Development and Assessment of Wildflower Seeding Systems

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16. Abstract

This project aimed to enhance the North Carolina Department of Transportation (NCDOT) wildflower program by integrating precision planting technologies into existing seeding systems. The primary objective was to retrofit current DOT-operated wildflower seeders with spatially responsive, prescription-based control systems to improve the efficiency, accuracy, and visual appeal of roadside wildflower establishment. An existing Strickland Brothers Greenscape 600 seeder was modified with electric drive components and a Raven Rate Control Module (RCM3), later replaced with AgLeader hardware to align with DOT standards. Static and field testing validated the system's ability to follow complex seeding prescriptions, including on-the-go seed variety changes. Although full biological assessment was limited due to weed management interventions, the control system demonstrated functional success. Results indicate that upgrading DOT's existing equipment with commercially available precision agriculture components is a viable and scalable approach for improving wildflower planting efforts. Future work should focus on increasing system resolution, optimizing seeding transition dynamics, and providing operator training to support widespread adoption.

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Executive Summary

This project explored the integration of precision planting technologies into the North Carolina Department of Transportation's (NCDOT) wildflower seeding program, with the goal of improving the efficiency, safety, and visual impact of roadside wildflower establishment. Two primary objectives guided the work: (1) develop and test a prescription-based wildflower seeding system compatible with NCDOT’s existing equipment, and (2) assess the feasibility of advanced agricultural row-crop planting systems for roadside use. Due to practical and logistical constraints, the project focused on Objective 1—enhancing NCDOT's current seeder platforms.

The project team retrofitted a Strickland Brothers Greenscape 600 seeder with electric drive components and integrated a Raven RCM3 rate control module to allow variable-rate seeding based on GPS-enabled prescription maps. The system was calibrated and tested in both static and field settings to evaluate performance, seeding accuracy, and the ability to switch between seed varieties on the fly. Field demonstrations showed the system could successfully follow complex planting prescriptions and alternate seed varieties in real time. Although weed control issues prevented a full biological assessment of establishment, the mechanical and control systems performed as intended.

Following successful testing, the control platform was migrated from the Raven RCM3 to AgLeader hardware to ensure compatibility with existing DOT fleet systems. Additional modifications were made to improve field readiness and safety.

The project concludes that prescription-based wildflower planting using upgraded DOT seeder equipment is feasible and promising. While current systems operate more like drop spreaders and lack fine-scale resolution, the technology is sufficient for large-scale implementation with continued refinement. With further training and modest investment, this approach could significantly enhance the effectiveness and aesthetics of NCDOT's roadside beautification efforts.

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Introduction

Purpose and Scope

Precision planting technologies have developed to the point that nearly all variables in row-crop planting systems can be controlled through off-the-shelf electronics. These controls could be leveraged into seeding systems that would allow the DOT wildflower program to continue to innovate and make the establishment of wildflower areas faster and safer while creating unique and visually appealing public displays. The overall goal of this project was to deliver preliminary technologies and mechanical systems to improve wildflower establishment. To meet this goal, the specific objectives were to: 1.) develop and test a system for prescription-based wildflower systems based on current seeding equipment in use by DOT, and 2.) Assess current advanced row-crop planting systems for wildflower establishment.

Organization of Report

Based on the early work and reporting on Objective 2 related to leveraging row-crop planting systems into the roadside environment, it was decided to focus primarily on Objective 1 and the existing seeder systems in operation by NCDOT. The multiple logistical and technical challenges associated with transporting and successfully operating an agricultural plate planter in the roadside environment were too much to overcome within the context of this project. Therefore, the remaining report will focus exclusively on Objective 1 with an emphasis on seeder systems.

Results of Literature Review

Large-scale wildflower establishment has gained interest in recent years for both ecological and aesthetic purposes, particularly along roadways and other disturbed landscapes. Wildflowers provide multiple ecosystem services, including erosion control, pollinator habitat, and biodiversity support (Xerces Society for Invertebrate Conservation, 2018).

Despite these advantages, current planting methods limit broader adoption. There is little formally published literature on the mechanical establishment of wildflowers, but there are some observations that have been made about key challenges and opportunities in the process and how they relate to current agricultural systems.

