WEED POLLEN SEASON TRENDS IN RELATION TO ATMOSPHERIC CO_2 CHANGES IN INDIANA AND OHIO

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Allergic rhinitis (AR) and asthma both lead to significant morbidity and healthcare usage in the United States.[1,2] Pollens contribute to increased AR symptoms and asthma exacerbations. Ragweed (*Ambrosia spp*) and other weed pollens have been shown to affect AR and asthma issues in the Midwestern US, especially in the late summer and early fall season. Knowledge about pollen season lengths and patterns can help with management of allergic rhinitis and asthma.[3,4,5]

Atmospheric carbon dioxide (CO_2), precipitation, and temperature all impact the length of weed pollen season.[4,6] Atmospheric temperature has significantly increased in the past century.[4] Global atmospheric CO_2 levels, collected at the Mauna Loa observatory in Hawaii, have increased from 312 parts per million(ppm) in 1960 to 415ppm in May 2019 (https://scripps.ucsd.edu /programs /keelingcurve/Accessed May 20, 2019).

Ragweed pollen season has been shown to increase in the presence of increased atmospheric CO_2.[6] In multiple areas of the central United States, the pollen seasons of ragweed and other weeds have increased in the past two decades.[4,7,8] Weed pollen trends in relation to CO_2 and temperature changes have not previously been studied in the midwestern states of Indiana and Ohio. One hundred twenty miles separate Indianapolis, Indiana, and Dayton, Ohio. Despite their close location and similar latitude of 39.7°FN, significant pollen variation has been demonstrated between these two cities.[9] The purposes of this study are to study trends in the lengths of pollen seasons for ragweed and other weeds in Indianapolis and in Dayton, in relation to changes in atmospheric CO2, temperature, and precipitation, from 2003-2018.

The American Academy of Allergy, Asthma and Immunology-National Allergy Bureau (AAAAI-NAB) and the Regional Air Pollution Control Agency (RAPCA) for Dayton provided pollen counts for Indianapolis and Dayton, respectively (Data from AAAAI- NAB, for Indianapolis from 2003-9, and Communication from RAPCA, Dayton, Ohio, February 6, 2019). RAPCA also posts Dayton pollen counts to the NAB website. Indianapolis had complete pollen data from 2003-2009. Dayton had pollen counts from 2003-2006, and 2008-2018. In Indianapolis, pollen counts were reported daily, with limited exceptions. In Dayton, pollen counts were mainly reported Monday through Friday. Both sites used Burkard spore traps atop urban buildings, and reported counts in grains/m^3 air, per NAB guidelines. Data were analyzed via Statistical Analysis Software v9.4 (SAS Institute Inc, Cary, NC).

There were no significant differences in annual temperature or precipitation between Indianapolis and Dayton from 2003-9 (median 51.9°F vs 53.7°F; p=0.07, NS) (median 44.4in vs 49.0in; p=0.08, NS). There were no significant differences between in Dayton between 2003-9 and 2010-18, regarding precipitation (median 42.5in vs 41.4in, p=.72, ns). Temperature did significantly increase from 2003-9, to 2010-18, in Dayton (51.8°F vs 53.2°F; p=0.03). (National Oceanic and Atmospheric Association, www.ncdc.noaa.gov, accessed March 31, 2019) In the past century, average temperature has increased 0.1°F per decade in Indiana, and 0.2°F in Ohio. (NOAA Climate at a Glance Database)

The same weed pollens were reported in Indianapolis and Dayton—Ragweed (*Ambrosia*); English plantain (*Plantago*); dock/sorrel (*Rumex*); nettle (*Urtica*); chenopods (*Chenopodiaceae*); and mugwort/ sagebrush (*Artemisia*). The start and end of a pollen season were defined as the first two, and the last two, consecutive days on which at least five pollen grains/m^3 were reported. Weed pollens other than *Ambrosia* are grouped together as "other weeds."

