# Comparison of Soy Protein Based and Commercially Available Seed Lubricants for Seed Flowability in Row Crop Planters

S. Badua, A. Sharda, R. Strasser, K. Cockerline, I. Ciampitti

**Abstract.** *Seed lubricants play a crucial role in proper seed singulation by ensuring a smooth flow of the seeds through the metering unit. However, the harmful chemicals inadvertently expelled along with the air during the seed metering process have raised concerns regarding the negative effects of available lubricant to the environment. An alternative has been developed from soy protein, however, no knowledge exists regarding its suitability as a potential seed lubricant. Therefore, the objectives of this study was (1) to assess seed flowability by quantifying seed singulation for both corn (*Zea mays*) and soybean (*Glycine max*) crops, and (2) to perform a simple cost analysis to determine the cost of usage of each seed lubricant. To address these objectives, two Horsch planter row units were used to run simulated planting scenarios in the laboratory. One row unit was equipped with a seed tube sensor to record seed tube seed count and time interval while the other one was fitted with an encoder to record seed meter motor rpm. These data were used to quantify percentage seed singulation, skips/misses, and multiples. Treatment factors were seed size with three levels: small, medium, large and seed lubricant with four levels: talc, fluency agent; soy protein based, and fourth being no lubricant. Row unit was programmed to plant seeds at 7.2 kph (5 mph) simulated ground speed with a target population of 89,000 seeds/ha for corn and 370,000 seeds/ha for soybean. Each test was replicated three times in a completely randomized design. For corn, result suggests that large seeds of different shapes showed greater singulation irrespective of type of seed lubricant. For soybeans, results suggest that both seed lubricant and seed size could potentially affect seed flowability. Medium size soybeans exhibited greater singulation for all four levels of seed lubricants while Fluency Agent and soy protein resulted in greater singulation along with fewer skips and multiples. A cost analysis shows that usage cost of soy protein as seed lubricant is 63% less expensive as compared to Fluency Agent although slightly expensive by 44% compared to talc. In summary, soy protein could be an alternative seed lubricant for row crop planters in providing equivalent or better seed flowability, cost-effectiveness and environmental stewardship.*

***Keywords.*** *Seed flowability, Row crop planter, Singulation, Seed lubricant, Soy protein.*

The use of seed lubricants on pneumatic row crop planters has been recommended by most planter manufacturers (DuPont Pioneer, 2014) and as a standard practice for growers during planting (Xue et al., 2015) Seed lubricants improve seed flowability and singulation by reducing seed-to-seed-friction and preventing seeds from sticking together. Flowability is defined as the ability of the seeds to seamlessly flow within the seed metering system while singulation is the accuracy of the metering system to deliver individual seeds from the metering system to the ground. Sidhu et al. (2017) studied the effect of various coating materials and seed lubricant on singulation of coated sunflower kernels using a precision planter and reported a significant increase in the overall singulation and post-planting germination of coated kernels with the use of seed lubricant. Most widely used seed lubricants are talc and graphite. Graphite is a naturally occurring mineral form of the element carbon. Hexagonal network of carbons atoms in graphite forms sheets that are poorly connected and easily cleave or slide over one another. The characteristics of this mineral gives its very low hardness, and its distinctive greasy feel (King, 2018). This property of graphite makes it an excellent dry lubricant in reducing friction between seeds and seeding mechanisms. Talc is a hydrous magnesium silicate mineral. Similar to graphite, talc has a poorly bonded sheet structures which is responsible for its softness, soapy and greasy feel (geology.com). In powder form, it has the ability to absorb moisture and can also provide lubrication.

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This property makes talc an ideal material for a drying agent. During planting, the high volume of air taken up by pneumatic seed metering systems contains water vapors that could be absorbed by insecticide and fungicide coatings due to the inherent hygroscopic characteristics of these chemicals. Mixing talc with the seeds prevents them from sticking to each other, to the seed metering components and allows free flow of seeds during planting (Krupke et al. 2012).

Neonicotinoid insecticide was commercially introduced in the 1990s by Bayer CropScience (Alford and Krupke, 2017) and since become the widely used insecticide class in the world (Douglas and Tooker, 2015). Neonicotinoids are a new class of neuroactive insecticide chemically similar to nicotine (Fischer and Chalmers, 2007) and commonly used systemic insecticides for seed treatments (Jeschke and Nauen, 2008) because of its ability to protect the seeds from early season pests and sucking insects in various crops such as corn and other cereals (Nuyttens et al., 2013). Rapid increase in neonicotinoid use was reported between 2003 to 2011 accounting for more than 40% and 90% of hectares of soybeans and corn, respectively, treated with this insecticide (Douglas and Tooker, 2015). Although seed treatments using neonicotinoids have shown some benefits (Jeschke and Nauen, 2008) as compared to other methods of pesticide application (Nuyttens et al., 2013; Bailey et al., 2015), the increased use of this systemic insecticide has been implicated in a significant exposure at varying concentration of the active ingredient contaminating the air, vegetation, soil surface, and water sources (Xue at al., 2015; Nuyttens and Verboven, 2015; Van der Sluijs et al., 2013). Previous studies showed that some of the systemic insecticide seed coatings are abraded and attached with talc as it comes out of the vacuum exhaust fan system of the planting system (Xue et al., 2015) and is dispersed into the atmosphere. These residual talc contains a concentration of up to 15 mg/g of seed treatment compounds which are above the contact lethal dose for bees (Bonmatin et al., 2015) When settled on vegetation, these chemicals from the seed kernels contaminates the air and surrounding vegetation and is harmful to these pollinators during foraging (Samson-Robert et al., 2017). Preventive measures have been done which include modifying the planting equipment by placing deflectors to reduce exhaust wind speed and dust drift (Biocca et al., 2011 and Pochi et al., 2012). Nevertheless, these measures were unsuccessful in preventing emission of contaminated dust particles (Tapparo et al., 2012). Moreover, many growers still prefer planters without deflectors due to high generation of soil dust especially when planting at dry soil conditions reducing visibility and equipment contamination (Nuytens and Verboven, 2015).