Most wildflower seeds are small and irregular in shape, making them poorly suited to conventional row crop planting equipment without meaningful modification (Jin et al., 2019). As a result, broadcast seeders or drills are used. These implements are typically ground-driven and lack precision in seed placement, allowing limited in-situ control over seeding rate and species composition. Transitioning to electric drive systems rather than ground-driven allows more precise on-the-go metering of seed, enables multi-product application, and pairing these advances with prescription maps unlock greater control in seeding. Together this approach should increase the feasibility of large-scale wildflower programs.

Modern row crop planters commonly utilize electric drives. The motor rotates the seed meter input shaft to deliver the seed to the ground (He et al., 2017). Electric drives provide several advantages over ground-drive. Automatic shutoff prevents planting in areas that have already been seeded, which reduces seed waste. Real-time adjustments allow seeding rates to change with field conditions. Shaft speed can be automatically adjusted based on tractor speed, ensuring uniform planting. When integrated with GPS, electric planters follow prescription maps with high accuracy, enabling variable-rate application and data recording for long-term management.

Multi-product applications allow at least two inputs to be delivered simultaneously or alternately, as seen in fertilizer spreaders or intercropping systems. This approach could benefit wildflower establishment by accommodating species with different germination and blooming times. Staggered germination reduces the dominance of a single species and extends bloom duration. For example, Cirujeda et al. (2006) found germination of multiple wildflower species was highest from September to November, lowest in March, and restarted in June, highlighting the importance of timing in sowing strategies. From a beautification perspective, multi-product seeding could allow wildflowers with different bloom color to be planted in specific patterns, allowing new creativity in roadside displays. Currently, changing seed types requires manual adjustments and cleaning out product hoppers on seeders, reducing efficiency. Multi-product application could address this inefficiency while enhancing biodiversity and beautification.

Prescription maps are GPS-based field layers used for planting, spraying, and spreading in commercial agriculture. On-vehicle electronics send control signals to application controllers to modify machine settings based on the spatial location of the machine and the variable being controlled (Virk et al., 2020). In the roadside wildflower context, the prescription map could alter target seeding rates or turn specific seed hoppers on or off to replicate the desired map in the planting area.

Advancements in row crop planting technology - particularly electric drives, multi-product application, and GPS integration via prescription maps - have significantly improved precision and efficiency in production agriculture. However, small-seed sowing, including wildflowers, lags in technological innovation. Bridging this gap represents an opportunity to expand ecological restoration and roadside beautification through more efficient wildflower establishment. Applying precision agriculture principles to small-seed planting could improve germination, reduce costs, and create more sustainable, diverse, and visually appealing plantings.

Report Body

NCDOT provided an existing Strickland Brothers Greenscape 600 seeder as the test and development platform. To create seeding controls that are spatially informed by the location of the seeder inside of seeding prescription at a roadside location, the first step was to convert the seeder from a ground-driven unit into a motor-driven unit that can receive on/off as well as speed control signals. Together, these controls provide the basis to have the seeder follow a spatial seeding prescription, maintain a target seeding rate despite seeder ground speed, and to change seed varieties on the go.

The initial step was retrofitting the Greenway seeder by replacing the mechanical ground drive system with an electrically driven, precision-controlled seeding system. Key components included the integration of electric motors and a commercially available Raven Rate Control Module (RCM3), selected for its compatibility with ISOBUS virtual terminals and its capability to control multiple seed species simultaneously using prescription maps. For the preliminary development work, the Raven RCM3 and associated cabling were loaned to the BAE department by B&S Enterprises (Wilson, NC). A custom interface component was developed to adapt the RCM's pulse width modulation (PWM) output for electric drive control. The system was installed and tested with various seed types.

Figure 1. Seeder in initial phases of motor-driven conversion.

