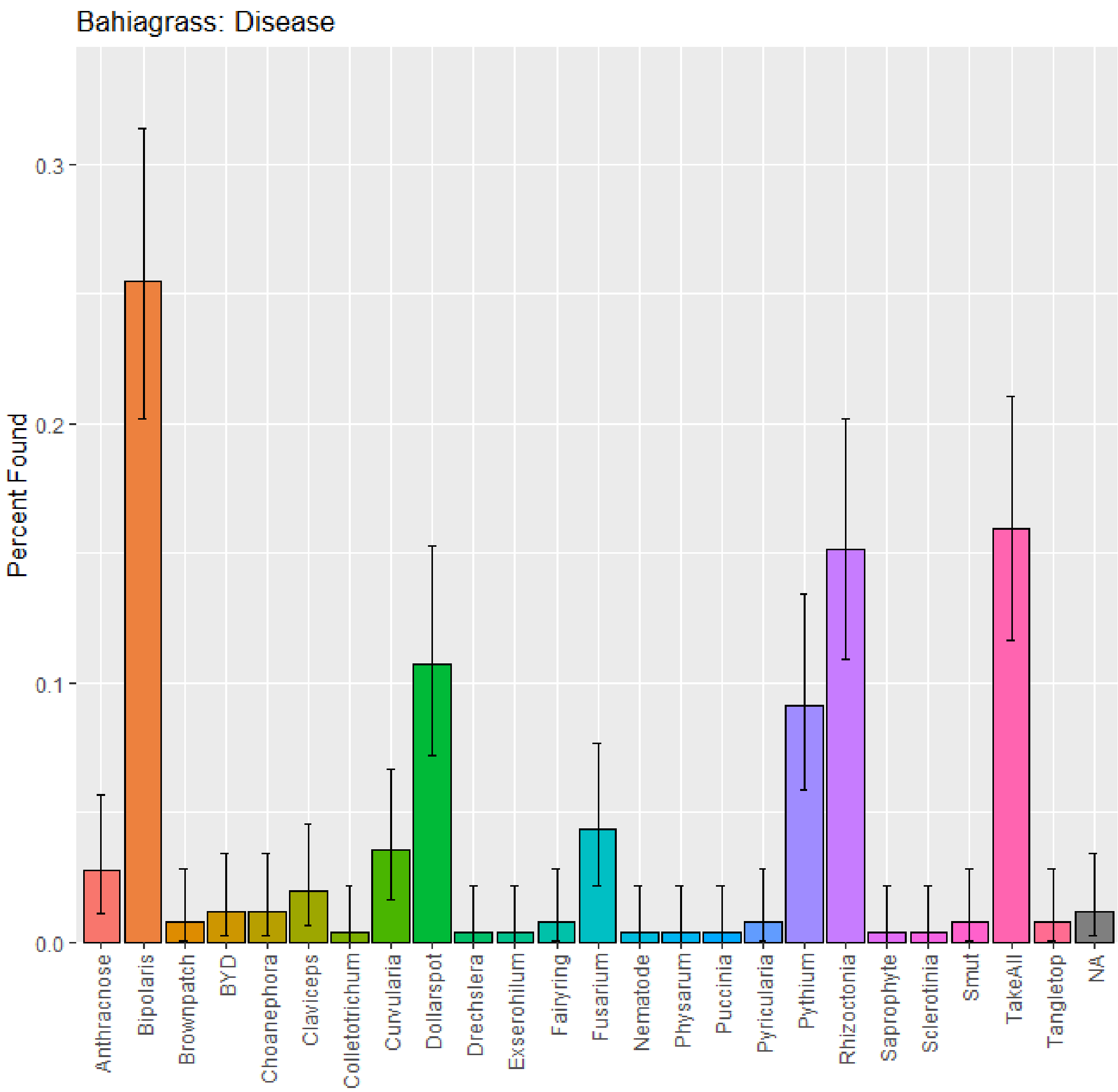

Figure 15: Bahiagrass Disease cases, with. y-axis = percent (0 to 0.35 = 0 to 35%) of the categories identified within the total cases identified as Disease causes. Error bars represent 95% confidence intervals.

