Recommendation of the Interagency Group Establishing Agronomic Rates for Energy Crops for Utilization by Biofuels Facilities.

Final Report as required by Session Law 2011-198

December 1, 2014

Submitted to:

NC Environmental Review Commission

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Executive Summary

Senate Bill 378 (Session Law 2011- 198) directed the Interagency Group to develop interim agronomic rates and guidance to ensure proper application levels of animal waste for the following energy crops: miscanthus, switchgrass, fiber sorghum, sweet sorghum, and giant reed (arundo donax) no later than July 1, 2011. The Interagency Group was further directed to continue the evaluation process, and develop a final report no later than December 1, 2014.

The Interagency Group requested a literature review be completed by Dr. Ron Gehl, Assistant Professor and Extension Specialist in the NC State University Department of Soil Science, to provide the Interagency Group a proper, science based foundation on which to recommend interim nitrogen rates. The group also requested its technical advisory subgroup, Interagency Nutrient Management Committee (INMC), to provide recommendations based on the Gehl literature review and other available scientific information. The Interagency Group considered the recommendations from the INMC to develop the interim agronomic rates. On June 30, 2011, the Interagency Group adopted interim agronomic rates for energy crops for utilization by Biofuels facilities. The June 2011 interim rates are summarized in Appendix A.

Over the next three years, the Interagency Group continued to review additional information related to agronomic rates for energy crops as requested. Revisions have been made to agronomic rates for giant reed, miscanthus, switchgrass, and fiber sorghum based on new research. On September 25, 2014, the Interagency Group adopted revised agronomic rates for energy crops for utilization in biofuels production for the purposes of the final report. As with all crops that receive animal waste, the Interagency Group will continue to evaluate updated information and further revise agronomic rates as justified by new data. The most recent agronomic rates for energy crops are summarized in Table 1.

Table 1. Summary of Recommended Agronomic Rates for Energy Crops as required by S.L. 2011-198
September 11, 2014

For all energy crops listed below where animal waste is applied, total harvestable biomass must be removed from the field. Harvest dates should be documented in waste management records.

Switchgrass[1]	Nitrogen Agronomic Rates	Application Window	Management Considerations
Plugged			
Year 1	150 lbs per acre regardless of soil type	March 1 – August 31	1217 Guidance regarding overseed for Bermudagrass is applicable for all switchgrass systems.
Year 2 and subsequent years	Equivalent to Hybrid Bermudagrass rates, not to exceed 250 lbs per acre	March 1 – August 31	Overseed not recommended
Seeded			
Year 1	30% of the third year N rate	March 1 – August 31	1217 Guidance regarding overseed for Bermudagrass is applicable for all switchgrass systems.
Year 2	70% of the third year N rate	March 1 – August 31	Overseed not recommended
Year 3 and subsequent years	Equivalent to Hybrid Bermudagrass rates, not to exceed 250 lbs per acre	March 1 – August 31	Overseed not recommended

Sorghum	Nitrogen Agronomic Rates	Application Window	Management Considerations
Fiber Sorghum	Equivalent to Sorghum Sudan Hybrid rates.	March 15 – August 31	
Sweet Sorghum (single green harvest)	80 lbs of N regardless of soil type	May 1 – July 31	
Sweet Sorghum (multiple green harvest)	First Harvest: 80 lbs of N regardless of soil type Second Harvest: 20 lbs of N regardless of soil type	First Harvest: May 1 – July 31 Second Harvest: Extend until August 31	

Miscanthus x Giganteus (Giant Miscanthus)[4]	Nitrogen Agronomic Rates	Application Window	Management Considerations
Single Harvest System			
Establishment - Year 1	30 lbs of N per acre regardless of soil type	March 1 – September 30	
Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	March 1 – September 30	
Double Harvest System			
Establishment - Year 1	30 lbs of N per acre regardless of soil type	March 1 – September 30	No multiple harvests during the first year.
First Harvest, Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	March 1 until first harvest	Harvest should be completed by June 30. If not completed by July 15, the producer is limited to the single harvest system.
Second Harvest, Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	Following first harvest until September 30 [3]	Harvest before March 1

Arundo Donax	Nitrogen Agronomic Rates	Application Window	Management Considerations
Single Harvest System			
Establishment - Year 1	30 lbs of N per acre regardless of soil type	March 1 – September 30	
Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	March 1 – September 30	
Double Harvest System[2]			
Establishment - Year 1	30 lbs of N per acre regardless of soil type	March 1 – September 30	No multiple harvests during the first year.
First Harvest, Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	March 1 until first harvest	Harvest should be completed by June 30. If not completed by July 15, the producer is limited to the single harvest system.
Second Harvest, Year 2 and subsequent years	60 lbs of N per acre regardless of soil type	Following first harvest until September 30 [3]	Harvest before March 1