In 2014, Bayer CropScience introduced a new seed flow lubricant formulation alternative to talc and graphite known as the Fluency Agent. This lubricant is a polyethylene-wax-based powder that was developed to reduce the dispersal of contaminated dust into the atmosphere during planting. It also claims improved seed flow, providing good singulation and less residue build up resulting in easier cleaning of the seed hopper. Independent performance trial tests comparing talc and the new Fluency Agent Advance showed more than 88% reduction in total dust and 65% reduction in the active ingredient (neonicotinoid) dust when using Fluency Agent (Bayer CropScience, 2017). However, a study conducted by the Corn Dust Research Consortium (2017) reported little evidence of reduction in insecticide leaving the planter compared to talc and graphite. Several options to modify planting systems have been identified to minimize contaminated dust released during planting which includes using a seed lubricant that can reduce seed abrasion. Recently, an environmentally friendly material has been developed as a potential seed lubricant alternative. Soy protein is produced after dehulling and defatting of soybean which are available in various forms such as soy flour, soy protein concentrate, and soy protein isolate. Soy protein isolate contains three major proteins of varying proportions where one of them is phospholipids which is associated with lecithin (Samoto et al., 2007). Lecithin derived from soybean has been widely used as an emulsifier, stabilizer, and lubricant (Xu et al., 2011). Soy protein has been extensively used in many industrial applications due to its environmentally friendly properties such as renewable agricultural feedstock, abundantly available, low cost, and biodegradable (Swain et al., 2004; Chhavi et al., 2017). Moreover, soy protein is an ideal source of amino acids (Singh et al., 2008) which can act as a biostimulant for plant leading to better seed germination and biological activity (Popko et al., 2018).

The use of a green source material has the ability to reduce negative environmental impacts created by commercially available seed lubricants. However, no evidence exists if the soy protein lubricants aid in proper seed flow through planting system. Therefore, this study was designed with the objective of quantifying seed flowability of corn and soybean seeds in a simulated controlled experiment and determine the economic viability of soy protein as an alternative to commercially available seed lubricants.

# METHODOLOGY

## ROW UNIT CONFIGURATION AND DATA ACQUISITION

The study was conducted using a production Horsch Maestro planter row unit (Horsch Maschinen GmbH, Schwandorf, Germany) equipped with an electronic drive seed meter. The seed meters were linked through ISOBUS to the Horsch Terminal ME controller display (Horsch Maschinen GmbH, Schwandorf, Germany) that controlled the desired ground speed and seeding rate. The row unit's vacuum system was set at 7.5 kPa (1.08 psi). Two row units were utilized in the experiment. The first row unit was used to plant the target seeding rate of 89,000 and 370,000 seeds/ha for corn and soybean, respectively, at a simulated speed of 7.2 kph (5 mph). A 21-notch seed plate for corn and a 96-hole plate for soybean, delivering 21 and 96 seeds per revolution, respectively, was placed on the electric seed meter. For corn, one seed plate with was used for small seeds while another seed plate was used for medium and large seeds. For soybeans, one seed plate was used for all seed sizes. Seed count and time interval were recorded using a seed tube sensor (Hy Rate Plus™, DICKEY-john, Auburn, Illinois) already installed on the first row unit. The second row unit was used to record real-time seed meter motor revolutions using an incremental thru-bore encoder (Accucoder, Encoder Product Company, Sagle, Idaho) with 3000 pulses per revolution and ±0.2 rpm measurement error that was attached to shaft of the seed meter's electric motor. Previous research conducted on the planter row units (Mangus et al., 2017) indicated that there is less than 0.2% error in seed meter motor rpm and the seed tube count when simultaneously measuring these from two separate row units. Therefore, two row unit setup was utilized, one row unit for collecting seed tube data, and second row unit to measure seed meter motor rpm (fig. 1). These data was collected using a custom program developed in LabVIEW using a Compact Rio (cRIO) (9204, National Instruments, Austin, Tex.) field-programmable gate array (FPGA) chassis and C-Series modules at 40 Hz sampling rate. A custom visual basic program developed in Microsoft Excel was then used to calculate percent seed singulation, skips/misses and multiples. These parameters were used to analyze flowability across seeds of varying sizes using the different levels of seed lubricant.