Discussion

From a broad perspective, plant diagnostic services have increased from 2005 to 2020 (Figure 6). Based on the data provided, we cannot provide a reason for the increase, but possibilities include increases in turf damaging influences, such as fungal diseases, pests, and nematodes. With increasing human populations in the southern United States, and increasing land utilization for residential and commercial turf, more turf issues is to be expected. Another possibility might be increased awareness of diagnostic lab services through education and interaction with state and county extension specialists.

Based on the number of diagnostic samples submitted and identified (Figure 7), fungal disease influences affected bahiagrass samples more then abiotic, insect, or nematode influences, indicating that fungal disease may have a greater impact on pasture health and perhaps decline than producers realize. Likewise, bermudagrass results suggest that nematodes were by far the largest occurrence in diagnostic submissions. While a majority of the bermudagrass samples may not have been submitted from pastures or hay fields, differences between pasture systems and other turf systems are likely not too different, as the same species and often cultivars are used. Further study regarding nematode interactions with pasture systems was an unexpected results and may require further inquiry.

Conclusions

Fungal disease issues were more prevalent in bahiagrasses then other factors, such as abiotic issues or other pest issues. Specifically, root-related fungal diseases, such as Pythium and Take-All root rot as well as foliar diseases of Bipolaris and Rhizoctonia were the most prevalent among all fungal disease, representing over 50% of all the bahiagrass samples. This suggests that fungal diseases may play a greater role in pasture health then many producers realize. Likewise, with bermudagrass, nematode samples consisted of over 60% of the total bermudagrass submissions. Interactions of bermudagrass stress due to nematode interactions may play a larger role in pasture health and decline, as well.

Chapter 4

Strategies to help foster resilient forage systems in the southeastern United States

Pasture health for warm-season perennial grass species has been extensively discussed in the literature, covering many different factors, such as abiotic influences, management influences and biological influences. There are different strategies that help foster resilience for forage systems. These strategies can be grouped within three areas: 1) pasture and grazing management, 2) soil fertility, 3) pest management, and 4) use of diagnostic services.

Based on previous literature (Reeves et al., 2000; Rinehart, 2017; Vendramini et al., 2007), pasture management strategies are an integral part of pasture health. Strategies such as proper grazing periods and recovery periods allow forage to maintain appropriate canopy heights for supporting both, grazing and photosynthesis to grow more leaves. Proper stocking rates of cattle, along with proper grazing periods can help maintain the appropriate amount of forage. Rotational grazing may need to be utilized to provide a recovery period for forage regrowth.

Strategies for proper fertilization of forage systems can have a profound effect on pasture health. Fertility in pasture settings is constantly in flux and may require adjustments through additional fertilizer applications through the season. Recommended fertilizer applications between hay cuttings can return nutrients that were removed with the hay. Adjusting soil pH to the proper level of soil acidity will help optimize nutrient availability to the plants.

Pest management strategies in pasture systems focus largely on weed management, as weed pressure can impact forage production through competition. Proper and constant scouting and identification of weeds can prevent weed populations from competing with forages for resources and space. Recommended herbicide applications may be necessary for problematic weed populations that cannot be controlled by mechanical removal or other cultural practices. Pest pressures can impact warm-season perennial grasses.

In general, the most identified stress category for bermudagrass was nematode pressures and for bahiagrass it was disease pressures. While producer survey results indicated that pest and diseases were not important to their pasture health, based on the diagnostic lab database results, we might assume that nematode and diseases are affecting bahiagrass and bermudagrass more often than producers realize..

Lastly those who stated they had cases of pasture decline rarely used a diagnostic test to help identify the cause of decline or obtain recommendations to correct the problem. Diagnostic services, such as soil and tissue analytic labs, disease diagnostics and professional consultation can be utilized to create a management plan to improve producer forage systems and as a category, they should be considered a pasture health strategy unto itself. These services provide the foundation for understanding the current interactions between physical, chemical, and biological properties of the pasture system and can provide guidance, in combination with other strategies used for a given system.

The survey and this report provide evidence of topics requiring further study and producer educational topics. Further attention should be directed at several areas: Disease interactions with warm-season perennial grasses in the Southeastern United States and their potential effects on pasture health, with particular interest in root related diseases and relations with resistance/susceptibility among plant genetics is a large area for further research. For example, Blount et al. (2002) findings of interactions of dollar leaf spot with different bahiagrass cultivars should be expanded to include interactions with root fungal diseases affecting both, bahiagrass and bermudagrass. Fungicide interactions with pasture health and interactions with disease occurrences is another related area requiring further attention. While there are no non-OMRI listed fungicides labeled for use in pasture systems for either grazing or haying, studies might be designed to test disease control and potential impact on longer term pasture health and decline.

