Climate Change Impacts on Weeds

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Among the questions farmers need to answer regarding weeds, carbon dioxide (CO_2), and climate change, the most important are:

- How will increased CO_2 effect weed growth?
- What effect does increased temperature have on weeds?
- How does a change in precipitation effect weed growth?
- Why can't we simply control CO_2, climate and weed?
- If climate change/CO_2 alters weed biology, will this impact human health?

How will increased CO_2 effect weed growth?

Weeds have a greater genetic diversity than crops. Consequently, if a resource (light, water, nutrients or carbon dioxide) changes within the environment, it is more likely that weeds will show a greater growth and reproductive response. It can be argued that many weed species have the C_4 photosynthetic pathway and therefore will show a smaller response to atmospheric CO_2 relative to C_3 crops. However, this argument does not consider the range of available C_3 and C_4 weeds present in any agronomic environment. That is, at present, the U.S. has a total of 46 major crops; but, over 410 "troublesome" weed species (both C_3 and C_4) associated with those crops (Bridges 1992). Hence, if a C_4 weed species does not respond, it is likely that a C_3 weed species will. In addition, many growers recognize that the worst weeds for a given crop are similar in growth habit or photosynthetic pathway; indeed, they are often the same uncultivated or "wild" species, e.g. oat and wild oat, sorghum and shattercane, rice and red rice. To date, for all weed/crop competition studies where the photosynthetic pathway is the same, weed growth is favored as CO_2 is increased (Table 1, Ziska and Runion, In Press).

In addition to agronomic weeds, there is an additional category of plants that are considered "noxious" or "invasive" weeds. These are plants, usually non-native whose introduction results in wide-spread economic or environmental consequences (e.g. kudzu). Many of these weeds reproduce by vegetative means (roots, stolons, etc.) and recent evidence indicates that as a group, these weeds may show a strong response to recent increases in atmospheric CO_2 (Ziska and George 2004). How rising CO_2 would contribute to the success of these weeds in situ however, is still unclear.

Overall, the data that are available on the response of weeds and changes in weed ecology are limited. Additional details, particularly with respect to interactions with other environmental variables (e.g. nutrient availability, precipitation and temperature) are also needed.

What effect does increased temperature have on weeds?
Increasing temperatures may mean an expansion of weeds into higher latitudes or higher altitudes. Very aggressive weeds that are currently found in the south are limited in the northern states by low temperatures. Many C_4 grass weeds are serious problems in the southern U.S. but do not occur at problem levels in the U.S. cornbelt. Studies have shown that itchgrass, a profusely tillering, robust grass weed could invade the central Midwest and California with only a 3° warming trend (Patterson, 1995). Witchweed, a root parasite of corn, is limited at this time to the coastal plain of North and South Carolina. With an increase of temperature of 3° it is speculated that this parasite could become established in the Corn Belt with disastrous consequences. The current distribution of both Japanese honeysuckle and kudzu is limited by low winter temperatures. Global Warming could extend their northern limits by several hundred miles.

How does a change in precipitation effect weed growth?
Response to drought in agronomic conditions is dependent on species and cultural conditions. Any factor which increases environmental stress on crops may make them more vulnerable to attack by insects and plant pathogens and less competitive with weeds (Patterson, 1995).

Why can't we simply control CO_2, climate and weeds?
Clearly, any direct or indirect impacts from a changing climate will have a significant effect on chemical management. Changes in temperature, wind speed, soil moisture and atmospheric humidity can influence the effectiveness of applications. For example, drought can result in thicker cuticle development or increased leaf pubescence, with subsequent reductions in herbicide entry into the leaf. These same variables can also interfere with crop growth and recovery following pesticide application. Overall, pesticides are most effective when applied to plants that are rapidly growing and metabolizing, i.e. those free from environmental stress.

But does rising CO_2 per se alter chemical management? There are an increasing number of studies (Ziska et al. 2004, Ziska & Teasdale 2000, Ziska et al. 1999) that demonstrate a decline in chemical efficacy with rising CO_2. The basis for this reduction is unclear. Recent work with Canada thistle grown in monoculture under field conditions suggested a greater root to shoot ratio and subsequent dilution effect of glyphosate when grown at elevated CO_2 (Ziska et al. 2004). However, it is not clear if this is a ubiquitous response. In any case, if CO_2 does reduce efficacy, then additional work is needed to determine herbicide specificity, concentration and application rates as possible means of adaptation.

Biological control of pests by natural or manipulated means is likely to be affected by increasing atmospheric $CO_2$and climatic change. Climate as well as CO_2 could alter the efficacy of weed bio-control agents by potentially altering the development, morphology and reproduction of the target pest. Direct effects of CO_2 would also be related to changes in the ratio of C:N and alterations in the feeding habits and growth rate of herbivores. As pointed out by Patterson (1995), warming could also result in increased overwintering of insect populations and changes in their potential range. Although this could increase both the biological control of some weeds, it could also increase the incidence of specific crop pests, with subsequent indirect effects on crop-weed competition. Overall, synchrony between development and reproduction of bio-control agents and their selected targets is unlikely to be maintained in periods of rapid

climatic change or climatic extremes. Whether this will result in a positive or negative benefit remains unclear.

A standard means of controlling weed populations, and the one most widely used in developing countries is mechanical removal. Tillage (by animal or mechanical means) is regarded as a global method of weed control in agronomic systems. Elevated CO_2 could lead to further below ground carbon storage with subsequent increases in the growth of roots or rhizomes, particularly in perennial weeds (see Rogers *et al.* 1994 for a review). Consequently, mechanical tillage may lead to additional plant propagation in a higher CO_2 environment, with increased asexual reproduction from below ground structures and negative effects on weed control (e.g. Canada thistle, Ziska et al. 2004).

Overall, there are strong empirical reasons for expecting climate and/or rising CO_2 to alter weed management. Adaptation strategies are available, but the cost of implementing such strategies (e.g. new herbicides, higher chemical concentrations, new biocontrol agents) is unclear. Herbicide use is controlled by individual state regulations. If an increase in CO_2 and temperatures allow invasive weed species to expand their geographical locations new herbicides may be needed to combat them. Often it takes a period of time to receive state approval of a new chemical or a chemical that has not been previously used.

If climate change/CO_2 alters weed biology, will this impact human health?

Weeds are recognized by the general public as significantly affecting human health either through allergenic reactions, skin irritations, mechanical injury or internal poisoning (Ziska 2001). For the most part, we are only in the initial stages of quantifying how changes in climate and/or CO_2 may affect those specific weeds associated with public health. One exception has been changes in pollen production and allergenicity in common ragweed (a recognized cause of allergic rhinitis) with changing CO_2 and temperature in both indoor (Ziska and Caulfield 2000, Wayne et al., 2002) and in situ experiments Ziska et al. 2003). Additional research on how rising CO_2 can affect both poison ivy growth and toxicity is currently ongoing. No information is available on how CO_2 could alter the toxicity of secondary compounds associated with mortality in weedy species.

Summary

Changes in temperature and carbon dioxide are likely to have significant direct (CO_2 stimulation of weed growth) and indirect effects (climatic variability) on weed biology. In spite of the importance of weed biology in both the environment and in farms, very little is known regarding the impact of these environmental changes on either the reproductive success of agronomic or invasive weeds, and the potential consequences for their management. Yet, given what is known, it is clear that the agricultural, environmental and health costs of not understanding the impact of CO_2 on weed biology may be substantial. It is hoped therefore that the current article may serve to both emphasize the critical nature of this topic, and to serve as an initial guide to those who wish to recognize the ramifications of rising CO_2 beyond the polemic of global warming.

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