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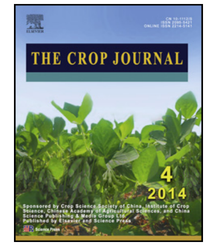

Effect of different levels of nitrogen deficiency on switchgrass seedling growth

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ABSTRACT

Switchgrass (*Panicum virgatum* L.) is a warm-season rhizomatous perennial grass that can tolerate diverse abiotic stresses while yielding relatively high biomass, and is considered a leading biofuel feedstock for marginal lands. Nitrogen (N) is crucial for the growth and development of switchgrass, and its tolerance to low N supply and high N use efficiency are very important for its production under poor conditions. The large-scale planting of switchgrass on marginal lands could be an effective approach to solving the problem of feedstock supply for biomass energy. This study used a hydroponic experiment to evaluate the effect of N deficiency on switchgrass seedlings. Three N treatments (0, 0.15, and 1.50 mmol L^{-1} Hoagland's solution) and six cultivars were used, three of each ecotype (upland and lowland). The results showed that biomass, leaf area, root surface area, net photosynthesis, and total chlorophyll content significantly decreased under low N treatments compared with those in full strength Hoagland's nutrient solution. However, once established, all plants survived extreme N stress (0 mmol L^{-1}) and, to some extent, were productive. Cultivar Kanlow performed best of the six cultivars under stress. Significant interactions between stress treatment and cultivars showed that breeding for cultivars with high yield and superior performance under N deficiency is warranted. The lowland outperformed the upland ecotypes under stress, suggesting that lowland cultivars may survive and be productive under a wider range of stress conditions. However, given the better adaptability of lowland ecotypes to hydroponic cultivation, further study is needed.

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1. Introduction

Increasing energy security and mitigating climate change are the two main motives that have pushed renewable energy production to the top of global agendas [1]. They are encouraging the agronomic production of biomass to help meet renewable bioenergy needs. Perennial grasses are attractive as biomass sources, as they can meet the agronomic, environmental and social requirements for successful deployment as energy crops. Perennial rhizomatous grass is an ideal biofuel crop, because it displays the agronomically desirable traits of broad climatic tolerance, rapid growth rates, and relatively high yield. Furthermore, owing to the recycling of nutrients by their rhizome systems, perennial grasses have a low nutrient demand [2]. They are also seldom attacked by pests and so can be produced with few or no pesticides [3].

Given these unique advantages, the interest in using biofuel crops for energy production is soaring. However, because China cannot afford biomass energy production from its croplands [4], biofuel cultivation, to be competitive with conventional energy sources and avoid the supplantation of food crops, will likely be relegated to less productive soils and will receive minimal inputs of water, fertilizer, and pesticides [5]. Thus, marginal lands may play an important role in biomass energy production. It is estimated that the quantity of marginal land that could be used in biofuel production in China is near 110 million ha, of which about 45 million ha would support economic operation [4]. Abiotic stresses including lack of nutrients, drought, and high salt levels in these areas are common factors that will limit the production of biofuel crops.

Under environmental stress such as nitrogen (N) deficiency, which will be a major limiting factor to cultivating biofuel crops in northwestern and northern China, plants show varying adaptations at the morphological, biochemical, molecular and physiological levels. It is imperative to increase our knowledge on the tolerance of biofuel crops to diverse nutrient deficiency conditions to allow continuous biomass industrialization on marginal lands. Efficient production of bioenergy from such marginal lands requires the choice of the most stress-tolerant grass species. Biofuel crops are being screened for superior characteristics or bred and genetically modified for enhanced abiotic stress tolerance traits that will expand their cultivable area [6]. It is accordingly desirable to evaluate the responses of promising biofuel crops to N-deficiency stress and identify cultivars that are most suitable for biomass production under N-deficiency conditions.

Switchgrass (*Panicum virgatum* L.) is a warm-season rhizomatous perennial C_4 grass that originated in the North American tall grass prairie. It is a leading dedicated biofuel feedstock candidate in the United States, owing to its broad adaptability, rapid growth rate, ability to grow in low productivity soils, and ability to function as one component in a multipurpose cropping system [7,8]. It responds strongly to N fertilizer and is often drought tolerant [9–12]. It can effectively sequester carbon in the soil, and provide excellent cover for wildlife [13,14]. With many beneficial attributes as energy crops, the Department of Energy's Bioenergy Feedstock Development Program (BFDP) decided to focus research on a model crop system and to concentrate research resources on switchgrass, in order to rapidly realize its maximal output as a biomass crop [15].

There are two distinct ecotypes of switchgrass: lowland tetraploid and upland octoploid. The lowland tetraploid ecotype originates primarily in the southern extent of the native range and the upland octoploid primarily in its middle to northern extent [7]. Several dozen cultivated varieties of each ecotype are commercially available, most of which are high-yielding selections from native populations [7]. The species shows wide variation in performance relative to environmental variables, though lowland ecotypes typically produce larger yields than upland ecotypes [16].

Previous studies have focused mainly on the responses of switchgrass biomass to N nutrient application [17–19]. The effect of N deficiency on switchgrass has not been extensively studied, especially for hydroponically cultivated seedlings, and knowledge of the effects of various levels of N deficiency on agronomic traits, photosynthetic parameters, and chlorophyll content in switchgrass is limited. The objective of this study was to evaluate the performance and reproductive potential of six cultivars from the two ecotypes in response to N deficiency stress and provide some theoretical basis for relatively high-yield cultivation of switchgrass in low-fertility soils and for breeding for high N use efficiency.

2. Materials and methods

2.1. Materials

Six cultivars of two switchgrass ecotypes, including the lowland ecotypes Alamo, Kanlow, and BJ-1 and the upland ecotypes Forestburg, Pathfinder, and Trailblazer were used (Table 1). Seeds were obtained from the National Demonstration for Precision Agriculture Experiment Station (39°34′ N, 116°28′ E) in Changping District, Beijing, China.

2.2. Experimental design

The experiment was performed in a greenhouse at the Beijing Academy of Agriculture and Forestry Sciences. Conditions were a 29/21(±2) °C day/night cycle with 32.2%–53.0% humidity. Sodium lamps were used to maintain a 12-hour photoperiod with an illumination intensity of 400 $\mu mol\ m^{-2}\ s^{-1}$.

Each treatment had eight replications laid out in a completely randomized design. Seeds of each cultivar were disinfected in 9% hydrogen peroxide solution for 30 min, rinsed three times with distilled water, and sown in flats filled with washed sand on July 20th 2010. Five weeks after germination, uniform seedlings with two leaves were selected and transplanted into 14 L plastic pots (41.0 cm × 30.5 cm × 13.5 cm) containing full-strength Hoagland's nutrient solution, modified in a random complete block design for eight replications [20]. Seedlings of each cultivar were then exposed to different N deficiency stress treatments at the five-leaf stage.