Soil chemical properties and interactions with pasture health and decline, including soil pH interactions and fertility (particularly potassium) should be addressed. Use of commercial fertilizers has always been at the mercy of economics. Additionally, further study of alternative methods of improving soil health, such as the use of cool-season forages, particularly leguminous cover crops, may be beneficial. Further research should be focused in the areas of soil additives and bio-stimulants and their potential uses for improving soil health for pasture and haying systems. As an example, biofertilizers containing N_2-fixing microorganisms (free-living and endophytes) could provide sources of plant-available N, thereby reducing N fertilizer applications. It may also include testing of different commercial bio-stimulant products. Claims include increasing soil fertility, plant root growth, and plant disease resistance in forage systems.

Herbicide interactions with pasture health and decline might provide valuable insights. While herbicide chemistry and weed pressures are not emphasized in this report in terms of interactions with forage health, producers generally noted that weed pressures were among their largest problem. Additionally, a weak pasture stand allows for greater weed intrusion.

Above all, furthering the educational guidance of producers in the southeastern United States on pasture health concepts needs to be part of all these research areas. These educational concepts should include a more wholistic pasture management approach to foster resilient forage production systems. Educational topics that should be addressed include utilizing good forage plant genetics and proper forage selection/establishment, as this was a requested topic from producers under ‘further guidance’. Suitability of each plant material for a given region and environmental requirements and grazing management has typically been supplied with new plant releases but the information also needs to be easily accessible over time.

Weed management and herbicide recommendations was listed as a necessary need according to the producer survey. While herbicide recommendation publications currently exist (Sellers and Devkota, 2022), this publication is limited to only common pasture weeds in Florida, while many more weed species can be a problem in individual fields. A visual, field flip deck identification guide as a companion to traditional fact sheets, such as EDIS publications, is recommended.

Additional educational materials on grazing management strategies should be developed for Florida producers. The UF/IFAS Extension EDIS publication SS-AGR-84 goes into forage requirements for grazing, but further publications with more depth on how different grazing strategies impact forage health will also be useful. Emphasis should be placed on paddock design and rotational grazing methods and interactions with stocking rates.

Lastly, further educational materials need to emphasis the importance of soil health in relation to pasture health. Although producers did not rank this as a high need, numerous studies (Kemp and Dowling, 2000; Hutchinson and King, 1999; Muller et al., 2004) point to the fact that soil health can impact pasture grass health through soil properties such as fertility, pH, and soil microbiome. Additionally, publications with recommended soil fertility for grazing and haying systems exist, recommendations are based on amounts of nutrients, rather the amounts of fertilizer. Basic or beginner guidance on conversion of nutrients to common fertilizers and their rate might be helpful to producers who do not understand how to interpret soil reports relative to fertilizer selection and application rates. More education is needed in the areas of cover crops, especially legumes, showcasing the many benefits to soil health, including potential economic benefit of offsetting some fertilizer costs for producers.

Future improvements are needed to identify and correct pasture decline issues and ultimately help producers create a resilient forage system to maximize efficiency of their enterprises. This report has help to identify the current health state of Florida's warm-season perennial pasture and hay systems. It also shared through a small sample of producers, perceptions and preconceptions of pasture health in Florida, pasture decline, and practices producers often use to remediate poorly performing fields. Further effort is required to better link producer perceptions with winning actions for managing healthy forages and to successfully intervene before pasture decline takes hold.

Acknowledgements

I would like to thank the following for their contributions to this report:

Dr. Carrie Harmon and the National Plant Diagnostic Network (NPDN)
Use of National Data Repository resources in this project was authorized by the National Plant Diagnostic Network, a USDA-NIFA funded consortium that is part of the US Food and Agriculture Defense Initiative.

UF/IFAS County Extension directors and agents for assisting with survey collection:
Paulette Tomlinson, Columbia County Extension
Ray Bodrey, Gulf County Extension
Lauren Butler, Okeechobee County Extension
Joe Walters, Brevard County Extension

James Colee, UF/IFAS Statistical Consulting Unit for assisting with the statistical analysis of the survey and NPDN data.

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