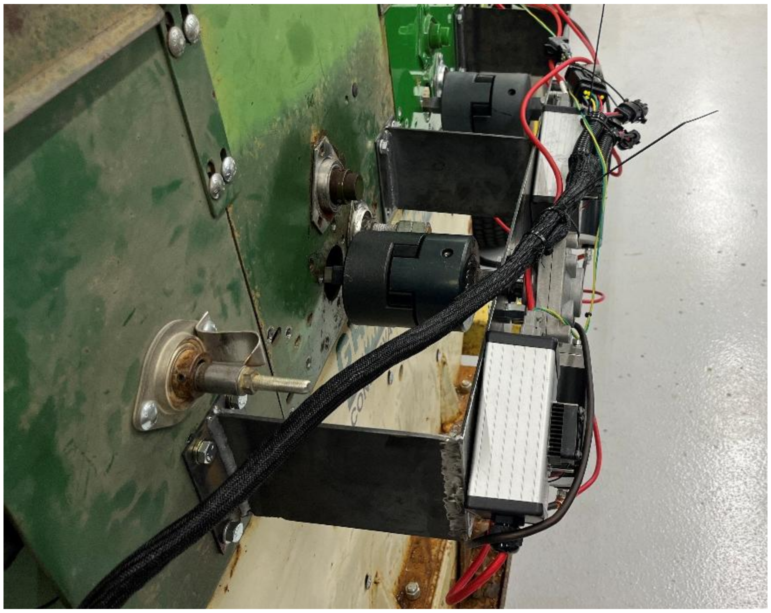

Figure 2. Initial motor-driven conversion with interface devices.

Two distinct testing phases were undertaken prior to taking the seeder to the field for a functional demonstration. The first was static testing to understand the mechanical system limitations along with the functional seed densities and application rates. The key variables were: look-ahead time in the rate controller, calibration of the rate control to varying seed densities, and evaluation of the smallest ground area that allows the seeder to change between products. These were initially tested using a fixed test stand with the motor and controllers attached to a single distribution cup. NCDOT provided an estimated seed density and a target application rate for a range of wildflower seeds. This was an appropriate starting point, but further information was needed to convert this data into the target RPM for the drive motors as they change speed to maintain the target seeding rate across a range of ground speeds. After static testing, the motors were converted from direct drive to chain drive to provide a more appropriate speed range to the seed cups.

The second phase was field testing at a location at Lake Wheeler Field Lab in Raleigh, NC. A small linear plot was established to test the statically measured variables and to assess overall system performance, especially in terms of changing seed varieties on the go. Testing indicated that all systems were functional and that a full-scale test was needed. Additional fine-tuning on the seed transition distance and the look-ahead distance required for accurate seeding zone change was required and conducted.

Figure 3. Seeder with RCM and electric drive components during initial field testing.

An existing wildflower bed location near Wilson, NC was identified for full-scale testing. A GPS survey was conducted at the location to create the boundary map and seeding prescription. The goal was to plant the complex geometry of the location while switching between two different varieties of wildflower seed in a checkerboard pattern. The prescription was created using QGIS software and was uploaded to the tractor terminal.