### Experimental Lay-out

The study was conducted at the advanced planting systems laboratory of the Biological and Agricultural Engineering Department at Kansas State University. Two set of experiments were performed utilizing corn and soybeans with varying sizes to understand the performance of seed lubricants by quantifying seed flowability. For the first experiment, referred herein as E1, three corn hybrids (table 1) and soybean varieties (table 2) from Ohlde (Ohlde seed farms, Palmer, Kan.) were used while the second experiment, referred herein as E2, utilized three corn hybrids (table 3) from Pioneer (DuPont Pioneer, Johnston, Iowa) and three soybean varieties from Ohlde (table 4). Seed hybrid/variety corresponds to the size of the seed and each hybrid/variety was treated with different levels of seed treatment. For soybeans, varieties were treated with SDPI (Servo™ DPI) and Inoculant. For corn, Oldhe hybrid seeds were treated with Acceleron® Basic and Pioneer® hybrid seeds were treated with Optimum® Acre Max® Xtra. Two treatment factors were implemented for each experiment. Factor A is the seed size with three levels: small, medium and large; and factor B is the seed lubricant with four levels: talc (John Deere, Moline, Ill.), fluency agent (Bayer CropScience, Research Triangle Park, N.C.), soy protein (Lowmutech, Calamus, Iowa) and a control treatment or no lubricant. The amount of seed lubricant mixed on each experimental unit (EU) were based on recommended levels of the product manufacturer. Each EU consists of 1,800 grams of seeds. Seeds and the recommended amount of lubricant for that sample were placed on a storage plastic bag and

**Table 1. Properties of corn used in E1.**

| Seed Brand | Seed Variety | Seeds/kg (Seeds/lb) | Seed Size/ Shape | Seed Treatment |
|---|---|---|---|---|
| Ohlde | 24-14 | 4,546(2,057) | Small flat | Acceleron® Basic |
| Ohlde | 27-16 | 3,439 (1,556) | Medium round | |
| Ohlde | 28-13 | 3,066 (1,387) | Large flat | |

**Table 2. Properties of soybeans used in E1.**

| Seed Brand | Seed Variety | Seeds/kg (Seeds/lb) | Seed Size/ Shape | Seed Treatment |
|---|---|---|---|---|
| Ohlde | O-45L6-B | 7,455 (3,373) | Small round | Inoculant |
| Ohlde | O-42L6-B | 6,690 (3,027) | Medium round | |
| Ohlde | O-42X6 | 6,359 (2,877) | Large round | |

**Table 3. Properties of corn used in E2.**

| Seed Brand | Seed Variety | Seeds/kg (Seeds/lb) | Seed Size | Seed Treatment |
|---|---|---|---|---|
| Pioneer | P1271YHR | 4,772 (2,159) | Small | Optimum® Acre Max® Xtra |
| Pioneer | P1522YHR | 3,857 (1,745) | Medium | |
| Pioneer | P2089YHR | 2,968 (1,343) | Large | |

**Table 4. Properties of soybeans used in E2.**

| Seed Brand | Seed Variety | Seeds/kg (Seeds/lb) | Seed Size | Seed Treatment |
|---|---|---|---|---|
| Ohlde | O-45L6 | 7,455 (3,373) | Small | SDPI (Servo™ DPI) |
| Ohlde | O-37X6 | 6,336 (2,867) | Medium | |
| Ohlde | O-37L7 | 6,197 (2,804) | Large | |


**Figure 1. The laboratory set up at the Planting Systems Laboratory where the simulated planting tests were performed.**

mixed thoroughly before each test run. For each experiment, EUs were arranged in a 3×4 factorial treatment structure in a completely randomized design (CRD) with 3 replicates corresponding to 182 test runs. Number of samples for each test run ranged from 4,200 to 5,800 seeds for corn and 7,200 to 10,500 seeds for soybean and varying number of sample is due to seed size. For each test, simulated planting will start once samples are placed on the seed hopper mounted on the row unit (fig. 1) and stops once last seed passes through the seed tube. Each test run lasted from 3 to 5 min. Statistical tests for the main effects and interactions were performed using the PROC GLIMMIX procedure in SAS University Edition 2017 (SAS Institute Inc., Cary, N.C.). A Tukey (HSD) post-hoc analysis was used to separate significantly different treatment means. Effects were considered statistically significant at the 0.05 level of probability unless otherwise indicated.

A cost analysis was performed by considering manufacturers recommended application rate for each type of seed lubricant. The industry standard unit of 140,000 soybean seeds per bag and 80,000 corn seeds per bag were used in the analysis. Likewise, cost per container was obtained from manufacturer to determine the cost per unit weight of the lubricant. This value was multiplied to the application rate to calculate the usage cost of lubricant per hectare (per acre).

