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Analyzing Robustness of Granular Agrochemicals: Basis for the Development of a Pneumatic Spot Applicator

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Abstract— This methodology is part of a larger work to develop a granular agrochemical spot applicator for a variety of on farm applications. As part of the development, it is critical to analyze the robustness of the target agrochemical to ensure that the product does not breakdown when cycled pneumatically. Prior to this work their existed no such methodology for analyzing a granules ability to resist degradation resulting from pneumatic and impact stresses. To assess granule robustness, granules of three different agrochemicals (Casoron G-4, 9-30-11 MESZ granular fertilizer and clay filler) were cycled for one hour through 4.87 m of 31.75 mm inner diameter hose. Bulk densities of each agrochemical were recorded before and after cycling the product and used for comparison. If the product observed a significant increase in bulk density following cycling, then it can be stated that the granule was seeing significant degradation resulting from the stresses. Casoron G-4 did not see any significant degradation ($p = 0.220$) resulting from the cycling. Both the fertilizer and the clay filler did see significant breakdown ($p < 0.001$) resulting from the pneumatic and impact stresses.

Keywords- Casoron G-4, Clay Filler, Cycling, Fertilizer, Herbicide, Wild Blueberry

I. INTRODUCTION

Granular agrochemicals are typically applied using tow behind or tractor mounted spreaders/applicators. In many cases, these spreaders use broadcast applications which waste agrochemical and create economic and environmental loss for the grower (Hassen, Sidik, and Sheriff 2014; Pérez-Ruiz et al. 2011). While a number of spot and variable rate applicators have been developed for liquid agrochemicals (T. J. Esau et al. 2014; Gil et al. 2013; Hussain et al. 2020; Li et al. 2018; Partel, Kakarla, and Ampatzidis 2019; Samseemoung, Soni, and Suwan 2017; Tian, Reid, and Hummel 1999; Zaman et al. 2011) similar advancements for granular agrochemicals have not been realized. Granular agrochemicals provide a number of unique advantages over liquid herbicides which can include, lower chemical exposure risk, greater efficacy, inability to freeze and damage equipment, lower volume applications, reduced application drift, easier under canopy application, no mixing requirement and rain activated applications (Derksen et al. 2014; Dexter 1993; Flynt et al. 1976; Gove et al. 2007; Knarr et al. 1985; Nation 1972). These advantages combine to make granular agrochemicals the superior choice in many instances though, with the lack of a precision applicator, many of these advantages cannot be fully profited from.

This study serves as the basis for an under-development spot applicator for precise spot application of granular agrochemicals. The proposed system will modify a Valmar 1255 Twin Roller Pull Type Pneumatic Granular Applicator (Valmar Airflow Incorporated, Elie Manitoba, Canada) to accommodate spot application. As part of the working mechanism, agrochemical granules will need to be cycled through the system to ensure that there is always product at the nozzle. In doing so, stresses are introduced to the granules and it is important to assess how these granules might breakdown from this stress. If significant product breakdown is occurring, then the application rates will change, independent of any mechanical changes to the system.

As the under-development system is being targeted for wild blueberries, selected agrochemicals will reflect those in use and with potential within the industry. Casoron G-4 (MacDermid Agricultural Solutions, Guelph, ON, Canada) is a group 20 herbicide with the active ingredient dichlobenil (4%). Due to its elevated cost for broadcast applications (>$1400 CAD ha^{-1}) Casoron G-4 is not widely used in wild blueberries (White and Zhang 2020). That said, with the recent emergence of hair fescue and sheep sorrel as a problem weeds in wild blueberries, coupled with the relative lack of treatment options, Casoron G-4 shows potential for mitigating the effects of these problem weeds (Lyu et al. 2021; Munro, Newell, and Hill 2014; White and Kumar 2017; White and Zhang 2020). With the advent of a precision spot applicator, Casoron G-4 could see an increase in usage as application costs are reduced through spot application.

The development of a standard method for assessing agrochemical granule robustness is a critical step in the realization of a pneumatic spot applicator. This method will allow for equivalent comparison between granules and assess their potential to be pneumatically spot applied.

II. Methods

This study analyzed the effect of pneumatic cycling on the ability for agrochemical granules to resist degradation. Three different granules, Casoron G-4, 9-30-11 NPK MESZ fertilizer and a clay filler were analyzed.

Casoron G-4 used in this study consisted of 50-70% silicon dioxide, 10-20% aluminum dioxide 4% dichlobenil, 1-5% diiron trioxide, 1-5% magnesium oxide, 1-5% calcium oxide, 0.1-1% kaolin and 0.1-1% titanium dioxide. This is the standard formulation for Casoron G-4 and depending on the granule, concentrations of each component can vary within the outlined ranges. Casoron G-4 was included in this study as it is an emerging herbicide within the wild blueberry industry for dealing with several problem perennial weeds.

