Environmentally Sustainable Bioenergy Biomass Production

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Introduction

Costs of commercial fertilizers (particularly N) account for a substantial portion of the total production costs of cellulosic biomass and can be major obstacles to biofuel production. Organic nutrient sources, e.g. manures and biosolids, can be substituted for commercial N fertilizers (and incidentally supply P) to reduce the cost of nutrient supply. However, applying manure or biosolids based on crop N needs simultaneously supplies excess P to an ecosystem, which can cause eutrophication. Nutrient uptake and use efficiencies can be improved with growth stimulating hormones, like gibberellins (GA) and reduce offsite nutrient losses.

Objectives

1. Determine minimum combined rates of N and GA that optimize biomass yield
2. Evaluate cheap sources of N that could be used in combination with GA to optimize biomass yield

Hypotheses

1. Co-application of growth stimulating hormones and N fertilizers at optimum rates will enhance efficient biomass production
2. Growth stimulating hormones will increase nutrient uptake and thereby reduce nutrient losses to leachate and runoff from soils receiving fertilization

Materials and Methods

The study was conducted in a greenhouse with temperature control.

(a) Preliminary study

5 rates of GA (0, 2, 3, 4, and 5 g GA ha^{-1}) were combined with 5 N rates (0, 37.5, 75, 112.5, and 150 kg N ha^{-1}) to yield 25 treatments, each replicated 3X. Seeds of sweet sorghum *(Sorghum bicolor)*, were sown in the pots containing 4 kg of Immokalee fine sand. Five d after emergence, seedlings were thinned to 4 plants/pot, and N rate treatment assigned to each pot was applied. One wk after emergence, the plants were sprayed with appropriate concentrations of aqueous mixtures of GA. Other required nutrients (e.g. P, K, Mg S, and micronutrients were supplied at UF/IFAS recommended rates. Plants were harvested 8 wk after emergence, and dry matter yield, and N and P uptake were determined.

Nitrogen use efficiency (NUE; g g^{-1}) was determined as: $NUE = \frac{TDM}{NS}$

where TDM = Total above-ground plant dry matter (g plant^{-1}); NS= plant available N obtained from fertilizer (g plant^{-1})

Nutrient (N or P) uptake efficiency (NUpE; g g^{-1}) was computed as: $NUpE = \frac{Nt}{PNS}$

where Nt = total N or P in the plant (g plant^{-1}); PNS = plant available nutrient obtained from N or P fertilizer (g plant^{-1})

Following harvest, sufficient water was initially applied to each pot to yield ~500 mL (~0.25 pore volume) of leachate. Two additional leaching events followed at 1 wk intervals, resulting in a total of ~1500 mL (~0.75 pore volume) leachate. After each leaching event, the leachate was analyzed for SRP and total N.

(b) Follow-up Greenhouse Experiment

Two biosolids (GRU and Milorganite biosolids), poultry manure, and ammonium nitrate were separately mixed with 4 kg Immokalee fine sand at 75, and 150 kg PAN ha^{-1}. The manure- and biosolids-amended soils were equilibrated for 2 wk prior to planting. GA was applied to the plants at 3 g ha^{-1}. The experimental layout, design, setup, and data collection followed identical procedure as described above for the preliminary studies.

Results and Discussion

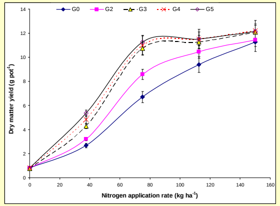

Figure 1. Sweet sorghum dry matter yield as a function of N and GA application rates (G0=no GA application, G2=2 g GA ha^{-1}, G3=3 g GA ha^{-1}, G4=4 g GA ha^{-1}, G5=5 g GA ha^{-1})

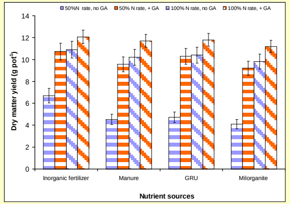

Figure 2. Sweet sorghum dry matter yield as a function of N sources co-applied with gibberellins at 3 g GA ha^{-1}

