The Use of Sodium Polyacrylate to Increase Crop Production in Dry-Land Farming

A Project Overview ◊ Kira Powell ◊ 2010-2011

Introduction

The community in which I live is founded on agricultural but the annual rainfall to support that industry is relatively low. I was curious to see if a chemical in baby diapers, sodium polyacrylate, could not only absorb the water in soil but make it available for crops. I was particularly interested in this chemical because of it's the absorbency capabilities and also the low level of toxicity. There was a small supply of the polymer in our lab and I conducted several small-scale trials with various ratios to test the material's potential. These tests along with extensive research would prove the foundation of my full project.

Sodium polyacrylate $(C_3H_3NaO_2)_n$, originally developed by the Dow Chemical Company, is a polymer that is a mix of sodium acrylate and acrylic acid. Commonly found in baby diapers and household cleaners, it can absorb 500 times its mass in water and thus is classified as a hydrogel (France, 2008). A hydrogel is a colloidal gel in which water is the dispersion medium. Sodium polyacrylate exists in randomly coiled chains, and there is an absence of Na^+ ions (salt is removed). The negative charges on the coils repel each other causing them to unwind. Water is then attracted to the negative ions and attached with hydrogen bonds. The polymer will continue to attach to water until all negative ions are linked to water. These bonds are physical, not chemical, allowing for the process to be reversed and then repeated indefinitely.

The hypothesis was if sodium polyacrylate was applied to farmable soil then the yield in the experimental sections will be higher than the control section. This should be reflected by an increase in wheat crop growth and water retention. Water retention in soil is directly linked to crop production, so theoretically, if water availability in farmable soil is increased for crops, crop production should also be increased.

Materials and Methods

For the full scale tests, a field located at 47.27º N and -118.85º W was selected. The ground was divided into three plots. Each was 3.66 m by 22.9 m with a 0.61 m) spacing between each plot. Soil samples were taken for nitrogen, potassium, sulfate, and phosphorus. The same test was preformed after the completion of the project in order to determine if the sodium polyacrylate had any effect on the soil nutrients and also to confirm the soil was adequate for growing purposes. Then the area was disced using a tillage attachment on the back of a tractor and basic fertilizer was applied.

The Control Plot was seeded with soft white spring wheat, *Triticum aestivum*, of the Louise variety. The field was seeded with a wheat seeder attached to the back of a tractor. The standard amount of wheat required to seed an entire acre is 27.2 kg (60.0 lbs). However, based on the test plot sizes, the wheat was measured for a half acre application, or 13.6 kg (30.0 lbs). The hopper was then cleaned out using a scoop and vacuum. For the Experimental Plot 1, wheat was mixed for a half an acre application, 13.6 kg (30.0 lbs) of wheat with 0.34 kg (0.75 lb) of sodium polyacrylate, a 1:40 chemical to wheat ratio or a 2.5 % sodium polyacrylate mixture. The chemical was weighed out and then mixed in a large flat plastic tub by hand. Because the chemical was not evenly spread within the wheat a small amount of water was applied via spray bottle to adhere the chemical to the wheat. This sample was inserted into the hopper and the Experimental Plot 1, was seeded.

This process was repeated for the Experimental Plot 2. The hopper was cleaned again, and the sample of sodium polyacrylate wheat was mixed. It comprised of 13.6 kg (30.0 lbs) of wheat and 0.68 kg (1.5 lbs) of sodium polyacrylate, adhered with water, a 1:20 chemical to wheat ratio or a 5.0 % sodium polyacrylate mixture. This batch was then planted (Experimental Plot 2).

In each of the plots, three different weekly data collections. The first was a water content test using moisture meter. This meter rated the soil moisture on a scale of 0-4. The second test was a plant count. An apparatus was dropped at random 10 times throughout all plots and the numbers of sprouts inside the area were counted. Five plants were also chosen at random and measured for plant height.

