Fate of Wheat

By Sean Day

Triticum aestivum better known as wheat, is the one of world's most important crops with a global harvest weight of roughly 750 million tons in 2016. It's used in cereals, pastas, bread, crackers, and numerous other foods that are staples in our everyday diet not just here in the United States but worldwide. However, wheat is facing a potential foe that it has not experienced in its 10,000 years of cultivation, rising temperatures as a result of climate change. There is much uncertainty about the future of earth's climate or how this will even affect farmers' abilities to produce wheat. One thing is clear though, if farmers' yields of wheat are diminished this will have negative effects in developed nations and especially in third world countries where starvation is already an issue in this age of abundance. (1)

Wheat, like 85% of most plants, conducts a type of photosynthesis called C_3 photosynthesis. Within chloroplasts all plants convert energy from the sun, water, and carbon dioxide (CO_2) into storable energy called glucose. This process is called photosynthesis. But in C_3 plants they only use the Calvin-Benson Cycle to capture carbon from the atmosphere which is called carbon fixing. Inside chloroplasts there are stroma that receive the CO_2 molecules. While inside they merge with ribulose 1,5-biophosphate. Using an important enzyme, oxygenase-carboxylase also called RuBisCO, it synthesizes a six-carbon molecule that is highly unstable. This six-carbon molecule breaks down to form 3-phosphogyceric acid, a stable three carbon molecule thus the name C_3 photosynthesis. (2)

Wheat does very poorly in hot and arid conditions due to its C_3 characteristics. Sometimes the RuBisCO decides to bind to oxygen instead. When the plant does so it bypasses the Calvin-Benson Cycle, never creates sugars, and is thrown into photorespiration. Photorespiration reverses carbon fixing and results in poor plant health because sugar synthesis is reduced. Under hot and/or dry conditions wheat will close its stomata, small pores on wheat leaves, to prevent water loss. But when it does so it fails to exchange O_2 for CO_2 in the atmosphere and as a result O_2 concentrations begin to increase. RuBisCO with its bipolar personality, has a much higher affinity for O_2 than CO_2 when temperatures rise. If temperatures are not reduced, wheat will not enter into the Calvin-Benson Cycle and thus never make any useable energy. This explains why an increasing global temperature could be so detrimental to the health of wheat. (2)

CO_2 enrichment will prevent wheat from going into photorespiration resulting in an increase its yields but this comes at a cost. Photorespiration is inhibited by an increase in concentrations of CO_2 which makes photosynthesis more efficient. Wheat retains more water as well because it has less need to open its stomata. With elevated carbon levels, the plant can afford to breathe proportionally less since its getting the same amount of carbon had it took proportionally more breathes under normal carbon levels. Whenever wheat can reduce its stomatal openings it can reduce its water use which is beneficial since water tables are dropping as fast as 30 feet per year in some areas. CO_2 fortification has even been shown to elevate wheat yields by about 11% when CO_2 levels are doubled to that of atmospheric conditions. There are drawback to all of these superficial profits though. Nitrogen and consequently the protein content found in seeds, the edible part in wheat, is diminished by 12% when CO_2 levels are at twice ambient CO_2 levels of roughly 410 ppm. In addition, zinc was 9% lower, iron was 5% lower, and trace elements such as phosphorous, sulphur, magnesium, were all suppressed in other similar studies. Evidence suggest that there doesn't seem to be a net benefit of increased CO_2 when all other factors are held constant to include temperature. (3)

It is unclear exactly why nitrogen is diminished in wheat when CO_2 levels are increased but it could be in its inability to assimilate it properly. The atmosphere is 79% nitrogen and roughly 18%

oxygen with the rest being an array of trace gases. Even though the earth is abundant with nitrogen it is not bio-available to wheat because it is stuck in N_2 form which has strong triple bonds. Wheat must rely on bacteria living in the soil called diazotrophs to convert N_2 into NH_3 in a process called nitrogen fixing. It appears that CO_2 levels are not affecting this process so researchers and farmers have added more bio-available ammonium using the Haber-Bosch method in an attempt to raise protein levels of wheat. This has only resulted in nitrogen being leached away into ground and surface waters resulting in disruption of fragile ecosystems because the wheat cannot assimilate ammonium even when given ample amounts. It is still unclear how CO_2 levels are affecting nitrogen and thus protein levels within wheat but it is clear that most countries already lack protein so this could be a highly negative outcome chiefly in poor nations. (4)

While it is well understood what the effects of CO_2 and temperature will have on wheat yields when the variables are isolated, little is known about how wheat will respond with the coalesced effects of both. CO_2 and temperature have a positive linear relationship. Historically, when one goes up the other will follow but within which order is still up for debate. (4) Regardless of the debate, it is highly relevant to study the effects of both climbing considering this is what wheat may experience in the future. (5,6)

Tomatoes also being a C_3 plant and studied in commercial CO_2 enrichment ventures within warmer than ambient air greenhouses, could shed some light on the true effects of climate change on wheat. In commercial greenhouses, propane is burned to provide heat but more importantly CO_2 levels of 1000 ppm to the tomatoes. In some species, this can result in a 30% increase in yields. Levels of 5,000 ppm have shown increases in yields but are not cost effective beyond 1,000 ppm. L. esculentum flowered seven days earlier than others left in ambient CO_2 concentrations of 400 ppm and ambient temperature levels. They used less water as stomata conductance was diminished as well. All varieties did have lower nutrient levels per unit of weight but did produce more overall nutrients. This could be because leaves are going through senescence at a higher rate resulting in assimilation of nutrients being diminished. (7)

The causes of climate change and what should be done if anything at all are still highly debatable topics. If anthropogenic climate change is accurate, the rest of the world will not likely cut down on their CO_2 production even if the United States does. This is why we need to assume temperatures and CO_2 levels will rise together and study the effects of both variables simultaneously to see if one offsets the negative effects of the other. Farmers will not experience lab conditions with single variable variances. They will see both factors change and need this vital data so that they can decide what if any viable solutions there are. Until this research is done by an agronomist, the future of wheat is unclear. (1)

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