### Soy Protein Based Material

The soy-based planter box lubricant is greater than 99% hydrolyzed isolated soy protein powder with less than 1% soy lecithin added to the particle surface. The particle shape of the powder is spheroid with the average particle size range from 90 to 100 microns (fig. 2).

The mechanism for the soy based planter box lubricant has two components. First, the spheroidal shape of soy protein particles allow the seeds to "roll" past one another as opposed to the irregular shape of talc and Fluency Agent which creates a "sliding" action between particles. (fig. 3). This mechanism may be the reason on the abrasiveness of talc (Xue et al., 2015). Rolling is less abrasive to the seeds. Second, the soy protein contains lecithin which acts as a lubricant for points of contact and as a dust control agent. Together the shape and composition of soy protein create a viable planter seed lubricant.

### Biodegradability

Another feature of hydrolyzed soy protein isolates is they are highly degradable, unlike synthetic polymers (Fluency Agent). Once the planting process is complete, soy protein are left to degrade in the soil. This minimizes issues with buildup and run off. Degradability can be measured in many ways. One measure that has been used by a number of researchers is the ratio of 5-day Biological Oxygen Demand to Chemical Oxygen Demand (BOD/COD). The BOD/COD ratio of soy protein is typically over 50%. Biodegradability of hydrolyzed soy protein isolates had also been measured using the Modified Sturm Test, (OECD 301B - CO2 Evolution Test), another measure of degradability. The biodegradation of the product is expressed as percentage of theoretical carbon dioxide 28 days after acidification and incubation at 22 ± 2°C. Hydrolyzed soy polymers were 88% degradable after 28 days, compared to an aniline control at 93%. Bacterial or fungal attack (biodegradation) usually results in the cleavage of covalent bonds along the polymer

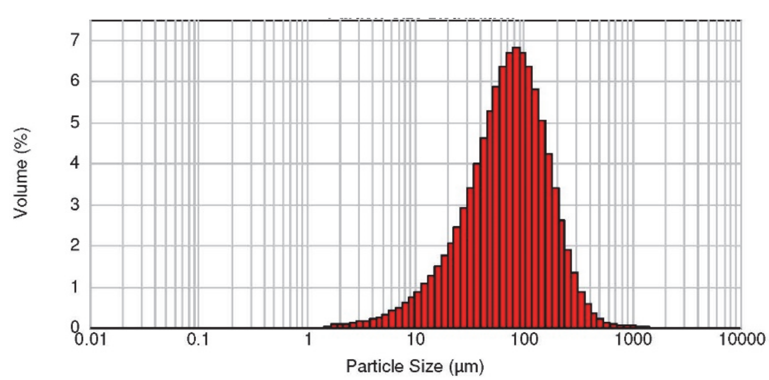
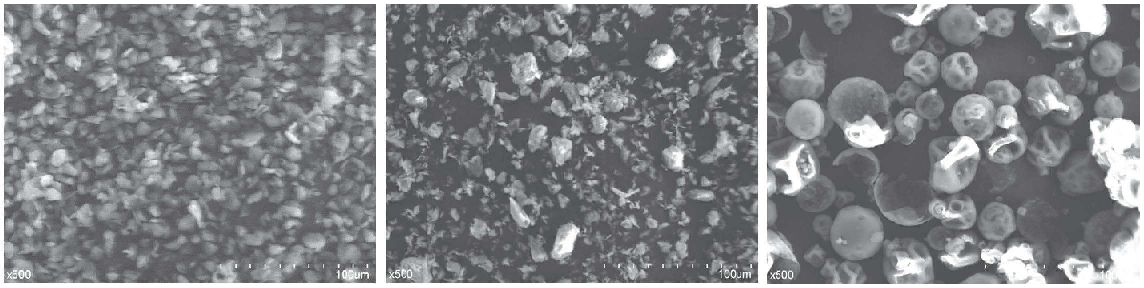



**Figure 2. Particle size distribution of the soy protein lubricant analyzed using a Mastersizer 2000 (Malvern Panalytical, Flanders Road Westborough, Mass.).**




**Fluency agent** **Talc** **Soy-based protein**

**Figure 3. Particle shape of commercially available seed lubricants and the soy protein lubricant magnified at 500X using a Hitachi S-3400N Scanning Electron Microscope (SEM) (Hitachi, Ltd, Prospect Ave., Tarrytown, N.Y.).**

chain, reducing the molecular weight of the polymer to permit metabolism of the polymer by the microbe.

## RESULTS AND DISCUSSION

### CORN SEED SINGULATION

Results on experiment E1 showed that average seed singulation across seed lubricant treatments ranged from 98.6% to 98.9%, 0.82% to 1.22% for skips and 0.41% to 0.54% for multiples. On the other hand, average seed singulation across seed size treatments ranged from 98.2% to 99.0%, 0.55% to 1.47% for skips and 0.36% to 0.66% for multiples. No significant difference on singulation, skips and multiples was observed across seed lubricants. Seed size influenced seed flowability resulting in a significant difference in singulation and skips while occurrence of multiples did not differ across seed sizes (table 5). Large seeds achieved significantly higher singulation of 99.3% and lower occurrence of skips at 0.2% across all seed sizes (table 6). There was, however, no significant differences across seed lubricant treatments and the interaction between seed lubricant and seed size.