Notes:

[1] Revised Interim Rates for Switchgrass were approved at the May 28, 2013 SB1217 Interagency Committee meeting.
[2] Revised Interim Rates for double-harvested Arundo Donax were approved at the June 26, 2012 SB1217 Interagency Committee meeting.
[3] If the second harvest occurs prior to September 30, the application window closes at the date of the second harvest.
[4] Revised Interim Rates for Miscanthus x Giganteus were approved at the May 15, 2014 SB1217 Interagency Committee meeting.

Establishment of agronomic nitrogen application rates and guidance on proposed biofuel feedstock grasses

The March 31, 2011 meeting of the Interagency Group heard from interested parties regarding the need of establishing agronomic rates for energy crops that could be utilized by Biofuels facilities. The Interagency Group requested the Interagency Nutrient Management Committee (INMC) to provide recommendations for establishment of interim agronomic rates for Miscanthus x Giganteus (Giant Miscanthus) and Arundo Donax (Giant Reed). Additionally, Senate Bill 378 (Session Law 2011-198) mandated that the Interagency Group develop interim agronomic rates to ensure proper application levels for the following energy crops; switchgrass, "fiber sorghum", "sweet sorghum", giant miscanthus, and giant reed (Arundo Donax) by July 1, 2011, with final agronomic rates to be established by December 1, 2014.

The INMC's charge from the Interagency Group was to focus on establishment of interim nitrogen application rates and development of interim animal waste technical specialist technical guidance for using these proposed biofuel grasses in waste utilization plans. The INMC met on June 24, 2011, and Dr. Ron Gehl, Assistant Professor and Extension Specialist in the NCSU Department of Soil Science, presented findings from a review of available literature on energy crops' (those species listed above) biomass production and nitrogen application/removal status.

Recommendations were made through INMC deliberation of and evaluative consensus on literature review findings. The INMC noted that the literature review found that 'luxury' consumption of nitrogen (uptake of nitrogen that is not used efficiently for yield gain) by these crops is largely untested, and that the crops have typically been managed to reduce required nutrient inputs. Also, Dr. Gehl noted that there are vast managerial differences in growing these crops for production versus growing them as biofuel feedstock. The processes of how these grasses affect the removal of other nutrients, such as phosphorus, potassium, calcium and magnesium were not addressed by the INMC or Interagency Group at this time.

To further document recommendation decisions made by the INMC, Dr. Gehl's report "Literature Review of Biomass Yield and Nitrogen Status from the Production of the Energy Crops: Switchgrass, Fiber Sorghum, Sweet Sorghum, Giant Miscanthus, and Arundo Donax (Giant Reed)" is attached to this report as Appendix C.

As required by S.L. 2011-198, the Interagency Group met on June 30, 2011 and adopted interim agronomic rates for energy crops for utilization by Biofuels facilities.

Over the past three years, research has continued into the five energy crops in North Carolina. Much of this research was originally funded by the Biofuels Center of North Carolina, and has been continued by the North Carolina Department of Agriculture and Consumer Services' (NCDA&CS) Bioenergy Research Initiative. This program awards grants to perform research on agronomic rates, establishment methods, weed control, harvest methods, and other appropriate research needs.

The Interagency Group continued to review additional information related to agronomic rates for energy crops as requested. Revisions have been made to agronomic rates for giant reed, miscanthus,

switchgrass, and fiber sorghum based on new research. On September 25, 2014, the Interagency Group adopted revised agronomic rates for energy crops for utilization in biofuels production for the purposes of the final report. As with all crops that receive animal waste, the Interagency Group will continue to evaluate updated information and further revise agronomic rates as justified by new data. The most recent agronomic rates for energy crops are summarized in Table 1.

Switchgrass

In June 2011, the Interagency Group confirmed the previously-established agronomic rate for switchgrass at 120 lbs N/acre regardless of soil type. It was determined that nitrogen application is not recommended in the first year in order to reduce weed competition. The waste application timing is March 1 – August 31 as currently reflected in the North Carolina Nutrient Management Software. The literature review noted that some yield response to applied N can be expected with adapted Switchgrass varieties.

As research into switchgrass continued, it became clear that there is a yield response to applied nitrogen for switchgrass, especially among newer, improved varieties that would be planted for energy production. In May, 2013, the Interagency Group approved a nitrogen agronomic rate for switchgrass that is tied to the rate for hybrid bermudagrass, not to exceed 250 lbs N/acre per year.