After 136 days, the wheat was harvested for each Plot using a combine. A tarp was installed in the hopper of the combine to catch the wheat from its respective Plot. The wheat was collected and weighed to find yield for each Plot.

To calculate the yield, the weights of the wheat had to be converted into bushels and then divided by the acreage of the test plots. The area of each of the Plots was 74 m^2 (792 ft^2) or 0.018 of an acre. The resulting numbers were scaled up using the standard acre 4,047 m^2 (43,560 ft^2) to find the bushels/acre that would have been recorded had the plots been full size. Kernel counts were taken for the yield by retrieving 5.0 g samples of the harvested wheat and counting out the individual kernels. This process was repeated 10 times for each Plot's yield. From that data, the average kernel mass was found by dividing the 5.0 g by the number of kernels.

Results (Main Points)

The preliminary soil test results showed nitrogen levels at 17 ppm, sulfate at 5 ppm, phosphorous levels at 30 ppm, and potassium levels at 708 ppm. Soil tests were run at the conclusion of the test as well indicating the nitrogen level was 3 ppm, phosphorous at 32 ppm, potassium at 939 ppm and sodium present at 0.12 meq/100g for the Control Plot. For the Experimental Plot 1, the nitrogen level was 4 ppm, phosphorous at 36 ppm, potassium level at 795 ppm and sodium present at 0.12 meq/100g. For the Experimental Plot 2, the nitrogen level was 3 ppm, the phosphorous at 31 ppm, the potassium at 844 ppm and sodium was present at 0.08 meq/100g.

The average wheat height within the Control Plot was 76.0 cm (±4.4), the Experimental Plot 1 81.6 cm (±3.2), and the Experimental Plot 2 was 80.3 cm (±3.7). A two tailed t-test was used to statistically compare the plots. The difference between the average wheat height in Experimental Plot 1 and the Control Plot was significantly different at the 99.9 % confidence level ($t = \pm7.258$; $df = 98$; $p < .001$), the Experimental Plot 2 and Control Plot were significantly different at the 99.9 % confidence level ($t = \pm5.243$; $df = 98$; $p < .001$) and there was no significant difference between the Experimental Plot 1 and Experimental Plot 2.

Kernel counts were taken for 5 g samples of the test plots. The Control average was 166.8 (±8.7), the Experimental Plot 1 was 158.2 (±8.0), and the Experimental Plot 2 was 143.0 (±6.2) kernels. A two-tailed t-test was used to statistically compare the plots. The difference between the average kernel count in the Control Plot and Experimental Plot 1 was significantly different at the 95 % confidence level ($t = \pm2.301$; $df = 18$; $p < .05$), the Control Plot and Experimental Plot 2 were significantly different at the 99.9 % confidence level ($t = \pm7.064$; $df = 18$; $p < .001$) and the Experimental Plot 1 and Experimental Plot 2 were significantly different at the 99.9 % confidence level ($t = \pm4.76$; $df = 18$;$p < .001$).

From the kernel counts the kernel masses were calculated. The Control Plot average kernel mass was 0.0301 g, the Experimental Plot 1 average kernel mass was 0.0317 g and the Experimental Plot 2 average kernel mass was 0.0350 g. The difference between the average kernel mass in the Control Plot and Experimental Plot 1 was significantly different at the 95 % confidence level ($t = \pm2.33$; $df = 18$; $p < .05$), the Control Plot and Experimental Plot 2 were significantly different at the 99.9 % confidence level ($t = \pm7.22$; $df = 18$; $p < 0.001$.), and the Experimental Plot 1 and Experimental Plot 2 were significantly different at the 99.9 % confidence level ($t = \pm4.84$; $df = 18$;$p < 0.001$.).

The wheat that was collected from each test plot was massed and the bushels/acre was calculated. The Control Plot wheat weighed 13.27 kg, which resulted in 26.8 bushels/acre, the Experimental Plot 1 weighed 16.27 kg converted to 32.8 bushels/acre and the Experimental Plot 2 weighed 16.91 kg converted to 34.1 bushels/acre.

