Effect of Potassium Polyacrylate in Soil to Growth of Zea mays in Polyethylene Glycol-4000 Simulated Drought

Mary Emmanuelle Castaneda[1], Glennel Jan Hallado[1], Recca Lujan[1], Catherine Joy Mediodia[1] and Lovie Grace Aguaras[1]

[1] *Philippine Science High School Western Visayas Campus - Bito-on, Jaro, Iloilo City 5000, Department of Science and Technology, Philippines*

Abstract – Zea mays L. (corn) is a staple food for about 20% of the Philippine population, making it one of the most important food crops in the country, but are threatened to have a decline in production due to El Nio and water shortage in the Philippines. This study aimed to investigate if the addition of potassium polyacrylate to the soil will improve soil water retention to help optimize the drought tolerance of Zea mays (maize). This can help develop a new method in assisting plant survival during drought conditions and increase crop yield and growth. Since drought is an impending problem that greatly affects agricultural industries, this study can help address the problem of hunger in some areas, especially those which rely greatly on corn produce.Thirty corn seeds were planted and divided among six different groups, five under PEG-induced drought stress with varying concentrations of potassium polyacrylate incorporated to the soil, and one under normal conditions. Height, number of standing leaves, and soil moisture content were determined weekly for four weeks. Twenty-five plants germinated after five to six days. By the fourth week, only 11 plants were left. The results of the different parameters were insignificantly different, indicating that potassium polyacrylate was ineffective in improving soil water retention and does not help in the optimization of drought tolerance of maize. Increasing sample size, measuring daily osmotic potential, increasing frequency of measurements, observing until the reproductive stage and using PEG 6000 or 8000 instead of PEG 4000 are recommended for further studies.

Introduction. – Zea mays L. (corn) is a staple food for about 20% of the Philippine population, making it one of the most important food crops in the country [1]. The largest corn producer in the country is Mindanao, which contributes 50% of the total national production. Due to the severe drought conditions brought about by the El Nio phenomenon however, corn prospects in Mindanao for 2016 were expected to decline relative to the five-year average and that of 2015 [2, 3]. The Philippine Statistics Authority reported the volume of corn production in 2015 to be 7,518.75 metric tons and in 2016 to be 7,218.81 metric tons, yielding a production growth rate of -3.99% for years 2015-2016 [4]. Moreover, the World Resources Institute (WRI) conducted a study which predicted that by the year 2040 the Philippines will have a high degree of water shortage. The study went further and predicted that the agricultural sector of the country would receive the highest degree of water stress among three sectors, the other two being the industrial and domestic sectors [5]. Currently, farmers would use various irrigation techniques or water at a certain schedule for optimal efficiency to address the effects of drought on their agriculture [6]. Essentially, drought refers to the fragile balance between water supply and demand and is not necessarily just a physical occurrence that is defined by the weather. Agricultural drought happens when there is insufficient moisture for average crop production on farms or average grass production on rangeland [7]. During this period, decreased rainfall and increased sunlight leads to soil moisture depletion. The quality of soil degrades because of lack of organic activity and increased wind erosion. Wind erosion causes dust storms and sand deposition which could kill even more vegetation [8,9]. Superabsorbent Polymers(SAP) are materials that are able to absorb and retain large volumes of liquid and aqueous substances up to hundreds of times its own weight and is made from partially neutralised, lightly cross-linked polyacrylic acid. SAPs are used ideally for diapers and adult incontinence pads for the absorption of medical dressings and controlled release medium. Potassium polyacrylate is a SAP that is helpful for plants and can improve its structure [10,11]. Potassium is important in numerous processes such as photosynthesis, photosynthate translocation, protein synthesis, control of ionic balance, regulation of plant stomata and water use, and activation of plant enzymes [12]. Potassium is also a primary osmoticum in the maintenance of low water potential of plant tissues, aside from being an essential macronutrient for plant growth and development. Therefore, the accumulation of abundant K+ in plant tissues may play a vital role in water uptake for plants under drought conditions [13]. Given the ability of Superabsorbent Polymers to retain water, an agricultural concern for soil under drought conditions, this study proposes to investigate if the incorporation of potassium polyacrylate to the soil will enhance its water retention and reinforce the drought tolerance of Zea mays. This study aimed to investigate if the addition of potassium polyacrylate to the soil will improve soil water retention to help optimize the drought tolerance of Zea mays (maize). Specifically it aimed to measure and compare the germination time, number of standing leaves, soil moisture content, height growth rate of Zea mays plants grown in drought and normal conditions with and without potassium polyacrylate as well as identify the relationship between the soil moisture content rate and height growth rate between the aforementioned conditions.