The fertilizer used in this study consisted of 9% nitrogen, 30% phosphate, 11% potash, 0.4 % magnesium, 7.9% sulfur and 0.8% zinc. The remaining 40.9% was made up of clay filler and trace micronutrients. This formulation was selected as it is the standard fertilizer used in wild blueberry operations (T. Esau et al. 2019). As the under-development spreader is being designed with both herbicide and fertilizer applications in mind, it is critical to assess standard fertilizers used within the industry.

The clay filler used in this study consisted of <3% copper sulfate, <0.7% zinc sulfate and <0.3% zinc oxide with the rest of the formulation being made up of the clay itself. This formulation was selected as it is used widely as a carrier/filler within the wild blueberry industry.

All three granules were cycled using a purpose-built apparatus which comprised of a 0.36 m x 0.15 m x 0.43 m collection funnel and 4.87 m of 31.75 mm inner diameter hose. A venturi was developed using a 38.1 mm x 38.1 mm x 12.7 mm Y-fitting to introduce air to the system without back flow. Air speed was monitored throughout the experiment and was maintained between 29 m s^{-1} and 44 m s^{-1}. Air speed fluctuated as a result of using compressed air and the compressors inability to maintain the desired higher air speeds. Too ensure as much consistency across samples as possible, a 12.7 mm ball valve with a mechanical stop positioned at 75% open was utilized. Tank pressure was also monitored at a booster tank throughout the experiment and ranged from 5.38 bar to 8.20 bar. Despite the small fluctuations in air speed and pressure, constant visual observation did not observe any instances where the product became stuck or stopped flowing due to air speed reductions.

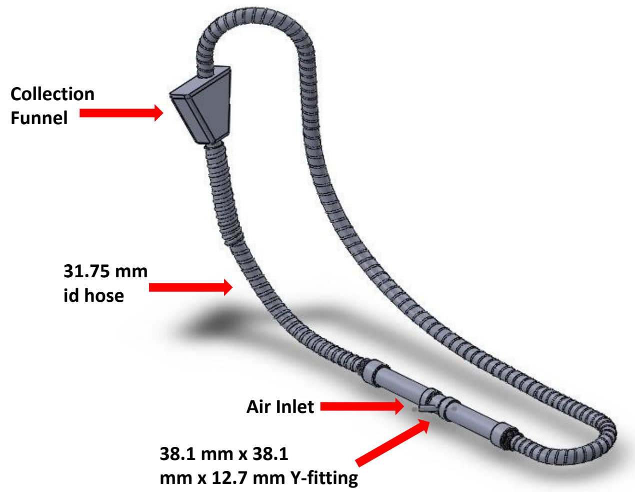

Figure 1: Apparatus for pneumatically cycling granular products

Before introduction into the cycling apparatus, the bulk density of nine unique samples was collected using the weights from 100 mL of packed granules in a 100 mL beaker. The term “packed” is used to define the tamping down of granules to the desired level as indicated by the beaker. 1 L of packed granules in a 1 L beaker were then introduced into the cycling apparatus and cycled for one hour. Following the hour of cycling, the granules were then collected and once again, nine unique bulk density samples were taken using the same process as above. Each analysis was performed in triplicate.

Granule size was also monitored before and after cycling. Using Vernier calipers, 25 granules were measured along their longest axis. This was performed for all three agrochemicals.

All granule degradation and size data were analyzed using 2-sample t-tests. Granule degradation was not analyzed between granules as the initial values were not comparable due to the significant differences in granule size, shape and weight ($p < 0.001$). All analyses were performed using Minitab 19 (Minitab Inc 2019).

III. Results and Discussion

Bulk density data was collected both before and after cycling and is summarized in the box plots in Figure 1.