Discussion/Conclusion

The hypothesis was accepted because the plant height, kernel, and yield results supported the theory that the sodium polyacrylate's addition to the soil resulted in increased crop growth and production.

The post-test soil data showed the sodium polyacrylate had no apparent negative effect on the soil. The nitrogen levels dropped from 5 ppm to 3 ppm, 4 ppm and 3 ppm for the Control, Experimental Plot 1 and Experimental Plot 2 respectively but this can be expected from a normal growth sequence.

The plant height data supported the hypothesis because the Control Plot was significantly different then both the Experimental Plot 1 and the Experimental Plot 2. This revealed that the sodium polyacrylate caused the wheat to grow higher. The growing trend of the wheat was compared to the time (in days) for each of the three Plots. The R^2 values, Control Plot (R^2=.991), Experimental Plot 1 (R^2=.970), and Experimental Plot 2 (R^2=.995) reflect all fields grew in a normal trend yet the Experimental Plot 1 and Experimental Plot 2 grew significantly higher than the Control Plot.

The kernel counts also supported the hypothesis. The Control Plot count of 166.8 were significantly different at the 95 % confidence level from the Experimental Plot 1 and the reduced number of kernels in the 5.0 g sample for the Experimental Plot 1 and Experimental Plot 2 allude to the fact that the individual kernels weigh more themselves. The Experimental Plot 1 kernels weighed 1.1 % more and the Experimental Plot 2 kernels weighed 1.2 % more than the Control Plot kernels. Higher kernel mass contributes to higher yields which are desirable, (Squires, 2011). The higher average kernel mass of the Experimental Plots means processed, more flour would be produced as compared to the Control. Kernels also indicate how stressful the growing season was on the plants. When kernels are large and heavy, it means they had plenty of the requirements needed for healthy growth, light, nutrients and most of all water. Water availability and kernel size are directly linked (Engle, 2011). The results of this test show that water was available for the plant throughout the growing season which was the focus of this research.

The calculated yields for the three plots were truly the indicator of whether the sodium polyacrylate was successful in retaining water. The Control Plot yielded 26.8 bushels/acre, the Experimental Plot 1 a 22 % increase to 32.8 bushels/acre and the Experimental Plot 2 a 27 % increase (from Control) to 34.1 bushels/acre. These percents are significant because it shows sodium polyacrylate could be applicable in large scale farming.

Although the yield increase is interesting it is the cost effectiveness that is truly astounding. With the current price of grain at $7.41/bushel (Odessa Union, 2011), a 640 acre field (one square mile) without sodium polyacrylate would harvest approximately 52 bushel/acre (the state average for spring wheat in 2010) resulting in a total of 33,280 bushels (Knopf, 2010). If this was multiplied by the price of one bushel, there would be a gross of $246,605. If the same field was treated with a 0.68 kg (1.5lbs)/acre application rate of sodium polyacrylate, there should be an expected 22% increase in bushels/acre (as shown in Experimental Plot 1). This would increase harvest to a rate of 63 bushels/acre, which translates into 40,320 total bushels or $298,771. That is an increase of $51,635 in revenue after the cost of the sodium polyacrylate ($531) was subtracted. The use of the 1.36 kg (3.0 lbs) application rate was also cost effective. It resulted in 66 bushel/acre harvest (27 % increase), 42,240 total bushels, $312,998 gross, and a $65,337 revenue increase (cost of sodium polyacrylate $1056).

In conclusion, the hypothesis was accepted. The application of sodium polyacrylate increased crop growth in dry-land farming, as shown through the improved average height, kernel count/mass, and yield results. It increased the bushels/acre by at least 20 %. For farmers this is a highly attractive figure. The application rates used in the Experimental Plot 1 and the Experimental Plot 2 were both cost effective.