Methods. – The study was conducted in a room in the Iloilo Sports Complex Hostel. There were six test groups with five maize plants each. One group was under normal environmental conditions, without potassium polyacrylate applications. Five other test groups were subjected to drought stress through the addition of PEG, and had five different concentrations of potassium polyacrylate applications in percentage ratio to the soil, specifically, 0, 0.08, 0.2, 0.5 and 1. The mean germination time, mean number of standing leaves, mean height and mean soil moisture content of all the plants in all the setups were determined and compared. Results were compared weekly to determine if there was a significant effect on the growth of plants in terms of the aforementioned parameters given the different treatments during each of the various stages of growth. The corn seeds were obtained from the Provincial Agriculture Office, Region 6. The polyethylene bags in which the samples were placed were bought from Janiuay Market in Iloilo. The loamy soil was obtained from Brgy. Danao, Iloilo City. PEG - 4000 and apparatuses were obtained from Patagonian Enterprises, Iloilo City. Potassium polyacrylate was obtained from Shanghai iChemical Technology Co., Ltd. Fluorescent lights were used as they are one of the best sources of artificial light for plant growth. The study utilized 20-watt fluorescent bulbs with a distance of 6ft and 9 inches from the pots. A daily photoperiod of 14 hours was used as most facilities growing corn in a greenhouse use this duration of artificial light [14]. One corn seed per pot with dimensions of 6 x 6 x 8 was planted 2 inches deep into 2500 grams of loamy soil. The plants were watered every day with the specified amount of water they need depending on which stage of growth they undergo as shown in Table 1. The area was kept at 25 C. PEG - 4000 solution was used to simulate drought conditions. The solutions were prepared at 20% concentration to be added at four-day intervals by quantities depending on the daily water requirement.The potassium polyacrylate was incorporated 15cm below the topsoil at a dose of 0.23g per square foot as shown below [15]. This is done with the purpose of improving soil structure and water penetration, increasing retention capacity, decreasing water runoff and avoiding erosion [16]. Potassium Polyacrylate is not mixed with the soil in order to keep the polymers together, since single polymers are unlikely to absorb water to their maximum potential [17]. The number of days lapsed after planting when the seed has sprouted were noted for the germination time. Physical parameters such as plant height and number of standing leaves were recorded weekly. A ruler was initially used to measure the height of the plants. When plant height became higher than 12 inches, a meter stick was used. Height growth rate was calculated based on the change of standing height within the span of one week. Measurement of soil water content was also done weekly at the PSHS laboratory by gravimetric method. Three out of five plants per test group were taken soil samples of one teaspoon or approximately 5 cc or 5 mL. The wet weight of soil samples was measured. Soil samples were oven dried at a temperature of 100-110C for an hour. Samples were weighed after oven drying and are to be dried again for 30 minutes. This process was repeated until the weight of the sample becomes constant to get the dry weight measurement. One-way ANOVA was conducted for three parameters to determine if the addition of potassium polyacrylate had a significant effect on germination time, number of standing leaves, height, soil water content among treatment groups. An alpha of 0.05 was used to compute for the significance of the data. Kruskal-Wallis was conducted for the number of standing leaves for the same purpose.