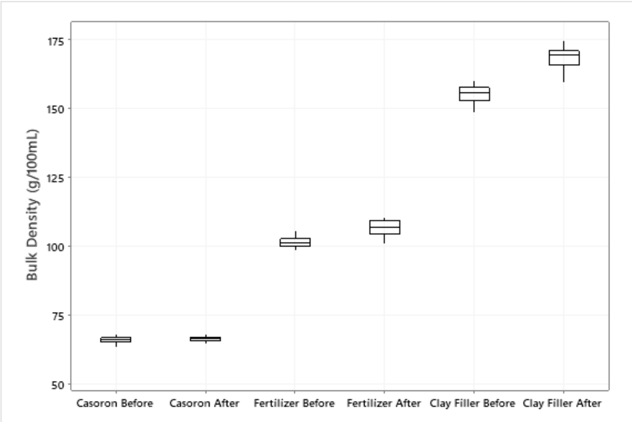

Figure 1: Box plots of bulk density both before and after cycling for each of the tested granules

Across all samples, variance was low, with a maximum standard deviation of 3.61 g 100 mL^{-1} observed with the clay filler after cycling sample. The reason that clay filler had the greatest variance was likely due to it having the greatest variation in before cycling granule size (SD = 3.09 mm).

Comparison of granule bulk density before and after cycling for Casoron G-4 was not significantly different ($p = 0.220$) while for the fertilizer and clay filler it was significantly different ($p < 0.000$ for both granules). For Casoron G-4 this is encouraging, as it indicates that the product will not significantly degrade when cycled pneumatically. As this is a requirement for the under-development spot applicator, it suggests that Casoron G-4 will make a good candidate for use in this system. It should also be noted that air speeds used in this study were in excess of what will be used with the spot applicator. This was done to assess the worst-case scenario. Air speeds used in this study ranged from 29 m s^{-1} to 44 m s^{-1} while the spot applicator uses an average air speed of 19.3 m s^{-1}.

While it was determined that there was a significant difference in bulk density for the granular fertilizer before and after cycling this could be down to the fact that the samples saw very little variation with means of 101.58 ± 0.36 g 100 mL^{-1} and 106.45 ± 0.56 g 100 mL^{-1} Further, through visual observation it was concluded the greatest proportion of the breakdown occurred in the potash component of the fertilizer. Following cycling, the potash granules were reduced to a powder while the nitrogen, phosphate and filler granules seemed to hold their relative shape through visual observation (Figure 2). It is hypothesized that the degradation of the potash is the greatest contributor to the significant increase in bulk density observed with the granular fertilizer.

Through analyzing granule length, it was determined that Casoron G-4 saw no significant reduction in size ($p = 0.378$). The fertilizer saw moderately significant size reduction ($p = 0.086$), further supporting the conclusion that the potash granules were the greatest contributor to the significant increase in bulk density seen with the fertilizer. The clay filler saw significant decrease in particle size ($p = 0.003$) which is in accordance with the bulk density data.

