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Development of a Granular Herbicide Spot Applicator for Management of Hair Fescue (Festuca filiformis) in Wild Blueberry (Vaccinium angustifolium Ait.)

Craig MacEachern[1], Travis Esau[1], Qamar Zaman[1]

[1]Dalhousie University, Faculty of Agriculture, Truro, Nova Scotia, Canada, B2N 5E3

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Abstract.

Hair fescue has quickly become the pest of greatest concern for the wild blueberry industry. This is largely due to its ability to outcompete wild blueberry for critical resources including water, nutrients and most importantly space. In Nova Scotia, between 2001 and 2019, hair fescue had increased in field frequency from 7% to 68% and in field uniformity from 1.4% to 25%. This rapidly spreading and economically destructive weed is likewise a significant challenge to manage, with only a single registered herbicide, Kerb SC (Propyzamide), demonstrating effective control and widespread use. That said, Kerb SC has become increasingly difficult to acquire in recent years and reliance on a single herbicide can lead to selection for herbicide resistance. Casoron G4 (dichlobenil) represents a possible alternative in that it too has shown success at managing hair fescue in initial trials. However, due to its granular nature and high application cost of up to $1770 ha^{-1}$ most growers have not explored it as an option. Given hair fescue's 25% field uniformity, there is a potential 75% agrochemical cost savings which could be achieved through the development of a spot applicator. The applicator developed in this study modifies a Valmar 1255 TR through the development of a recirculation system for the granular product and custom built, bistable solenoid driven valves. By constantly recirculating product, there is always product available at the valve, while avoiding the possibility of the valves becoming stuck from product buildup. In the final design, the valves will be controllable either through the use of a prescription map or in real time with a machine vision system trained to identify hair fescue. The machine vision system has been developed in isolation and currently boasts a Top-1 percentage of 96.25%. Future work will look at interfacing the machine vision system with the spot applicator.

Keywords.

Herbicide, Spot Application, Neural Network, Prescription Mapping, Applicator, Spreader

Wild blueberry (*Vaccinium angustifolium* Ait.) is one of Eastern Canada's most economically important crops with a five-year average farm gate value of CAD$101.1 million (Statistics Canada, 2022). Wild blueberries are a perennial crop which are typically managed on a biennial basis. This is because the plant produces significantly more yield in the second season after pruning than at any other point in their development (Eaton & Nams, 2006). The first season after pruning (sprout year), sees vegetative growth until tip dieback in July when the plant switches to focus on flower bud development. The plant then overwinters, and flower buds burst in spring of the second year (fruit year), are pollinated and begin to develop fruit. Fruit begins as small, hard and green berries and gradually transition to red and finally ripe, soft and blue berries. These berries are harvested in late summer and fields are once again pruned in late fall, repeating the process. Unlike traditional row crops, the wild blueberries are encouraged to spread from underground rhizomes in what is typically abandoned farmland or cleared forests. This, coupled with the significant differences between wild blueberry clones, results in a significant amount of variation between fields. This variation creates many unique management considerations with perennial weeds being among the most concerning. Being that wild blueberry fields cannot be tilled from year to year, means that hearty and difficult to eradicate perennial weeds impose a significant management challenge requiring several herbicide applications each year. The cost of these applications varies by product, but the variety and number of applications required coupled with external environmental and social pressures, highlight the need for suitable spot applicators within the wild blueberry industry.

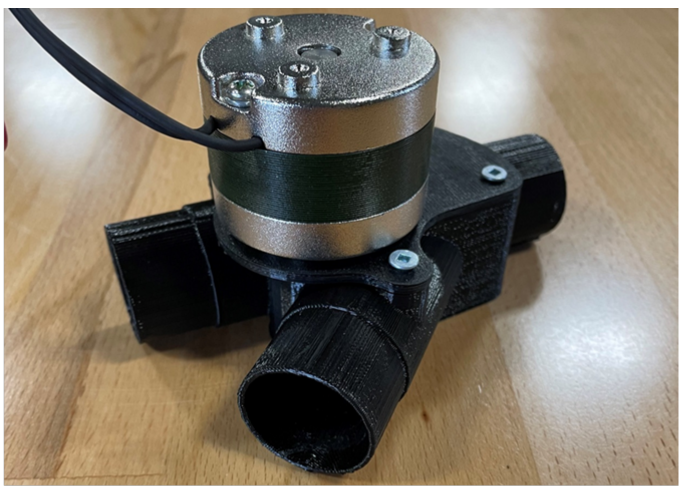
The weed of greatest concern to the wild blueberry industry is hair fescue (*Festuca filiformis*) (Figure 1) with the Wild Blueberry Producer's Association of Nova Scotia identifying its management as their number one industry priority in 2019 (Wild Blueberry Producer's Association of Nova Scotia, 2019).