Results. – *Germination Time* All plants with potassium polyacrylate had a germination time of about five days with group 1 and 0.08 having mean germination times of 5.5 days. All plants without potassium polyacrylate had a germination time of about six days. The plants which were put under drought conditions had the longest time to germinate among all the plants with a mean germination time of 6.25 days (Figure 1). Differences among the values were not significant at an alpha of 0.05. The P-value for the germination time was 0.235, signifying that any of the different concentrations of potassium polyacrylate treatments would not significantly affect the outcome of the germination time of maize plants.

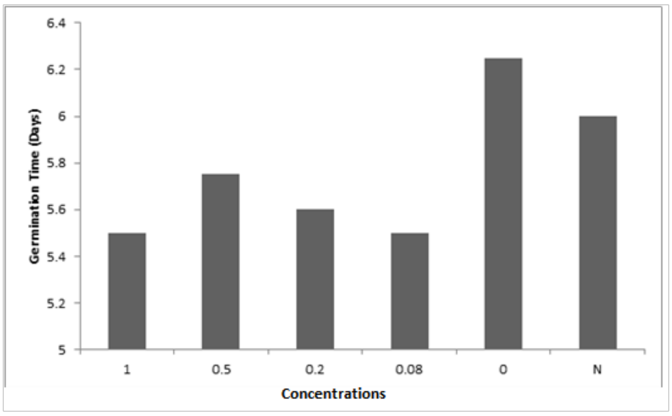

Fig. 1:

Number of Standing Leaves At week one, groups 1 and 0.08 had two standing leaves in all plants, while group 0.5 and group 0 had zero to two leaves and group 0.2 had one to two leaves. At week two, all groups had three leaves in all plants except for groups 1 and 0.2 with one plant in each of the groups having four leaves. At week three, groups 1 and 0.2 still had three to four leaves, group 0.5 still had three leaves in all plants, group 0.08 had only one standing leaf left in the only plant that was still alive and group 0 had two plants without any standing leaves and one plant with three leaves. At week four, group 1 had zero to one leaf, group 0.5 had zero to two leaves, group 0.2 had one to two leaves, group 0.08 plants were all dead and group 0 had one plant remaining without any standing leaf (Figure 2). Results were not significant at =0.05 for all weeks, indicating that the number of leaves among the plants were generally not affected by the potassium polyacrylate treatments and the different concentrations of those treatments in different stages of growth.

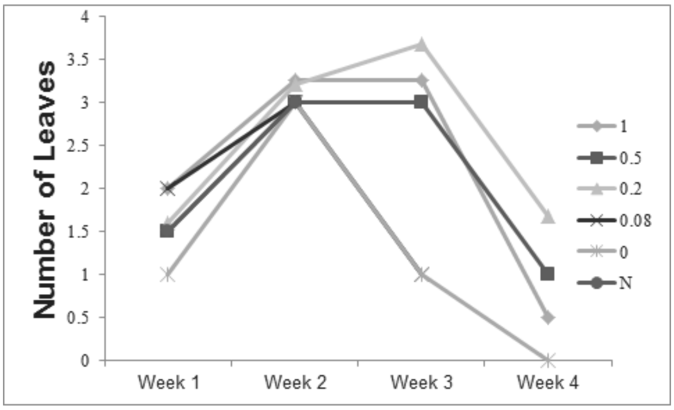

Fig. 2:

Moisture Content Groups 1, 0.5 and 0.08 had approximately 23% mean moisture content, group group 0.2 had approximately 24% and group 0 had approximately 21% (Figure 3). Moisture content for all groups, except for groups 0.2 and 0.08, generally increased on the second week. All groups decreased in soil moisture content on the third week. Moisture content among groups was only significantly different at an alpha of 0.05 in the second week with a p-value of 0.03. The moisture content in the third week yielded a p-value of 0.540, the greatest deviation to the critical value among the weekly results.