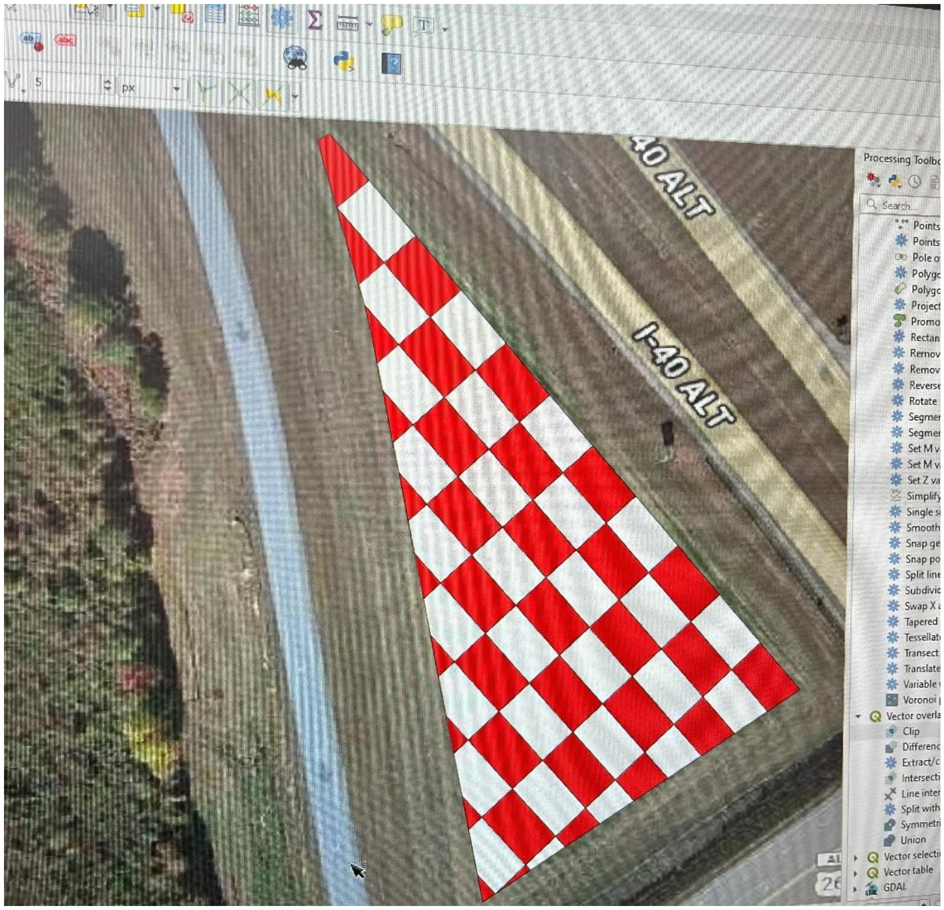

Figure 4.Planting prescription for field testing alternating between red and white flowers.

The tractor and seeder were delivered to the site, and with the support of the Roadside Environmental team, the seeder and control system successfully distributed seed within the prescribed boundaries and changed varieties as prescribed. There was, however, a weed pressure issue at the location that led to the application of herbicide to the site, which prevented the full assessment of emergence, target population adherence, and any lag time in the changing of seed varieties per the checkerboard prescription. From a systems perspective, the seeder and the control system functioned as expected.

Based on sponsor recommendations to align precision agriculture products within DOT, the RCM3 was replaced with comparable products from AgLeader. Existing vehicle-based application systems in use with the Roadside Environmental Unit utilize AgLeader products, so there is value in moving to a common platform for all users. The seeder underwent additional modifications to move from an initial prototype to a more field-ready system, including additional shielding for safety and more secure mounting for the new components.