Figure 1: Image of typical wild blueberry field with significant hair fescue pressure and example of typical topography (left) along with a close up, top-down image of hair fescue (right)

The concern with hair fescue arises from its economically destructive nature, the rapid rate that it is spreading throughout the region and the few herbicides which provide an adequate and consistent level of treatment. Presence of densely tufted hair fescue has been shown to reduce wild blueberry yields by more than 50% (White, 2019; Zhang, 2017; Zhang et al., 2018) with effective management strategies being largely limited to pronamide (Kerb SC)(White, 2019; White & Zhang, 2021; Yarborough & Cote, 2014; Zhang et al., 2018). Presence of hair fescue in Nova Scotian wild blueberries fields was 7% in 2001 and rose to 68% by 2019. In those fields infected with hair fescue, an average field uniformity of 37% was observed (Lyu et al., 2021). The rapid spread of the weed comes down to the lack of treatment options, the nature of the weed itself and the management practices of the wild blueberry cropping system. Single hair fescue tufts can produce up to 3000 seeds, which readily break from the panicle inflorescence and germinate aggressively in wild blueberry fields (Munro et al., 2014; White, 2020; White & Kumar, 2017). This is augmented by multiple passes of agricultural equipment across the field throughout the two year production cycle which readily distribute seeds throughout and between fields (Boyd & White, 2009).

Being that Kerb SC is largely the only product in use for managing hair fescue, it is at risk for herbicide resistance. Dichlobenil (Casoron G-4) is another herbicide which is registered in wild blueberries and whose mode of action suggests it could be used to manage hair fescue. The difficulty with Casoron G-4 arises from the fact that is a granular product, and that uniform applications are expensive, with applications costing between CAD$1070-1770 ha^{-1} (Perennia, 2019). This suggests that the development of an effective spot applicator could drastically reduce application costs given the average field uniformity of 37% observed with hair fescue in Nova Scotian wild blueberry fields. The difficulty is that there has been very little work done on the development of granular spot applicators with studies seeing limited success (Chattha et al., 2014; Schumann et al., 2006; Zaman et al., 2005).

This study looked at the development of a pneumatic spot applicator by modifying a Valmar 1255 Twin-Roller Air Boom Applicator (Valmar Airflow Incorporated, Elie Manitoba, Canada). By default, the applicator has 12 boom nozzles and two boom sections with rate control. The first step was to design a conveyance system which could ensure that there was always product at the nozzle without clogging up in the hoses. Unlike a spot application sprayer, product cannot be forced against a closed valve, as this would lead to difficulties actuating the valve, and clogs which the system's blower fan would not be able to clear. This was addressed by constantly cycling product past the valve and then diverting it either onto the deflector plate and subsequently toward the ground or through a series of recirculation hoses and back to the hopper. The direction of product delivery was controlled by a custom designed and 3D printed Y-valve with an internal gate (Figure 2). The gates actuation was controlled by a BRS50C39-6 bistable rotary solenoid (Geeplus, Beckenham, United Kingdom) which was able to switch states in approximately 10 ms.



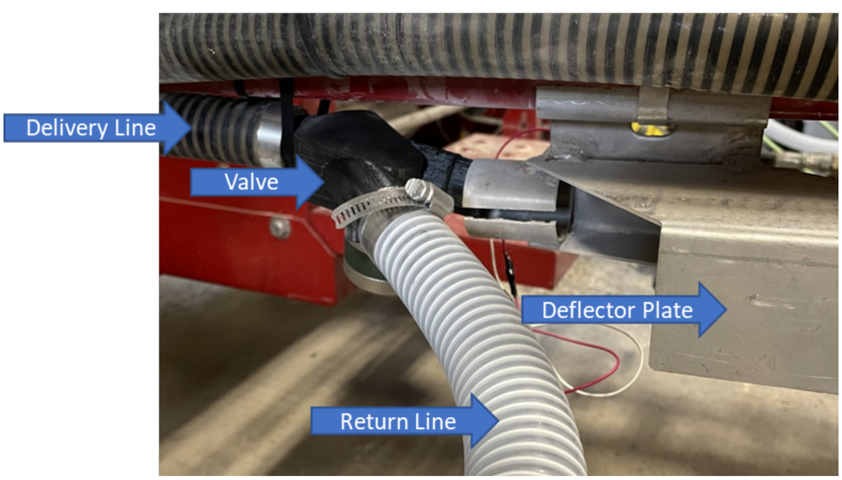


Figure 2: Custom designed and 3D printed Y-valve with internal gate controlled by BRS50C39-6 bistable rotary solenoid (top) and installation of valve on applicator boom showing the delivery and return lines along with the deflector plate (bottom)

To accommodate the additional hosing the pulley ratio between the 6.3 kW @ 3600 rpm Honda GX 270 motor (Honda Motor Company, Tokyo, Japan) and the blower fan was altered from 1:1 to 6:5 in order to increase the circulated air velocity. Mean air velocity at the base of the deflector plate was 7.89 m s^{-1}. The decision system utilised a John Deere RC2000 Universal Rate Controller paired with their 4640 display (John Deere, Moline IL, USA) to accommodate individual nozzle control (Figure 3).