Similarly, the experiment E2 showed significant difference in singulation, skips and multiples between sizes of seeds but no significant differences across seed lubricant treatments and the interaction between seed lubricant and seed size (table 7). Metering large seeds resulted in a higher singulation and lower skips at 99.0% and 0.6%, respectively. In contrast, smaller seeds achieved a significantly higher incidence of multiple seeds at 0.4% (table 8).

Such results indicate that seed size could potentially affect seed flowability regardless of the seed treatment applied. In general, large seeds whether round or flat singulates best irrespective of what type of seed lubricant was used. Small seeds achieved the lowest singulation and higher multiples because it may have required additional seed lubricant due to increase in surface area. Interestingly, seed lubricant did not appear to significantly differ in terms of singulation.

**Table 5. ANOVA table for the effect of seed lubricant and seed size on singulation, skips and multiples in corn for E1.**

| Source of Variation | Singulation[a] | Skips | Multiples |
|---|---|---|---|
| Seed lubricant | ns | ns | ns |
| Seed size | ** | ** | ns |
| Seed lubricant × seed size | ns | ns | ns |

[a] ns, non significant; and **, significant at P≤0.05, respectively.

**Table 6. Means of % singulation, skips, and multiples for corn as influenced by seed size for E1.**

| Seed Size | Singulation (%)[a] | Skips (%) | Multiples (%)[b] |
|---|---|---|---|
| Small flat | 98.1[c] | 1.26[a] | 0.6[ns] |
| Medium round | 98.9[b] | 0.5[b] | 0.6[ns] |
| Large round | 99.3[a] | 0.2[c] | 0.5[ns] |

[a] Means with the same letter are not significantly different at P≤0.05.
[b] ns: non significant.

**Table 7. ANOVA table for the effect of seed lubricant and seed size on singulation, skips and multiples in corn for E2.**

| Source of Variation | Singulation[a] | Skips | Multiples |
|---|---|---|---|
| Seed lubricant | ns | ns | ns |
| Seed size | ** | ** | ** |
| Seed lubricant × seed size | ns | ns | ns |

[a] ns, non significant; and **, significant at P≤0.05, respectively.

**Table 8. Means of% singulation, skips and multiples for corn as influenced by seed size for E2.**

| Seed Size | Singulation (%)[a] | Skips (%) | Multiples (%) |
|---|---|---|---|
| Small round | 98.3b | 1.2a | 0.6a |
| Medium round | 98.2b | 1.5a | 0.4b |
| Large flat | 99.0a | 0.6b | 0.5b |

[a] Means with the same letter are not significantly different at P≤0.05.

However, without seed lubricants friction inside the metering unit needing lubricant might reduce the operating life of the seed metering components in the long run (DuPont Pioneer, 2014). No significant differences across the seed lubricants on seed singulation suggested that soy-based protein seed lubricant have similar potential to provide the desired seed flowability comparable to other commercially available seed lubricants when planting corn seeds applied with different seed treatment coatings.

### SOYBEAN SINGULATION

For experiment E1, results suggest average seed singulation ranged from 78.1% to 79.4%, 8.70% to 10.9% for skips/misses, and 10.8% to 12.0% for multiples. Flowability was affected by seed lubricant resulting in significant differences in skips and multiples but no significant differences in singulation was observed. On the other hand, seed size had a significant effect on flowability while no significant interaction between seed lubricant and seed size was observed (table 9). Soy protein achieved the lowest misses/skips at 8.7% while Fluency Agent had the lowest multiple at 10.8% (table 10). Medium seeds achieved the highest singulation and lowest incidence of multiples at 79.6% and 10.8%, respectively. Large seeds achieved the lowest incidence of misses/skips at 8.8% (table 11).

Results show the average seed singulation ranged from 79.6% to 81.5%, 8.3% to 8.9% for skips/misses and 9.8% to 11.7% for multiples for experiment E2. Significant differences were observed in singulation, skips and multiples across seed lubricants and seed sizes (table 12). Fluency Agent achieved the highest singulation at 81.5% and lowest multiples at 9.8% while soy protein achieved the lowest incidence of skips/multiples at 8.3%. Soy protein resulted in a comparable singulation and multiples across all lubricants

**Table 9. ANOVA table for the effect of seed lubricant and seed size on singulation, skips and multiples in soybeans for E1.**

| Source of Variation | Singulation[a] | Skips | Multiples |
|---|---|---|---|
| Seed lubricant | ns | * | ** |
| Seed size | ** | ** | ** |
| Seed lubricant × seed size | ns | ns | ns |

[a] ns, non significant; *, significant at P≤0.10; and **, significant at P≤0.05, respectively.