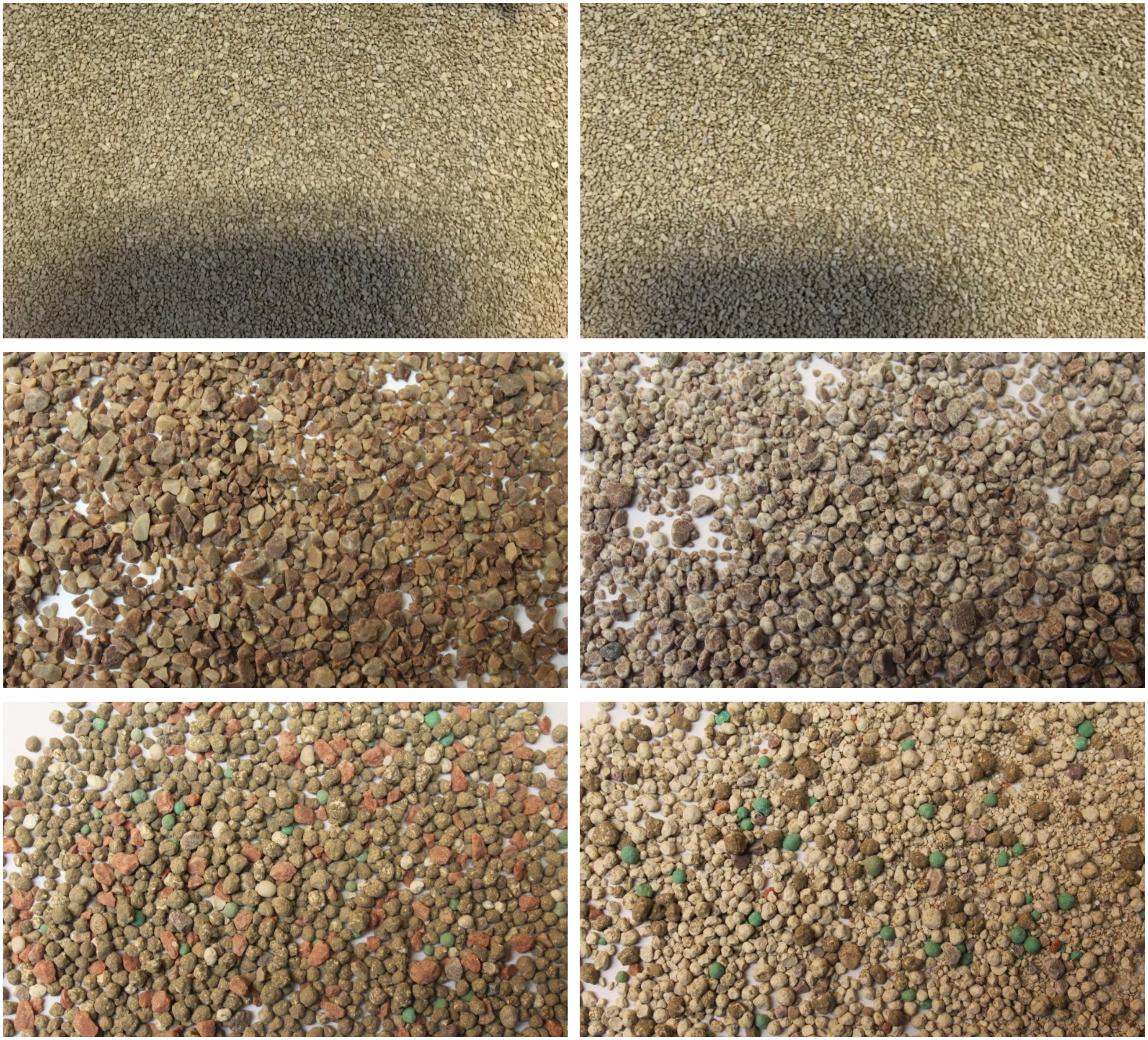

Figure 2: Images of agrochemicals before and after cycling; Casoron G-4 before (top left), Casoron G-4 after (top right), clay filler before (middle left), clay filler after (middle right), fertilizer before (bottom left) and fertilizer after (bottom right)

The clay filler saw the greatest increase in bulk density across all granules with a mean difference of 13.34 g $100mL^{-1}$ between the before and after samples. This data is in accordance with the particle size data which saw an average reduction of 0.721 mm between the before and after cycling samples of clay filler.

The results of this study serve as a baseline for the development of a pneumatic spot applicator for granular agrochemicals. While this study did see significant breakdown in both the fertilizer and clay filler, the system was presenting the worst-case scenario, where the product was cycled at high speed, constantly, for an hour. Consider the initial average bulk density for the fertilizer of 101.57 g 100 mL^{-1}. This means that the most fertilizer which could be loaded into the hopper would be 588.15 kg. At an application rate of 200 kg ha^{-1} (Chattha et al. 2014) this amount of product could cover 3.82 ha, assuming 30% bare spots (Chattha et al. 2014) to which fertilizer is not applied. At an average travel speed of 1.33 m s^{-1} (Chattha et al. 2014) the hopper would be emptied in 71.39 minutes, only slightly longer than the cycling time used in this experiment. That said, the cycling done in this experiment was performed at a higher air speed than the applicator will use, and with only 1 L of packed sample. This ensured that the product was in constant motion and did not have time to sit in the collection funnel. In the theoretical calculation, the fertilizer would encounter a far longer retention time in the hopper, limiting the total amount of cycling time and stress it would incur. Only as the system neared emptying the hopper would the product see anything close to constant cycling. Assuming the application rate is held constant throughout, the average retention time in the hopper for a single particle would be 28.74 minutes. This could further be improved by refilling the hopper before the product level gets too low.

IV. Conclusion

In all, it is conceivable that a pneumatic based spot applicator would be viable from the standpoint of granule robustness. Particularly, when it comes to Casoron G-4 which saw no significant product degradation ($p = 0.220$) as a result of pneumatic cycling. While the fertilizer used in this study did see some product breakdown ($p < 0.000$), it was visually determined that this was primarily due to breakdown of the potash granules within the sample. The clay filler sample also saw significant product degradation ($p < 0.000$) both in terms of bulk density and through visual assessment. Despite the significant differences in before and after cycling bulk densities for the fertilizer and clay filler, the experimental setup was designed as a worst-case scenario. Air speeds used in the applicator range from 9.7 m s^{-1} to 24.7 m s^{-1} slower that what was used in the test experiment and hopper retention time should be much longer in the applicator. This will have the effect of reducing the total cycling time over the total application time. Further work is planned to expand the number of tested agrochemicals and to observe the effect which cycling in the applicator would have. In all, this study lays promising groundwork for the development of a pneumatic spot applicator for application of granular agrochemicals.

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