There was no significant difference between Indianapolis and Dayton regarding *Ambrosia* season length (p=0.51) or other weeds pollen season length (p=0.84) from 2003-9 (Table 1). In Dayton, between 2003-09, and 2010-18, there were no significant changes regarding *Ambrosia* or other weeds pollen season length (*Ambrosia* p=0.33; other weeds p=0.14). From 2003-2009, *Plantago* and *Rumex* were detected on significantly more days in Dayton versus Indianapolis (*Plantago*—p=0.01; *Rumex*—p=0.01). *Plantago* and *Rumex* were also detected on significantly more days from 2003-9, in Dayton, vs 2010-18 (*Plantago* p=0.01; *Rumex* p=0.02).

In Indianapolis, from 2003-8, the length of the other weeds pollen season decreased over the years (2003-118 days ;2004-113 days ;2005-86 days ;2006-101 days; 2007- 77 days;2008-67 days;p=0.01). [(Slope parameter, -9.94 (2.20), p=0.01; R2=0.84). Figure available upon request.]

This study does not support recent findings that the pollen seasons of *Ambrosia* and other weeds are lengthening in the Midwest. However, variations among definitions of the length of a pollen season may account for this finding. Studies have defined the start of a specific pollen season as one where 1% to 3% of the pollen, of the season's total amount, is detected, and the

end, as when 97% to 99% have been detected. One day or five consecutive days have also been used to define the start and end of a pollen season.[4,10] As noted, this study used the threshold of five grains/m^3, on two consecutive days, to define the start and end of a pollen season. We could not use five consecutive days as a benchmark as data was often not available for five consecutive days in Dayton. The multiple strategies used to define pollen season duration may explain some of the differences in our findings.

Strengths of this study include the use of Burkard pollen counters, placed in similar locations, at both sites. This study also underscores the importance of having NAB-certified pollen counters around the country. The state of Indiana has not had an NAB-pollen counter since 2009. Pollen data from close locales may not reflect local changes. Having pollen count data over the past decade for Indiana would have added to our findings.

In addition, this study did not assess the overall pollen counts and pollen loads for the time periods studied. Assessing these data, and data over a longer period, may provide further insights. Moreover, there may be other factors in the local environment that affect weed pollen seasons, which merit further study. Interestingly, *Plantago* and *Rumex* pollens appear to have decreased in the past decade in Dayton, suggesting the need to further examine individual pollen species in relation to CO_2 and temperature changes over time. Further study into weed pollen patterns in the US Midwest is needed as trends of increased pollen season length may develop here as well.

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	2003-9 Indianapolis (Median # of days/year, range)	2003-9, Dayton (Median # of days/year, range)	p-value (Indy vs Dayton, 2003-9)	2010-8 Dayton (Median # of days/year, range)	p-value (Dayton, 2003-9 vs 2010-8)
Ambrosia	68 (52-71)	65 (55-84)	0.51	51 (38-85)	0.33
Other Weed pollens (in total)	93 (67-118)	91 (82-103)	0.84	77 (49-128)	0.14
→Artemisia	0 (0-4)	5 (0-10)	0.06	5 (0-12)	0.67
→Chenopodiaceae	10 (5-20)	10 (6-17)	0.94	7 (0-18)	0.34
→Plantago	0 (0-3)	7 (0-29)	0.01*	0 (0-5)	0.01*
→Rumex	0 (0-0)	7 (0-15)	0.01*	0 (0-5)	0.02*
→Urtica	19 (7-47)	14 (5-27)	0.15	10(0-23)	0.28

Table 1: Season length for Ambrosia and Other weed pollens, between Indianapolis and Dayton from 2003-9, and Dayton itself, from 2003-9 vs 2010-8. (p-values from Wilcoxon non-parametric test, due to data skewness). Plantago and Rumex seasons were significantly longer in Dayton from 2003-9, vs Indianapolis 2003-9, and Dayton 2010-18.