**Table 10. Means of% singulation, skips and multiples for soybeans as influenced by seed lubricant for E1.**

| Seed Size | Singulation (%)[a] | Skips (%)[b] | Multiples (%)[c] |
|---|---|---|---|
| No lubricant | 78.4[ns] | 9.7[a] | 11.9[c] |
| Talc | 78.1[ns] | 9.9[a] | 12.0[c] |
| Fluency Agent | 79.1[ns] | 10.1[a] | 10.8[d] |
| Soy protein | 79.4[ns] | 8.7[b] | 11.9[c] |

[a] [ns] Non significant
[b] [ab] Means with the same letter are not significantly different at P≤0.10.
[a] [cd] Means with the same letter are not significantly different at P≤0.05.

Table 11. Means of % singulation, skips and multiples for soybeans as influenced by seed size for E1.

| Seed Size | Singulation (%)[a] | Skips (%) | Multiples (%) |
|---|---|---|---|
| Small | 77.7[b] | 10.3[a] | 12.0[a] |
| Medium | 79.6[a] | 9.6[a] | 10.8[b] |
| Large | 79.0[a] | 8.8[b] | 12.2[a] |

[a] ab Means with the same letter are not significantly different at P≤0.05.

Table 14. Means of % singulation, skips and multiples for soybeans as influenced by seed size for E2.

| Seed Size | Singulation (%)[a] | Skips (%) | Multiples (%) |
|---|---|---|---|
| Small | 81.1[b] | 7.2[c] | 11.8[c] |
| Medium | 83.2[a] | 8.2[b] | 8.6[b] |
| Large | 76.8[c] | 10.3[a] | 12.9[a] |

[a] abc Means with the same letter are not significantly different at P≤0.05.

(table 13). Medium seeds achieved the highest singulation and lowest incidence of multiples at 83.2% and 8.6%, respectively, while small seeds achieved the lowest incidence of misses/skips at 7.2% (table 14).

Such results suggest that seed lubricant and seed size could potentially affect seed singulation when planting soybeans. Unlike corn, Fluency Agent and soy protein revealed the highest singulation and the lowest skips and multiples. This indicates that soy protein is capable of providing same level of flowability across a wide range of seed size comparable to other seed lubricants. Medium size soybeans achieved the best singulation and lowest incidence of multiples. Such result can be due to the recommended increase in application rate of seed lubricants for smaller or larger seeds (DuPont Pioneer, 2014). The recommended application rate used in the study as suggested by the manufacturer may be best for medium or average seed size resulting in better seed flowability across seeds sizes. In general, this is somewhat expected as larger seeds coated with seed treatments requires more management of appropriate planter settings (vacuum pressure and seed plate size) to ensure proper seed singulation (DuPont Pioneer, 2019). Large seeds may require greater vacuum pressure or larger seed plate slot diameter to allow the seeds to remain in the seed slot until it is ready to be dropped in the seed tube.

Overall, results indicate that soy protein seed lubricant can provide comparable flowability to currently available seed lubricants by providing equally good singulation, misses/skips and multiples. No significant differences in singulation show that soy protein can effectively provide the lubrication inside the metering system reducing friction between seeds and metering components (Krupke et al., 2012). Moreover, the spheroidal particles of soy protein can act as a roller bearing which could potentially reduce abrasiveness of the material compared to talc. This property of soy protein

Table 12. ANOVA table for the effect of seed lubricant and seed size on singulation, skips and multiples in soybeans for E2.

| Source of Variation | Singulation[a] | Skips | Multiples |
|---|---|---|---|
| Seed lubricant | ** | * | ** |
| Seed size | ** | ** | ** |
| Seed lubricant × seed size | ns | ns | ns |

[a] ns, Non significant; *, significant at P≤0.10; and **, significant at P≤0.05, respectively.

Table 13. Means of % singulation, skips, and multiples for soybeans as influenced by seed lubricant for E2.

| Seed Size | Singulation (%)[a] | Skips (%) | Multiples (%) |
|---|---|---|---|
| No lubricant | 79.8[d] | 8.5[b] | 11.7[c] |
| Talc | 79.6[d] | 8.9[a] | 11.5[c] |
| Fluency Agent | 81.5[c] | 8.7[b] | 9.8[d] |
| Soy protein | 80.4[cd] | 8.3[b] | 11.2[c] |

[a] ab Means with the same letter are not significantly different at P≤0.10.
cd Means with the same letter are not significantly different at P≤0.05.

as a seed lubricant could potentially reduce the amount of insecticide abraded from treated seeds. On the other hand, large corn seed while medium soybean seeds provided the highest singulation. Differing seed flowability across seed sizes could indicate proper selection of planter settings to achieve optimum singulation.

### Cost Analysis

A simple cost analysis showed that using the soy protein resulted in cost of usage at \$1.26/ha for corn and \$2.79/ha for soybeans (table 15). The usage cost of Fluency Agent is almost tripled when compared to soy protein at \$3.43 and \$7.61/ha for corn and soybean, respectively. However, usage cost of soy protein is slightly higher than talc. The cost analysis suggests that soy protein seed lubricant would be a great alternative to other commercially available seed lubricants, although slightly more expensive than talc, the benefit of using a renewable and biodegradable alternative seed lubricant is environmental stewardship.

