

ASSESSING THE QUALITY OF POLYMER-COATED UREA

Matt Ruark and Mack Naber ^{1/}

Introduction

Polymer-coated urea (PCU) is a fertilizer product in which each urea prill is individually coated with a polymer (or plastic) coating. All PCUs are considered a slow or controlled release fertilizer, which is defined by the Association of American Plant Food Control Officials as a fertilizer that contains plant nutrients in a form that extends its availability significantly longer than a reference fertilizer (in this case urea) (Slater, 2014). The way PCU works is that urea dissolves inside the coating and slowly diffuses into the soil over time. The mechanism for the nitrogen-release from PCU includes three phases: (1) lag phase, (2) constant release phase, and (3) release decay phase (Shaviv et al., 2003). During the *lag phase* water is absorbed inside the coating through the pores of the polymer. Little, if any, N is released into the soil during this phase. During the *constant release phase* the water dissolves the urea and the dissolved nitrogen diffuses through the polymer into the soil. While urea in PCU readily dissolves in water, the nitrogen-release from PCU is controlled by the rate urea diffuses through the polymer coating. Diffusion is a process where the N moves from an area of high N concentration (inside the polymer coating) to an area of low N concentration (the soil environment). Nitrogen release increases as temperature increases as the coating slightly expands making the pores in the plastic bigger; N release decreases as temperatures get cooler. During the third phase, *release decay*, the release rate of N through the polymer coating slows after the urea is completely dissolved within the polymer. Unprotected urea rapidly dissolves with water and then converts (via the soil enzyme urease) to the ammonia/ammonium form. Through the microbial process of nitrification, ammonium is then converted to nitrate. While both nitrate and ammonium are plant available forms of N, they are subject to losses especially when plants are small. The advantage of PCU over unprotected urea is that it prevents large amounts of nitrate from existing in the soil early in the growing season, reducing the likelihood that it could be leached, denitrified, or volatilized. Use of PCU will have the most benefit (and is perhaps the most widely used) on sandy soils where nitrate leaching can be problematic. Use of PCU on sandy soils can lead to increases in NUE and decreases in groundwater nitrate and need for supplemental N later in the growing season (Bero et al., 2013; Maharjan et al., 2016; Wilson et al., 2010). PCU can also be beneficial on wet or poorly drained soils where denitrification losses (conversion of nitrate to nitrous oxide [N₂O] or N₂ gas) can be substantial (e.g., Halvorson et al., 2011; Noellsch et al., 2009). The PCU can also reduce N loss through ammonia volatilization compared to non-coated urea when surface applied (e.g., Connell et al., 2011) compared to non-coated urea.

^{1/} Associate Professor and Former Research Specialist, respectively, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 537056.

PCU is more expensive than urea fertilizer although the difference in price will vary year to year. Thus, the advantage of using PCU over urea may not be economical every year. The benefits of PCU are only realized when there are environmental conditions causing substantial nitrogen loss. Deciding to use PCU means you are accepting an additional cost every year to mitigate the risk that can occur in any one year.

PCU is marketed under several trade names including, in alphabetical order, CoteN® (Haifa), DurationCR® (Agrium), ESN® (Agrium) and Polyon® (Harrell's), although new products may be available on the market at any time. Each product's polymer is company specific and proprietary, and different PCU products will have different release rates of N based on the molecular characteristics and thickness of the polymer. The thickness of the coating reduces the N concentration of the fertilizer product. For example, urea is 46% N by weight while ESN® is 44% N and Polyon® is 43% N. Some of these products are marketed for agricultural crops and some for horticultural crops, turf, or ornamentals. For the purposes of this publication, mention of specific products does not indicate endorsement.

Evaluating Quality of PCU

Damage to PCU's polymer coating can result in faster nitrogen-release rates and in its effectiveness as a controlled-release fertilizer. Once the polymer is cracked, water can easily enter and the release of N will be similar to uncoated urea. Damage can occur as a result of handling practices, blending or mixing the PCU with other fertilizers, or the method of application (e.g., Agrium's ESN Use and Handling FAQ, www.smartnitrogen.com). The most severe damage has been seen during handling of PCU, especially when transferring in equipment with scaly deposits (Beres et al., 2012). Transporting with a belt conveyer instead of a steel auger would further reduce damage (Beres et al., 2012). Asking for the PCU to be the last component mixed can reduce the time in contact with other fertilizers and reduce damage as well. Also, changing the way the fertilizer is applied can also reduce damage. For example, use of airboom spreaders to apply the PCU tends to increase polymer damage. However, as long as the PCU is not damaged prior loading into the airboom truck, the amount of damage with the airboom spreader is usually less than 15% of the prills (Rosen, unpublished). Spinner spreaders or drop spreaders will result in less damage than airboom spreaders. The bottom line is not to mix the PCU with other fertilizers and avoid any unnecessary handling prior to application.

Damaged to the polymer coating can change the release pattern of N during the growing season. Research conducted at the Sand Plain Research Farm in Becker, MN showed that damaged PCU (damaged via applicator) released 60% of its N after 8 days, while undamaged PCU only released 12% (Bierman et al., 2015). Since there is extra cost of the fertilizer N with the polymer coating, it is important to know that you are receiving PCU that is relatively undamaged and that your fertilizer application method is not damaging the product. A simple test, explained here, can be conducted to test the damage to the PCU. It is recommended that fertilizer dealers and co-op test PCU at different points in the handling process and before and after mixing and that farms and crop consultants test the PCU after mixing or after land application. Knowing if PCU is damaged and may release over a shorter period of time is important when interpreting mid- and late-season plant

nitrogen levels especially if tissue results are low. Any damage that occurs to a prill of PCU is not visible to the naked eye and the only way to assess the quality is to quantify its release. The PCU N release test described here is a 24-hour water test that can be conducted with minimal effort.

