The following is a review of the paper titled “Water Release from Cross-linked Polyacrylamide” by C.H. Green, C. Foster, G.E. Cardon, et al.,Dept of Soil & Crop Science, Colorado State University, 2004.

Neil Kitchen, American Soil Technologies, Inc. Chief Technical Officer authored this review. Given the many misperceptions about polymers and their utility for agriculture, American Soil Technologies is working with the agricultural research community to realize the technological improvements in polymers for agriculture.

Background on CLP polymers

The authors’ background statement reflects the outdated image held by researchers concerning polymer manufacturing. The statement alleges, “Polyacrylamide polymer (PAM) is a byproduct of the plastics industry that necessitates disposal” and “In an effort to find a beneficial use for this byproduct the plastics industry has been marketing CLP.” Although it is possible that the product used in the subject study may have been formulated from PAM that was a waste byproduct, it is inaccurate to suggest that PAM is commonly produced as a byproduct and that CLP is manufactured for the purpose of selling an otherwise useless byproduct.

PAM is synthesized from natural gas and was originally used about a half century ago for soil conditioning. Depending on how polyacrylamide is formulated with respect to chemical and physical properties, it is used extensively in many industrial applications that include potable water treatment, dewatering sewage sludge, washing and lye-peeling fruits and vegetables, clarifying sugar juice and liquor, thickening and suspending agents in animal feeds, manufacturing paper, mining and drilling applications, and other industrial applications. Accordingly, it is also inaccurate to suggest that PAM is produced from floor sweepings that result from the manufacture of a plastic product (even if the product used in the study was formulated from waste material).

Although virtually hundreds of types of hydrogels (CLPs) exist (Bouramis et al. 1995), three classes of CLPs are commonly used today. These can generally be classified as natural polymers, semi-synthetic or synthetic polymers (Mikkelsen 1994). Research has shown that soluble salts in irrigation water suppress the performance of all polymers, but to very different degrees depending on the polymer group tested and on the properties of the water used in the experiment. In an experiment conducted with three groups of CLPs, the PAM-based group was proven to have the highest salt buffering capability, thus the PAM-based group was able to retain a significantly larger amount of water in saline conditions (Woodhouse and Johnson 1991).

The class of CLP used in the subject research work was not described. However, if we assume it was “synthetic polymer” (polyacrylamide) based on the authors’ assertion that CLP is formulated from waste material from the plastics industry, there are virtually hundreds of specific polyacrylamide (PAM) formulations that can vary in accordance with the polymer's chain length and the kinds of functional groups substituted along the chain.

Because PAM is the backbone of synthetic CLP, and because there are numerous "cross linking" chemicals used to formulate CLP, the chemical and physical properties of CLPs can vary significantly. By not recognizing this important fact, the usefulness or applicability of the data presented and conclusions made in the subject study are significantly diminished.

Unfortunately, generalizations about CLP are often found in university research and many conclusions reached in studies are tantamount to "scientific" character assignation. In sum, findings about one CLP product may or may not be applicable to another.

All polymers are not created equal. While the polymer industry has not fully addressed this issue since its inception, American Soil Technologies is working to set the record straight.

Off-label Field applications

To "elucidate the effectiveness of CLP as a soil amendment to reduce plant stress and sustain yields under reduced irrigation," the researchers report that CLP was banded (5 to 15 cm depth) along the seed row at "the manufacturer recommended rate" (22.4 kg ha^{-1}), at a super rate (20x the "recommended rate" – 448 kg ha^{-1}), and without CLP. The "recommended" application rate (approximately 20 pounds per acre) used in the study is a magnitude of 10-20 times the actual recommended application rate on the label for CLP products commonly used in agriculture.

It is possible that the excessive amount of CLP applied in the study resulted from misinterpretation of manufacturer recommendations by the researchers. The application rate used in the study would be applicable to "broadcast" applications, but would not be the recommended application rate for "banding along the seed row" as described in the subject study. This apparent technical oversight further diminishes the utility of the study's findings.

Is the water usable to the plants?
It is well known within the polymer research community that experiments have demonstrated a notable variation between CLP products in the binding tension of absorbed moisture. It is clear from these experiments that some cross-linked polyacrylamides can have a pronounced, simultaneous effect on the total and plant available levels of water (Johnson 1984). In sum, the conclusions reached in the subject study about the effectiveness of CLP to reduce water stress during periods of drought and conclusions made about environmental conditions leading to the failure of CLP as a water storage material, are based on test results not representative of the universe of CLP products or products currently being sold by American Soil Technologies, Inc. for use in agricultural applications.

Test results reported in this study apply only to a single, anonymous, failed product.

One of the primary issues faced by CLP manufacturers in formulating their respective CLP product is the issue of moisture release. Obviously, if the CLP does not release its moisture between field capacity tension and plant wilt point, the moisture retained by the CLP is of little benefit to the plant. Johnson (1984) tested three commercially produced polymers and found significant differences in moisture retention beyond pF 4.2 (wilt point) among the CLPs tested. Two of the three CLPs studied held 54.5 and 43.3 percent respectively of retained moisture at tension greater than pF 4.2. The third CLP tested ("polyacrylamide A") held only 4.7 percent of its moisture beyond pF 4.2

CLPs created to be used in agriculture today are designed to release a minimum of 90% of retained moisture between field capacity and wilt point and, to reduce plant stress, the best CLPs are formulated to release the preponderance of their retained moisture at tensions that approach wilt point. The conclusions made in the subject study suggest that only about 25% of the water absorbed by CLP is available to the plant during its initial wetting.