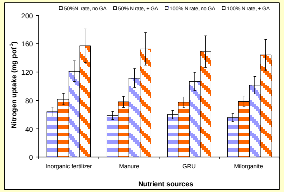

Figure 3. Sweet sorghum N uptake as a function of N sources co-applied with gibberellins at 3 g GA ha^{-1}

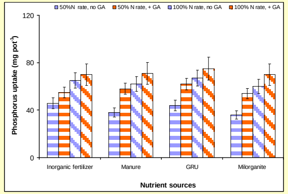

Figure 4. Sweet sorghum P uptake as a function of N sources co-applied with gibberellins at 3 g GA ha^{-1}

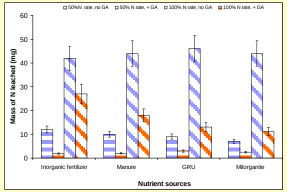

Figure 5. Total N measured in leachate as a function of N sources co-applied with gibberellins at 3 g GA ha^{-1}

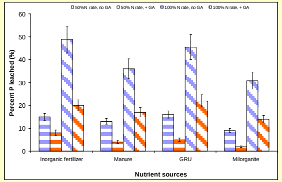

Figure 6. Percent of applied P measured in leachate as a function of N sources co-applied with gibberellins at 3 g GA ha^{-1}

Preliminary study

Co-application of N and GA significantly increased DMY, and an optimum yield was obtained for the treatment with N and GA application rates of 75 kg N ha^{-1} and 3 g GA ha^{-1} (Fig. 1), with NUE of ~49 g g^{-1}. At N application rate of 75 kg ha^{-1}, N uptake efficiency increased from 0.30 g g^{-1} (no GA application) to 0.52 g g^{-1} (≥ 3 g ha^{-1}). Similarly to the DMY data trends, an optimum P uptake efficiency of 0.58 g g^{-1} was observed with GA application rate of 3 g ha^{-1} and N application rate of 75 kg ha^{-1}. Improved N and P uptake efficiency, through the use of GA, significantly reduced masses of P and N lost to leaching from ~55 to ~21 mg P and ~12 to ~2 mg N respectively. Thus, co-application of 75 kg N ha^{-1} and 3 g GA ha^{-1} was identified as the minimum combined rates that optimize yield with minimal offsite losses

Substituting manure and biosolids for inorganic fertilizers

Across N sources, there were no significant differences between DMY of treatments with co-application of the 50% N rate plus GA, and the treatments with 100% N rate without GA application (Fig. 2). Across N sources applied at 75 kg ha^{-1}, N uptake efficiency increased by an average of 0.7 g g^{-1} when GA was applied at to the plants (Fig. 3). Co-application of GA enhanced P uptake (Fig. 4), and GA application increased P uptake efficiency from 0.36 g g^{-1} to 0.55 g g^{-1} when N was applied at one-half the recommended N rate; and from 0.33 to 0.57 g g^{-1} when N was applied at the recommended rate of application. Consequently, a significant reduction in the quantity of N and P lost was observed, particularly when the nutrient sources were applied at N-based rates (Figs. 5&6). Thus, with GA application, the concern that land application of organic sources of nutrients for production could negatively impact the environment can be addressed.

Cost Analysis

Nitrogen fertilizers account for ~80% of the total nutrient cost for biomass production. At N rate of 150 kg ha^{-1}, N cost could be ~\$330 ha^{-1}. The current cost of GA is \$30 g^{-1}. Co-applying N at one-half recommended rate, with 3 g GA ha^{-1} will reduce the cost to ~\$255 ha^{-1}. Substituting organic sources (which incidentally supply the required P) for inorganic fertilizers could result in a saving of >90% of the total nutrient cost for biomass production.

Conclusions

A low input technology, e.g., co-applying a modest rate of GA with one-half N-based application rate of manures and biosolids, could optimize biomass production without negatively impacting the environment. Field trials are needed to validate the findings of the greenhouse studies.

Acknowledgements

This study was funded by State of Florida Federal Stimulus Funds. We thank Dr. J.E. Erickson of the Agronomy Dept., University of Florida for his collaboration.