The 24-Hour Water Test Procedure

The method is quite simple: weigh out PCU fertilizer, put it in water for 24-hours, and weigh the PCU again. The method outlined here is a modified version originally reported by Bierman et al., 2015. The test requires at least 1 ounce (28 grams) of the PCU, an accurate scale, at least three containers able to hold 3 ounces (~ 90 mL) of water, a few miscellaneous supplies, and a place to dry wet samples. The scale needs to be accurate enough to measure ounces to two decimal places (i.e., down to 0.01 ounce) or grams to a tenth of a gram (i.e., down to 0.1 gram), and be able to weigh the PCU and the container at the same time. There are several common household items that are the right size including coffee cups, mason jars, plastic cups or drink containers, or yogurt containers.

To begin, the PCU fertilizer samples need to be dried – a warm dry place with plenty of air circulation is good, but a low temperature (105° F) drying oven is even better. If premade drying dishes are not available, drying dishes can be made from a sheet of aluminum foil. It is also ideal if a sample of undamaged PCU is also tested, but if one is not available, the values reported here can be used for comparison. Each PCU sample should be tested in triplicate, so label the containers accordingly. Here we test two PCU fertilizers (unblended and blended) and the samples are labeled: Unblended-1, Unblended-2, Unblended-3, Blended-1, Blended-2, and Blended-3. Using at least three replications per sample is the best way to account for variation given that we are only using a small sample compared to the amount applied to the field. The unblended PCU used here is Environmentally Smart Nitrogen (ESN®) and was obtained directly from the manufacturer (Agrium, Inc.). The blended fertilizer is also ESN® and was collected from after being blended at a fertilizer dealer with ammonium sulfate and potassium chloride. The fertilizer was collected directly from the bulk truck as it was falling out of the augur and into a spreader. Also, the blended PCU was evaluated alone, meaning the ammonium sulfate was removed. This was a specialty blend as requested by a farmer.

Results and Interpretations

- Unblended (and relatively pure) PCU lost about 6% of its mass during the 24-hour water test (Table 1). This is consistent with other findings. Thus there is always a minor percentage of the product that can be immediately lost and the minimum purity that can be expected is 94%.
- Blended PCU lost 22% of its mass in 24 hours (Table 1), indicating that blending with sharply angled fertilizer products can damage PCU during mixing. For purposes of this study, we attempted to find the most aggressive handling of the PCU. This handling process is not likely a standard practice and it was conducted upon farmer request.

- It is clear that the purity of PCU can be compromised during handling, mixing, and application of the product. The 24-hour water test outlined is a simple and effective approach that can be conducted by the fertilizer dealer, a crop consultant, or the farmer to evaluate the damage to the product at each stage in the handling and application of the product

Table 1. Example of data calculations to determine % mass loss of PCU from water immersion test.

Source	Initial	Post	Loss	Loss (%)
	I	P	L	
formula	--	--	I-P	100*(I-P)/(I)
	weight in grams			
Blended-1	10.1	7.3	2.8	27.6
Blended-2	10.6	8.5	2.1	19.7
Blended-3	10.0	8.3	1.7	17.1
			<u>average loss</u>	<u>21.5</u>
			<u>(AVG)</u>	
Unblended-1	10.1	9.3	0.9	7.8
Unblended-2	10.1	9.6	0.5	5.0
Unblended-3	10.1	9.6	0.5	5.2
			<u>average loss</u>	<u>6.0</u>
			<u>(AVG)</u>	

References

Beres, B.L., R.H. McKenzie, R.E. Dowbenko, C.V. Badea, and D.M. Spaner. 2012. Does handling physically alter coating integrity of ESN urea fertilizer? *Agron. J.* 104:1149-1159.

Bierman, P.M., J.E. Crants, and C.J. Rosen. 2015. Evaluation of a quick test to assess polymer-coated urea prill damage. *Agron. J.* 107:2381-2390.

Connell, J.A., D.W. Hancock, R.G. Durham, M.L. Cabrera, and G.H. Harris. 2011. Comparison of enhanced-efficiency nitrogen fertilizers for reducing ammonia loss and improving bermudagrass forage production. *Crop Sci.* 51:2237-2248.

Halvorson, A.D., S.J. Del Grosso, and C.P. Jantalia. Nitrogen source effects on soil nitrous oxide emissions from strip-till corn. *J. Environ. Qual.* 40:1775-1786.

Maharjan, B., R.B. Ferguson, and G.P. Slater. 2016. Polymer-coated urea improved corn response compared to urea-ammonium-nitrate on a coarse textured soil. *Agron. J.* 108:509-518.

Noellsch, A.J., P.P. Motavalli, K.A. Nelson, and N.R. Kitchen. 2009. Corn response to conventional and slow-release nitrogen fertilizers across a claypan landscape. *Agron. J.* 101:607-614.

Shaviv, A., S. Raban, and E. Zaidel. 2003. Modeling controlled nutrient release from polymer coated fertilizers: Diffusion release from single granules. *Environ. Sci. Technol.* 37:2251-2256.

Slater, J.V. (ed.). 2014. Official publication AAPFCO, No. 67. Association of American Plant Food Control Officials, Inc., West Lafayette, IN.

Wilson, M.L., C.J. Rosen, and J.F. Moncrief. Effects of polymer-coated urea on nitrate leaching and nitrogen uptake by potato. *J. Environ. Qual.* 39:492-499.