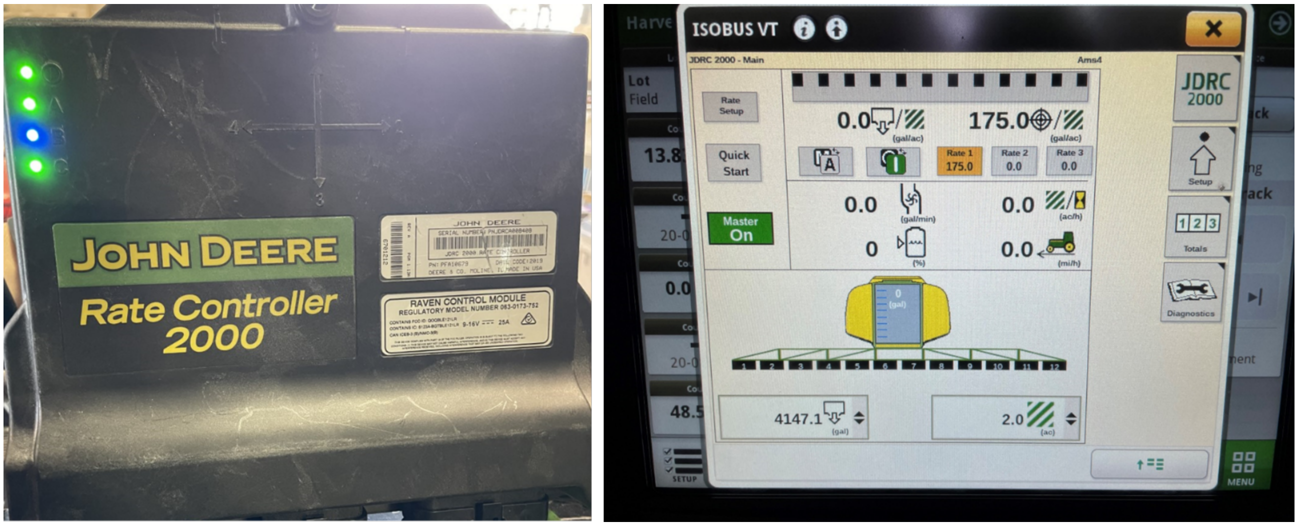


Figure 3: John Deere's RC2000 Universal rate controller (left) and 4640 display (right) showing the interface for the 12-nozzle sectional control for the applicator (right)

Prescription maps detailing where hair fescue was present in the wild blueberry field were developed from aerial drone imagery and loaded onto the rate controller. When one or more of the twelve boom sections enters a management zone as detailed by the prescription map, it sends a constant 12V signal to the control circuit. The control circuit utilises six Arduino UNO micro controller (Arduino, Somerville MA, USA) paired with six Pololu Dual G2 High-Power Motor Driver (Pololu Corporation, Las Vegas NV, USA) to send one second pulses of alternating polarities to the solenoids. By alternating the polarity of the outputted 24V pulse, the solenoids can actuate between the open and closed states. In all, when a boom section enters a management zone, the valves open and product is delivered, and when the boom section leaves a management zone the valves close. Positioning of the boom sections are defined based on their relative distance from a John Deere Starfire 6000 GPS receiver paired with John Deere’s SF1 correction signal. SF1 advertises a mean horizontal pass to pass accuracy of ±0.15 m (John Deere, 2020).

Moving forward, the goals of the project will be to replace the prescription mapping-based approach with a real time machine vision system. The real time approach is preferential as it doesn’t alter the way in which growers manage their fields. Prescription mapping is tedious and comes at a significant time cost for accommodating spot application. Neural networks for identifying hair fescue have already been developed (Hennessy et al., 2021) and will be implemented in the proposed machine vision system. The models have a testing Top-1% of 96.29% when identifying hair fescue. While it is expected that this number will decrease with the addition of motion to the collected images, the models show significant promise in early testing. Selection of cameras will likewise be critical for system success, and this work is currently underway. The overall goal will be to develop a system which can in real time, identify hair fescue, apply herbicide to the hair fescue, and shut the flow of herbicide off as it moves past. This all needs to happen with as little impact to growers’ current approach to herbicide application as possible. This study is novel in its approach to granular spot application which has yet to be done successfully in research or industry to the desired level of precision proposed in this work.

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