## Conclusions

The potential negative impact on the environment and high cost of commercially available seed lubricants motivated to look for an alternative seed lubricant. Soy protein is derived from dehulled and defatted soybean. Features of soy protein as a seed lubricant are environment friendly, renewable abundant source, contains compounds that improves plant growth, inexpensive material and biodegradable.

Test results suggest that seed size could potentially affect seed flowability regardless of the seed treatment coating applied in corn. Large seeds at varying shapes singulates best irrespective of what type of seed lubricant used. In soybeans, results suggest that seed lubricant and seed size could potentially affect seed flowability. Medium size soybeans achieved the best singulation while fluency agent and soy protein resulted the highest singulation and the lowest skips and multiples. In summary, soy protein seed lubricant have the potential to provide the desired seed flowability similar to other commercially available seed lubricants. Simple cost analysis showed that soy protein seed lubricant had lowest cost of usage per hectare compared to Fluency Agent at \$1.26 and \$2.79 for corn and soybeans, respectively, but slightly expensive than talc. However, using a renewable and biodegradable seed lubricant show a responsible practice of protecting the environment. Future tests should be performed to quantify dust emission and reduction of seed treatment coatings in the atmosphere during planting.

**Table 15. Simple cost analysis comparing the cost of applying the different seed lubricants for corn and soybean.**

| Seed Lubricant | Weight per Container kg (lb) | Cost per Container $ | Cost per g (oz) of Lubricant $ | Recommended Application Rate, g (oz) per 80,000 Corn Seeds | Recommended Application Rate, g (oz) per 140,000 Soybean Seed | Seeding Rate, Seeds/ha (seeds/acre) | | Cost of Lubricant $/ha ($/acre) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Corn | Soybean | Corn | Soybean |
| Talc | 17. 7 (8) | 20.0 | 5.7 (0.2) | 113.4 (4) | 113.4 (4) | 88,920 (36,000) | 345,800 (140,000) | 0.69 (0.28) | 1.56 (0.63) |
| Fluency agent | 9.7 (4.4) | 108.5 | 42.5 (1.5) | 8.0 (0.28) | 8.0 (0.28) | 88,920 (36,000) | 345,800 (140,000) | 3.43 (1.36) | 7.61 (3.01) |
| Soy protein | 24.3 (11) | 49.5 | 8.5 (0.3) | 113.4 (4) | 113.4 (4) | 88,920 (36,000) | 345,800 (140,000) | 1.26 (0.51) | 2.79 (1.13) |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## REFERENCES


Alford, A., & Krupke, C. H. (2017). Translocation of the neonicotinoid seed treatment clothianidin in maize. *PLoS One, 12*(3), e0173836. https://doi.org/10.1371/journal.pone.0173836

Bailey, W., DiFonzo, C., Hodgson, E., Hunt, T., Jarvi, K., Jensen, B., & Michel, A. (2015). The effectiveness of neonicotinoid seed treatments in soybean. Coop. Ext. Publ. No. E-268. West Lafayette, IN: Purdue University.

Bayer. (2017). Introducing fluency agent advanced. Retrieved from https://www.cropscience.bayer.us/-/media/Bayer-CropScience/Country-United-States-Internet/Documents/Products/Seeds-Treatments/Fluency-Agent/Fluency-Agent-Advanced-Product-Bulletin.ashx?la=en&hash=A41C0D41680A649299DAC0F7EFAFC15DB302D2F9

Biocca, M., Conte, E., Pulcini, P., Marinelli, E., & Pochi, D. (2011). Sowing simulation tests of a pneumatic drill equipped with systems aimed at reducing the emission of abrasion dust from maize dressed seed. *J. Environ. Sci. Health, Part B, 46*(6), 438-448. https://doi.org/10.1080/03601234.2011.583825

Bonmatin, JM., Giorio, C., Girolami, V., Goulson, D., Kreutzweiser D.P., Krupke, C., Liess, M., Long, E., Marzaro, M., Mitchell, E. A.D., Noome, D.A., Simon-Delso, N., & Tapparo, A. (2015). Environmental fate and exposure; neonicotinoids and fipronil. *Environ Sci Pollut Res.* 22, 35-67. https://doi.org/10.1007/s11356-014-3332-7

Chhavi, D. K., Singh, V. K., Sakshi, C., & Naman, J. (2017). Soy protein based green composite: A review. *Res. Reviews: J. Material Sci.* https://doi.org/10.4172/2321-6212.1000171

Corn Dust Research Consortium. (2017). Corn Dust Research Consortium Final Report. Retrieved from https://pollinator.org/assets/generalFiles/CDRC-FINAL-REPORT-October-2017.pdf

Douglas, M. R. & Tooker, J. F. (2015). Large-Scale Deployment of Seed Treatments Has Driven Rapid Increase in Use of Neonicotinoid Insecticides and Preemptive Pest Management in U.S. Field Crops. *Environ. Sci. Technol*. 49, 5088–5097. https://doi.org/10.1038/s41598-019-39701-5

DuPont Pioneer. (2014). Seed corn plantability guidelines by pioneer. DuPont Pioneer, Agronomy Sciences.