In reviewing research performed by Ron Gehl and others in North Carolina, there is a difference in yield for the establishment years (years 1 and 2) depending on whether the switchgrass is established through seeding or plugging. Plugged switchgrass is more likely to out-compete weeds, and generally shows much higher year 1 and year 2 yields. The Interagency Group concluded that it is appropriate to establish different agronomic rates for switchgrass in years 1 and 2, depending on the establishment method. Due to improved establishment methods and the introduction of labeled herbicides, the Interagency Group also removed the restriction on first year nitrogen application.

For seeded switchgrass, year 3 is considered to be the first year of full yield. As a result, there is a reduced N agronomic rate for years 1 and 2. The year 1 N rate is 30% of the agronomic rate at year 3. The year 2 N rate is 70% of the year 3 agronomic rate. The year 3 N rate is the full agronomic rate, tied to hybrid bermudagrass, not to exceed 250 lbs N/acre. For plugged switchgrass, the Interagency Group expects a full yield in year 2 due to better establishment. As a result, the year 1 N rate for plugged switchgrass is 150 lbs N/acre regardless of soil type. The year 2 N rate for plugged switchgrass is the full agronomic rate, tied to hybrid bermudagrass, not to exceed 250 lbs N/acre.

Fiber Sorghum

In June 2011, the Interagency Group defined “fiber” sorghum to be Sorghum Sudan Hybrid. There are several common names for this type of sorghum, but they all share the goal of biomass production, for energy production or other uses. The Interagency Group adopted the previously-existing North Carolina Nutrient Management Software database nitrogen rate and application timing for Sorghum Sudan Hybrid as meeting the need for fiber sorghum. The approved rates were 45lbs – 55lbs of N per unit yield (tons/acre) variable with soil type and utilizing the established realistic yield expectations (RYE). The RYE’s for Sorghum Sudan Hybrid range from 2.4 to 6.2 tons. The waste application timing is March 15 – August 31. Dr. Gehl noted that yield responses to applied N can be expected with sorghum varieties.

He further described many genetic and varietal types of sorghum being grown today, which can make specific yield and nitrogen application information difficult to establish. Therefore the Interagency Group established one interim N rate to be applied for all fiber sorghum varieties.

In September 2014, the Interagency Group clarified that the total nitrogen rate for fiber sorghum is tied to the nitrogen rate for Sorghum Sudan Hybrid, and not the RYE. Because newer fiber sorghum varieties can achieve very high yields (RYEs of 10-12 tons/acre), a nitrogen factor approach could result in extremely high nitrogen application rates that could put groundwater supplies at risk. Tying the N application rate to the existing N rate for Sorghum Sudan Hybrid will meet the needs of the crop in a manner that will protect groundwater.

Sweet Sorghum (single green harvest)

In June 2011, the Interagency Group adopted an interim application rate of 80 lbs of N/acre regardless of soil type for Sweet Sorghum single green harvest. This recommendation was developed based on literature review information stating N fertilizer applications generally range from 80 to 150 lbs N/acre, that the optimum N fertilizer rate to achieve maximum yields ranges from 60 to 134 lbs N/acre, and NCDA agronomic recommendations of 40-60 lbs N/acre for sweet sorghum. The recommended application timing for sweet sorghum with a single green harvest is May 1 through July 31. Total harvestable biomass is to be removed from the field.

No changes to the June 2011 agronomic rates are proposed at this time.

Sweet Sorghum (multiple green harvests)

In June 2011, the literature review resulted in limited data on multiple cuttings, as almost all available data assumed a single green harvest. The Interagency Group adopted an interim application rate of 80 lbs N/acre regardless of soil type prior to the first harvest cut, with an additional 20 lbs N/acre to be applied prior to the second harvest cut, for a harvest-dependent budgeted total of 100 lbs N/acre. The recommended application timing for Sweet Sorghum for the first harvest is May 1 through July 31; the second harvest application timing would be extended to August 31. Total harvestable biomass is to be removed from the field.

Harvest dates should be a part of regular recordkeeping for producers that utilize this cropping system as part of their certified animal waste management plan.

No changes to the June 2011 agronomic rates are proposed at this time.