It is noteworthy that the poorest CLP performance reported by Johnson more than 20 years ago in terms of moisture retention between field capacity and wilt point is nearly twice that reported by the subject researchers. Considering the three commercial polymers tested by Johnson (1984) were formulated with polymer technology that is now over 20 years old, one can only wonder why more recent technological improvements in CLP products were not considered in the subject study, rather an outdated CLP product was used in the subject study.

Salinity Experiment Exceeds Recognized Crop Tolerance Levels
In conjunction with related tests described above, the researchers conducted tests that ostensibly elucidate the sensitivity of CLPs in the presence of "dilute salt solutions." Based on the results of the subject salinity experiment, the researchers erroneously conclude that a solution of $CaCl_2$ with an EC value measured at 0.5 dS m^{-1}, "a very low salt concentration compared to typical soil water," established the sensitivity of CLP to the presents of "salts." While it is true that an EC value of 0.5 dS m^{-1} is a relatively low salt concentration in soil water (this EC value is characteristic of tap water), it is also true that $CaCl_2$ concentrations of 320 ppm (corresponding to an EC value of 0.5 dS m^{-1} in the subject study) and 2560 ppm (corresponding to an EC value of 4.0 dS m^{-1} in the subject study) are extremely high. Even the lowest concentrations of $CaCl_2$ used in the subject study would be virtually impossible to find on this planet at its corresponding measured EC value (0.5 dS m^{-1}) in tap water, soil water or irrigation water.

G.E. Cardon, one of the researchers named in the subject research, recently coauthored a publication from Colorado State University Cooperative Extension entitled "Irrigation Water Quality Criteria." In this publication Cardon opines, "although people frequently confuse the term 'salinity' with common table salt or sodium chloride (NaCl), EC measures salinity from all the ions dissolved in a sample." This includes all cations and all anions. Cardon further opined in the same publication (in connection with sprinkler irrigation) that plants sensitive to chloride will show injury when exposed to chloride concentrations between 70 and 140 ppm; and, plants moderately sensitive to chloride will show injury when exposed to chloride at concentrations between 141 and 350 ppm. The lowest Cl^- concentration used in the subject study, at EC value 0.5 dS m^{-1}, is approximately 204 ppm. If Cardon et al. are correct about chloride toxicity to plants, all EC values above 0.5 reported in the subject salinity experiment will have a corresponding Cl^- concentration that is previously reported by Cardon to be sufficient to cause severe problems for plants.

The study raises many questions in regards to the research approach.

- Why was a $CaCl_2$ solution used to test CLP sensitivity to salts if EC was to be the relative measure of sensitivity?

- Why would the study test the sensitivity of CLP to salts using solutions with respective chloride concentrations that the researcher knows, even at the lowest EC value tested above zero, can cause injury to plants?

- And why would research be conducted on the sensitivity of CLP given general knowledge that CLP should not be used in environments where the irrigation water alone is likely to cause damage to plants?

Prior research has established that conductivity measurements of dissolved salts are alone unreliable as predictors of CLP performance, unless the exact cation and anion composition of the irrigation water are known (A.K. Bajpai et al. 2002). It is important to note that Bajpai's research also established that the relative effect of added ions on decreasing CLP water absorbency follow an order of increasing effectiveness: $PO_4^{3-} < CO_3^{2-} < Cl^-$ It has also been previously shown that divalent cations, particularly Ca^{2+}, Mg^{2+}, and Fe^{2+} ions, can have a pronounced effect on decreasing CLP water absorbency performance (Evans et al. 1989 and Johnson 1984). The approximate concentration of calcium that would be present in a $CaCl_2$ solution with a measured EC value of 0.5 dS m^{-1} (the lowest concentration above zero EC used in the study), is 115.5 ppm. In "Guidelines For Interpretation Of Water Analysis" by Olsens's Agricultural Laboratory, it is reported that calcium concentrations in irrigation water above 100 ppm are "Very High." In sum, the researchers claim that the lowest salt solution used in the study is "a very low salt concentration compared to typical soil water", is severely inaccurate.

Johnson concluded from his experiments that soil water extracts, water conductivity and pH, and particularly the specific ions contained in irrigation water should be subject to careful analyses before a CLP is recommended for field application. American Soil Technologies endorses this approach and provides soil and water testing as a service to its customers before making specific recommendations.

Again, the research approach raises questions.

- Why would an experiment be conducted using a solution containing only those ions that are established by prior research to have the greatest detrimental effect on CLP absorbency?

The only possible conclusion that can legitimately be made from the design of such an experiment is that an anonymous CLP performed as reported when bathed in a $CaCl_2$ solution with EC values that range from 0.0 to 4.0.

If the objective of this experiment was to establish the sensitivity of CLP's to "soil water" using EC as a standard, the experiment failed. However, the objective of the experiment seems to have been to support a research paper designed to lead an uninformed reader to an inaccurate conclusion about the usefulness of CLP in agricultural applications.

Promoting Understanding of Polymer Technology

American Soil Technologies, Inc. offers assistance to researchers in designing studies and will provide information regarding current technology. Our objective is to promote a greater understanding of polymer technology and the proper use of our products for agriculture. We aim to leverage these innovations for the advantage of American growers where appropriate.

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