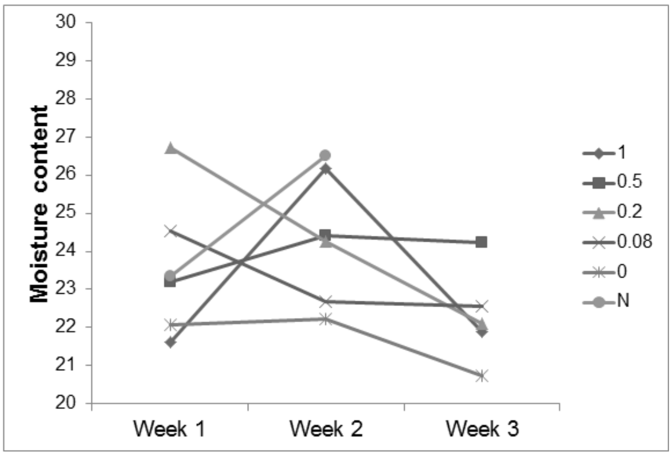

Fig. 3:

Height Growth Rate Between the second and first week, group 0 had the highest growth rate mean of approximately 400%, groups 1, 0.08 and N had the higher growth rate means at around 300%, while the other groups had around 200%. Between the third and second week, group 0.08 had the highest growth rate mean while group 0 had a negative growth rate mean. For the last and third week, group 1 had a negative growth rate mean, while group 0 was able to regain a positive growth rate mean (Figure 4). Group 0.08 continued to have the highest growth rate mean. Growth rates were only significantly different at an alpha of 0.05 in the last week, with only 11 plants left alive.

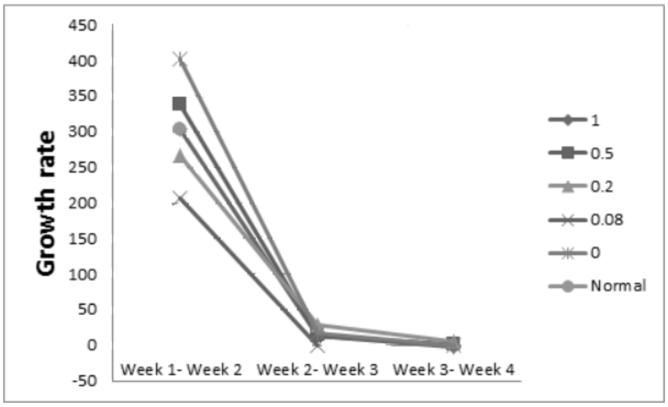

Fig. 4:

Mortality Rate By the end of the span of four weeks only the group with 1% Potassium Polyacrylate had sustained all of the plants that germinated. Groups with 0.5% and

0.2% had one and two deaths respectively. The group without reinforcement under drought conditions only had one plant left at the end of the study. The group under drought conditions with 0.08% and the group under normal conditions had no plants left at the end of the study (Figure 5).

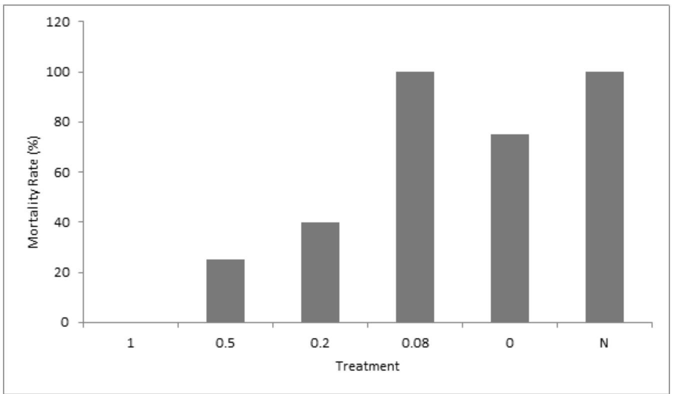

Fig. 5:

Discussion. − Since the results were generally not significantly different, three possibilities may be inferred. First, that drought conditions were not properly stimulated with PEG-4000. In the study that was used as basis for the application of PEG in this study, the effects of PEG were only investigated within a 12-day period [18]. At applications every four days for four weeks, osmotic potential may no longer be of similar value through time or may not have a damaging effect on plant growth.The means of the plant height and number of standing leaves were all less in group 0 than in group N, and germination time was longer in group 0 than in group N, indicating that growth was slightly stunted for group 0. However, in Table 8, these factors, although quantitatively still less in group 0 than in group N, increased at a greater rate in group 0 than in group N. The possible reason for this is that the plants could have developed coping mechanisms or acclimatized to the conditions. Plant acclimation is the process of adjusting to a gradual change in environmental conditions in order for a plant to maintain its performance. This is done by the development of tolerance, resistance or avoidance mechanisms [19]. Second, that potassium polyacrylate was not able to execute the mechanism involving osmosis. No study was found indicating the specific requirements for osmosis by potassium polyacrylate, such as extracellular and intracellular water volumes. Without the release of the absorbed water in dry conditions, potassium polyacrylate gives little to no effect on the growth of maize. Since moisture content was not significant between the different setups shown in Table 8, it is highly probable that osmosis was not in optimal conditions. Third, that the plants were not able to receive the requirements for optimal growth. Maize prefers pH in the range of 6.0-7.2 in order to maximize growth and ensure nutrients. However, the aging of PEG was found to have effects on its chemical properties, including a reduction in pH [20]. Furthermore, aging is accelerated by warm temperature or room temperature, light and the presence of oxygen, all of which are present in our set-up [20]. This means that the PEG that was watered on the plants might have affected the pH of the soil. Thus, since a regular soil test was not taken over the course of this study, it is possible that this requirement was not met, yet the issue was unidentified and contributed to the stunted growth of the plants. Moreover, the plants were watered at night time, past 6:00 pm. This may be a factor that could have affected the growth of the plants in two ways. First, because transpiration occurs during the day, moisture from watering at night would not have been expelled by the stomata and made the plant vulnerable to pathogen infiltration, which might have then caused rot or damaging injuries to the foliage. Second, because the soil is compacted, water moves slowly into the topsoil from the surface, and without the sun to evaporate the puddle of water on the surface, roots may have received less air and moisture. The plant stem and crown may have also been harmed by pathogens or may have rotted from the concentration of water in the plant base [21].

Conclusion. − In conclusion, the addition of Potassium polyacrylate to soil does not improve soil water retention and consequently does not help optimize the drought tolerance of Zea mays.The incorporation of Potassium polyacrylate to soil for plants under drought conditions had no significant difference to plants in both drought and normal conditions. All parameters namely germination time, number of standing leaves, soil moisture content, and height growth rate displayed no significant difference among all set-ups.

REFERENCES

[1] Greenpeace (19 December 2012) WHITE CORN IN THE PHILIPPINES: Contaminated with Genetically Modifi ed Corn Varieties. Greenpeace. Link: http://m.greenpeace.org/seasia/ph/PageFiles/566478/White-Corn-In-The-Philippines.pdf

[2] United States Department of Agriculture Foreign Agricultural Service (2016). PHILIPPINES: Drought in Mindanao Causes Corn Production Decline. United States Department of Agriculture Foreign Agricultural Service. Link: http://pecad.fas.usda.gov/highlights/2016/03/Philippines/Index.htm

[3] OpinYon News Magazine (2016) El Nio cuts Mindanao corn output. OpinYon News Magazine. Link: http://www.opinyon.com.ph/index.php/feature/1370-el-nino-cuts-mindanao-corn-output

[4] Philippine Statistics Authority (20 January 2017) Performance of Philippine Agriculture. Quezon City, Philippines. Link: https://psa.gov.ph/sites/default/files/par-oct-dec2016.pdf