Miscanthus x Giganteus (Giant Miscanthus)

Most of the available literature provided data for N applications and yield biomass when miscanthus is winter harvested (post senescence). Thus in June 2011, the Interagency Group chose to only provide recommendations for this type of harvest regime, as there was no substantive basis to provide recommendations for multi-harvest regimes. Dr. Gehl's report indicated that pre-senescence (green) harvest would likely remove larger amounts of nitrogen, however there are still many unknowns regarding nutrient use and continued crop sustainability due to potential root nutrient deficits when pre-senescence harvest is practiced. There is also limited data to suggest certain free-living nitrogen

fixing bacteria are associated with the root system of Miscanthus x Giganteus. There is little current research available on details of how these bacterial types may interact with plant roots in the soil environment, and thus potentially affect overall crop nitrogen requirements.

In June 2011, the Interagency Group adopted an interim nitrogen rate of 60 lbs of N/acre regardless of soil type, with an application window of March 1—September 30. The literature review report noted that according to University of Illinois and Iowa State University research, nitrogen fertilizer is not needed for the first 3 years after planting. Iowa State University research indicates that typically 36-89 lbs N/acre is sufficient for maximizing crop productivity. The literature review report also found that most studies show little yield response for nitrogen applications of over 100 lbs/acre. In Miscanthus cropping systems, winter overseed of small grains will likely not be practical due to crop winter harvest, which typically occurs after the first seasonal frost.

As additional research was completed and released, agronomic rates and guidance for green summer harvests/multiple harvests of this crop were further evaluated. In addition, weed control during the establishment years was further evaluated. In the June 2011 report, the Interagency Group recommended that no N be applied for the first three years due to poor yields and weed competition. Due to improved planting and establishment methods and the introduction of labeled herbicides, this recommendation has been revised. The current recommendation is for 30 lbs N during the first crop year, in both the single and double harvest scenarios.

The Interagency Group considered the potential of a double harvest scenario, with the first harvest taking place in June, and the second harvest taking place after the growing season. Research into this subject has continued since June 2011, and some results show that a large amount of N is removed from the field during an early harvest. Due to that N removal, the Interagency Group concluded that for the production system to remain sustainable, additional N applications will likely be needed. In May 2014, the Interagency Group established N rates for a double harvest scenario. As outlined in Table 1, for a single harvest scenario, the agronomic rate remains 60 lbs N/acre. For a double harvest scenario, the agronomic rate is 60 lbs N/acre before June 30, with an additional 60 lbs N/acre between the date of the first harvest and September 30. Note that for both scenarios, the first year agronomic rate is 30 lbs N/acre. Harvest dates should be a part of regular recordkeeping for producers that utilize the double harvest cropping system as part of their certified animal waste management plan.

Research continues into nutrient uptake and agronomic rates for Miscanthus. This research will be used by the Interagency Group to revise agronomic rates for Miscanthus in the future as appropriate.

Arundo Donax (Giant Reed)

As with Miscanthus, most of the available literature for Arundo Donax provided data for nitrogen applications and yield biomass when crop is winter harvested (post senescence). Thus, in June 2011, the Interagency Group chose to only provide recommendations for this type of harvest regime, as there was no substantive basis to provide recommendations for multi-harvest regimes. There was some data that indicated pre-senescence (green) harvest would likely remove larger amounts of nitrogen, however there were still many unknowns regarding nutrient use and continued crop sustainability due to potential nutrient deficits when pre-senescence harvest is practiced. However, there was some data

cited in the literature review that suggested significant amounts of N remaining in plant tissue even after senescence.

The 2011 literature review data showed little consistency in yield response to nitrogen applications for Arundo Donax. In June 2011, the Interagency Group recommended that in year 1, 30 lbs N/acre may be applied regardless of soil type, and in subsequent years 60 lbs N/acre may be applied regardless of soil type. The recommended application timing is March 1—September 30, with a single harvest system. In Arundo Donax cropping systems, winter overseed of small grains will likely not be practical due to crop winter harvest, which typically occurs after the first seasonal frost.

As with Miscanthus, the Interagency Group considered the potential of a double harvest scenario, with the first harvest taking place in June, and the second harvest taking place after the growing season. Research into this subject has continued since June 2011, and results show that a large amount of N is removed from the field during an early harvest. Due to that N removal, the Interagency Group concluded that for the production system to remain sustainable, additional N applications will likely be needed. In June 2012, the Interagency Group established N rates for a double harvest scenario. As outlined in Table 1, for a single harvest scenario, the agronomic rate remains 60 lbs N/acre. For a double harvest scenario, the agronomic rate is 60 lbs N/acre before June 30, with an additional 60 lbs N/acre between the date of the first harvest and September 30. Note that for both scenarios, the first year agronomic rate remains 30 lbs N/acre. Harvest dates should be a part of regular recordkeeping for producers that utilize the double harvest cropping system as part of their certified animal waste management plan.