Fischer, D. L., & Chalmers, A. (2007). Neonicotinoid insecticides and honey bees: Technical answers to FAQs. *Bayer Cropsci., 14*.

Jeschke, P., & Nauen, R. (2008). Neonicotinoids - from zero to hero in insecticide chemistry. *Pest Manag. Sci., 64*(11), 1084-1098. https://doi.org/10.1002/ps.1631

King, H. (2018). Graphite: A mineral with extreme properties and many uses. [online]. Geology.com. Retrieved from https://geology.com/minerals/graphite.shtml

Krupke, C. H., Hunt, G. J., Eitzer, B. D., Andino, G., & Given, K. (2012). Multiple routes of pesticide exposure for honey bees living near agricultural fields. *PLoS One, 7*(1), e29268. https://doi.org/10.1371/journal.pone.0029268

Mangus, D. L., Sharda, A., Flippo, D., Strasser, R., & Griffin, T. (2017). Development of high-speed camera hardware and software package to evaluate real-time electric seed meter accuracy of a variable rate planter. *Computers and Electronics in Agriculture*, 142, 314-325. https://doi.org/10.1016/j.compag.2017.09.014

Nuyttens, D., & Verboven, P. (2015). Dust emission from pesticide treated seeds during seed drilling. *Outlooks Pest Manag.,* 26(5), 215-219. https://doi.org/10.1564/v26_oct_07

Nuyttens, D., Devarrewaere, W., Verboven, P., & Foqué, D. (2013). Pesticide-laden dust emission and drift from treated seeds during seed drilling: a review. *Pest management science,* 69(5), 564-575. https://doi.org/10.1002/ps.3485

Pochi, D., Biocca, M., Fanigliulo, R., Pulcini, P., & Conte, E. (2012). Potential exposure of bees, *Apis mellifera* L., to particulate matter and pesticides derived from seed dressing during maize sowing. *Bull. Environ. Contamination Toxicol., 89*(2), 354-361. https://doi.org/10.1007/s00128-012-0664-1

Popko, M., Michalak, I., Wilk, R., Gramza, M., Chojnacka, K., & Gorecki, H. (2018). Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. *Molecules, 23*(2), 470. https://doi.org/10.3390/molecules23020470

Samoto, M., Maebuchi, M., Miyazaki, C., Kugitani, H., Kohno, M., Hirotsuka, M., & Kito, M. (2007). Abundant proteins associated with lecithin in soy protein isolate. *Food Chem., 102*(1), 317-322. https://doi.org/10.1016/j.foodchem.2006.05.054

Samson-Robert, O., Labrie, G., Chagnon, M., & Fournier, V. (2017). Planting of neonicotinoid-coated corn raises honey bee mortality and sets back colony development. *PeerJ, 5*, e3670. https://doi.org/10.7717/peerj.3670

Sidhu, H., Monono, E., Bora, G., & Wiesenborn, D. (2017). Performance of coated extra-large hulled confectionary sunflower kernels for precision planting. *Agric. Res., 6*(4), 347-358. https://doi.org/10.1007/s40003-017-0285-3

Singh, P., Kumar, R., Sabapathy, S. N., & Bawa, A. S. (2008). Functional and edible uses of soy protein products. *Compr. Rev. Food Sci. Food Saf., 7*(1), 14-28. https://doi.org/10.1111/j.1541-4337.2007.00025.x

Swain, S. N., Biswal, S. M., Nanda, P. K., & Nayak, P. L. (2004). Biodegradable soy-based plastics: opportunities and challenges. *Journal of Polymers and the Environment*, 12(1), 35-42. https://doi.org/10.1023/B:JOOE.0000003126.14448.04

Tapparo, A., Marton, D., Giorio, C., Zanella, A., Soldà, L., Marzaro, M., Vivan, L. & Girolami, V. (2012). Assessment of the environmental exposure of honeybees to particulate matter containing neonicotinoid insecticides coming from corn coated seeds. *Environ. Sci. Technol* . 46: 2592–2599. https://doi.org/10.1021/es2035152

Van der Sluijs, J.P., Simon-Delso, N., Goulson, D., Maxim, L., Bonmatin, JM., & Belzunces, L.P. (2013) Neonicotinoids, bee disorders and the sustainability of pollinator services. *Curr Opin Environ Sustain* 5:1–13. https://doi.org/10.1016/j.cosust.2013.05.007

Xu, Q., Nakajima, M., Liu, Z., & Shiina, T. (2011). Soybean-based surfactants and their applications. In *Soybean-applications and technology.* IntechOpen. https://doi.org/10.5772/15261

Xue, Y., Limay-Rios, V., Smith, J., Baute, T., Forero, L. G., & Schaafsma, A. (2015). Quantifying neonicotinoid insecticide residues escaping during maize planting with vacuum planters. Environmental science & technology, 49(21), 13003-13011. https://doi.org/10.1021/acs.est.5b03753