[5] Ranada P (2015) Philippines faces 'high' level of water shortage in 2040 study. Rap-

pler. Link: http://www.rappler.com/science-nature/environment/104039-philippines-water-stress-2040

[6] Nagappan P (13 May 2016) California Farmers Innovate To Fight Drought. NewsDeeply. Link: https://www.newsdeeply.com/water/articles/2016/05/13/california-farmers-innovate-to-fight-drought

[7] West L (2016) What Is Drought?. Aboutnews. Link: http://environment.about.com/od/environmentalevents/a/whatisdrought.htm

[8] eSchoolToday (n.d.) Environmental impact of droughts. eSchoolToday. Link: http://eschooltoday.com/natural-disasters/droughts/environmental-impact-of-droughts.html

[9] Owen G (2008) Drought and the Environment. Southwest Climate Change Network. Link: http://www.southwestclimatechange.org/impacts/land/drought

[10] Elliot M (n.d.) Superabsorbent Polymers. BASF. Link: http://chimianet.zefat.ac.il/download/Super-absorbant-polymers.pdf

[11] Soco (n.d.) Super Absorbent Polymer For Plants. Soco. Link: http://www.socochem.com/super-absorbent-polymer-for-plants.html

[12] Reddya AR, Chaitanya KV, Vivekanandanb M (2004) Drought induced responses of photosynthesis and antioxidant metabolism in higher plants. Journal of Plant Physiology. 161(11): 1189-1202. Link: https://www.ncbi.nlm.nih.gov/pubmed/15602811

[13] Zare K, Vazin F, Hassanzadehdeloui M (2013) Effects of Potassium and Iron on yield of corn (Zea mays L.) in drought stress. Cercetri Agronomice n Moldova. 47(1): 39-47. Link: http://www.uaiasi.ro/CERCET-AGROMOLD/CA1-14-05.pdf

[14] Eddy R, Hahn DT. (1 March 2010). Optimizing Greenhouse Corn Production: What Is the Best Lighting and Plant Density?. Purdue University Purdue e-Pubs. Link: http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1005context=pmcg

[15] Recinos JRA (n.d.) Evaluation of potassium polyacrylate, in the cultivation of beans (Phaseolus vulgaris L.) as a potential practice adaptation in the face of drought, Parramos, Chimaltenango. Instituto Privado de Investigacin sobre Cambio Climtico -ICC. Link: http://icc.org.gt/wp-content/uploads/2016/12/Evaluation-of-potassium-polyacrylate-in-the-cultivation-of-beans.pdf

[16] Akelah A (2013) Polymers in Plantation and Plant Protection. Springer US. 65-131. Link: http://www.springer.com/cda/content/document/cda-downloaddocument/9781461470601-c1.pdf?SGWID=0-0-45-1402868-p174976651

[17] MJ Guide (n.d.) What are Water-Absorbent Polymers and how do I use them?. MJ Guide. Link: https://www.mjguide.com/tutorials/SoilandSoiless/1490.htm

[18] Zeid IM, El-Semary NA (2001) Response of Two Differentially Drought Tolerant Varieties of Maize to Drought Stress. Pakistan Journal of Biological Sciences. 4:779-784. Link: http://scialert.net/fulltext/?doi=pjbs.2001.779.784org=11

[19] Tuteja N, Gill SS, editors (6 December 2012) Plant Acclimation to Environmental Stress. Springer Science + Business Media. Link: http://www.springer.com/gp/book/9781461450009

[20] Hampton Research Corporation (16 May 2012) PEG Stability: A Look at pH and Conductivity Changes over Time in Polyethylene Glycols. Hampton Research Corporation. Link: https://hamptonresearch.com/documents/growth-101/27.pdf

[21] Rodriguez A (n.d.) Why Should Plants Not Be Watered at Night? SFGate. Link: http://homeguides.sfgate.com/should-plants-not-watered-night-66422.html