Research continues into nutrient uptake and agronomic rates for Arundo Donax. This research will be used by the Interagency Group to revise agronomic rates for Arundo Donax in the future as appropriate.

Invasive Potential

The Interagency Group discussed the potential of some of these crops, particularly Giant Miscanthus and Arundo Donax, to have invasive tendencies. Various stakeholders including the Biofuels Center and NCDA&CS have developed a set of voluntary best management practices that can be utilized to reduce this potential.

In addition to best management practices recommended by NCDA&CS, the US Environmental Protection Agency's rules have established a mandatory series of best management practices. These practices must be maintained and documented in order for ethanol derived from Arundo Donax to receive federal renewable energy credits.

Future Steps

The Interagency Group and the Interagency Nutrient Management Committee routinely evaluates requests from technical specialists, farm owners, and others to determine appropriate agronomic rates for various crops. As new information becomes available for energy crops, or as new energy crops emerge, the Interagency Group will continue to evaluate and make changes to the agronomic rates as appropriate through its routine evaluation process.

Research into appropriate agronomic rates, establishment methods, harvest methods, harvest timing, and weed control is continuing in North Carolina, largely through the NCDA&CS Bioenergy Research Initiative. This research is taking place statewide, at Research Stations located in Wallace, Oxford, Mills River, and other locations including swine farms. This research may allow further revisions to agronomic rates in the future, in support of the state's biofuels industry.

Appendix A. Summary of Adopted Interim Agronomic Rates as of June 30, 2011

Energy Crops for Biofuels Feedstock	Interim Nitrogen Agronomic Rates	Application Timing	Management Considerations
Switchgrass	120 lbs per acre regardless of soil type	March 1 - August 31	N application is not recommended in the first year.
Fiber Sorghum (Sorghum Sudan Hybrid)	45 lbs – 55 lbs of N per unit yield (tons) variable with soil type	March 15 – August 31	
Sweet Sorghum (single green harvest)	80 lbs of N per acre regardless of soil type	May 1 - July 31	Total harvestable biomass is to be removed from the field.
Sweet Sorghum (multiple green harvest)	First Harvest: 80 lbs of N per acre regardless of soil type Second Harvest: 20 lbs of N per acre regardless of soil type	First Harvest: May 1 – July 31 Second Harvest: Extend until August 31	Total harvestable biomass is to be removed from the field. Harvest dates should be documented in waste management plan records.
Miscanthus x Giganteus (Giant Miscanthus)	60 lbs of N per acre regardless of soil type	March 1 – September 30	N application is not recommended during the first 3 years after planting
Arundo Donax (Giant Reed)	Year one: 30 lbs of N per acre regardless of soil type Subsequent years: 60 lbs of N per acre regardless of soil	March 1 – September 30	

Appendix B. Additional Information Sources Considered by the Interagency Group and INMC

Arundale, R.A., F.G. Dohleman, E.A. Heaton, J.M. McGrath, T.B. Voigt, S.P. Long. 2013. Yields of Miscanthus x giganteus and Panicum virgatum decline with stand age in the Midwestern USA. GCB Bioenergy 6: 1-13.

Christensen, C.A., G. Koppenjan, eds. Blade Energy Crops. Planting and Managing Switchgrass as a Dedicated Energy Crop. Blade Energy Crops. 2010.

Kering, M.A., T.J. Butler, J.T. Biermacher, J.A. Guretzky. 2012. Biomass Yield and Nutrient Removal Rates of Perennial Grasses under Nitrogen Fertilization. Agronomy & Horticulture – Faculty Publications. Paper 540.

Palmer, I.E., R.J. Gehl, T.G. Ranney, D. Touchell, N. George. 2014. Biomass yield, nitrogen response, and nutrient uptake of perennial bioenergy grasses in North Carolina. Biomass and Bioenergy 63(2014): 218-228.

Pedroso, G.M., R.B. Hutmacher, D. Putnam, S.D. Wright, J. Six, C. van Kessel, B.A. Linquist. 2013. Yield and Nitrogen Management of Irrigated Switchgrass Systems in Diverse Ecoregions. Agronomy Journal 105: 311-320.

Appendix C. Literature Review of Biomass Yield and Nitrogen Status from the Production of the Energy Crops: Switchgrass, Fiber Sorghum, Sweet Sorghum, Giant Miscanthus, and Arundo Donax (Giant Reed). June 2011 – TO BE ADDED LATER.