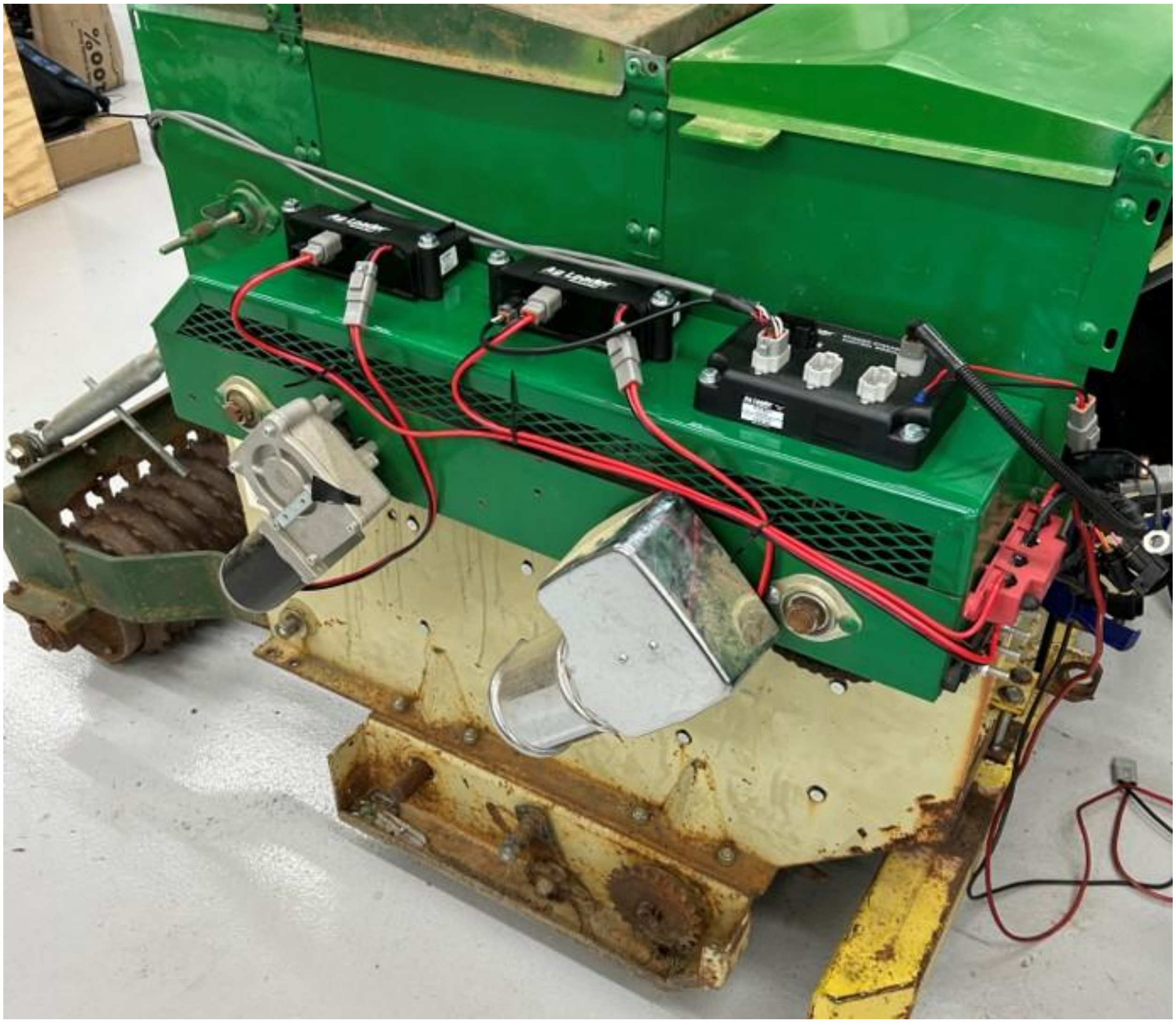

Figure 5. Upgraded wildflower seeder equipped with AgLeader control components.

Functionally, the control system sees the seeder as a drop spreader, and as such, it is designed for bulk product control rather than fine-scale seeding, restricting the system's resolution at narrow swath widths. There are approaches to achieving individual row or cup-level control that would require additional electric drives or clutches, significantly increasing cost and complexity beyond the scope of an off-the-shelf solution.

Findings and Conclusions

From the control system perspective, the seeder functioned well with the addition of electric drive and control systems. Functional and field-scale tests revealed that prescription planting of wildflowers with upgraded existing seeders is a viable tool that can contribute to roadside environmental and beautification goals. There are some challenges to be met with finetuning lookahead times and seeding rates to optimize seeding prescriptions. With some additional research and training for DOT staff, this is a tool that could be readily available to deploy on North Carolina roadways.

Transitioning to use components from a single supplier, AgLeader, will simplify deployment and reduce compatibility issues that can arise from integrating multiple different systems.

Recommendations

Based on the proofs of concept from this project, it is technically feasible to upfit existing DOT seeding systems in inventory with nominal mechanical modification. Combining the mechanical modifications with commercial precision agriculture components provide the necessary control to enable rate and section control in roadside seeding operations. There are no specific commercial products specifically for precision seeding control on a drill or seeder platform, especially on smaller scale equipment like those used by NCDOT. The recommendation of this project is to continue the development of the retrofit upgrade system to a structured set of components and modifications that can make upfitting a repeatable process for deployment. Further, other seeding methods should be researched including uncrewed aerial vehicles that could reduce logistical resources needed to establish and maintain wildflower plots.

Implementation and Technology Transfer Plan

Research Products

The primary research products of this project were: 1.) the identification of the modifications and components necessary to convert a ground-drive seeder to a precision seeder, 2.) the control variables necessary to optimize the seeding process, and 3.) the process to create wildflower seeding recommendations.

Department Use and Applications

Primary users are Roadside Beautification staff. The application is the more controlled creation and management of DOT’s signature wildflower beds.

Training needs

Identified training gaps were in the process of the creation, transfer, and execution of seeding prescriptions. Through a combination of workshops and written guides the necessary training can be completed.

Technology / Knowledge Transfer Opportunities

Two presentations have already been shared in academic conferences on the topic and an additional publication will be developed.

The technology transfer itself will revolve around working with the precision agriculture components manufacturers and retailers to create kit or part number that can be directly ordered for future retrofits along with creating a set of working plans for the modifications.

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