Climate Change Impacts on Tree Fruits and Viticulture in the Midwestern Region

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Tree fruits* are a group of specialty crops that has wide-ranging production totals in the Midwestern U.S. (Figure 1a). Similarly, the Midwest is an important region for viticulture (grape production; Figure 1b). Tree fruit and grape reported production statistics for Midwestern states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) from the 2022 United States Department of Agriculture (USDA), National Agricultural Statistics Service Census of Agriculture (Quick Stats)[1] indicate:

- **14,701** farms produced at least 1 type of tree fruit (see Figure 1a for farm distribution by county). Total farms with grape production were **3,626** (Figure 1b).
- Over **130,000 acres** of farmland are in tree fruit or grape production.
- Total sales for fruits and tree nuts (excl. berries) were over **$641 million.**

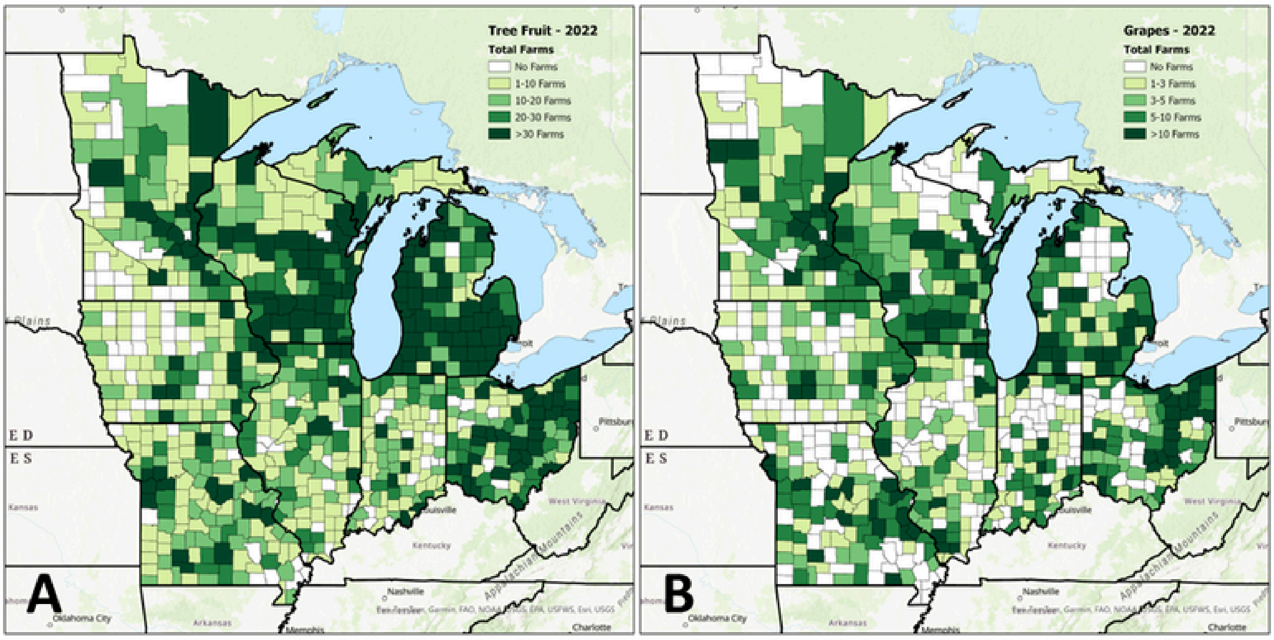

Figure 1: Tree fruit and grape production by county, according to the 2022 USDA Census of Agriculture. Maps show reported number of farms for (a) tree fruits and (b) grapes.

Tree fruits and grapes, like all crops, are susceptible to challenges caused by a changing climate. Currently observed changes and projected future changes will affect tree fruit and grape production in unique ways and producers may need to consider different practices to mitigate climate-related problems. This bulletin will discuss climate trends, expected impacts for tree fruit and grape production, and methods to mitigate these challenges.

*For this document, tree fruits include apples, cherries, peaches, and pears.

Climate Trends

The data and trends provided in this section are a synopsis of observed changes (1979-2021) and modeled projections across the Midwest. Observational changes in the region's climate are calculated from gridded meteorological data from 1979 to 2021 (period of record for the dataset) by partners at Michigan State University and the Great Lakes Integrated Science and Assessment (GLISA).[2] The following assessments reflect climate models' projected values in mid-century (2040-2059), based on a climate scenario with emissions increasing over time without substantial reductions (RCP 8.5).[2,3] Projected values are compared against the 1979-2005 averages. For a detailed assessment of changes and trends in your state as well as for additional climate scenarios, refer to your state's agriculture vulnerability assessment available from the USDA Midwest Climate Hub (https://www.climatehubs.usda.gov/hubs/midwest/topic/assessing-impacts-climate-change-midwest-agriculture).

Temperature

Annual and Seasonal Averages

- Current annual temperatures have increased by 1-2°F (~1°C), averaged across Midwest states, compared to late 1970s averages (Figure 2, "Avg.").
- Autumn is the season with the largest observed increase in temperature (2.1°F, or 1.2°C), averaged across Midwest states (Figure 2).
- Annual average temperatures are expected to rise by another 5-6°F (~3°C) by mid-century under a very high scenario (RCP 8.5; Figure 2, "Avg.").
- By mid-century (2040-2059), summer is projected to be the season with the highest increase in temperature (relative to observed averages) under a very high scenario (RCP 8.5; Figure 2).

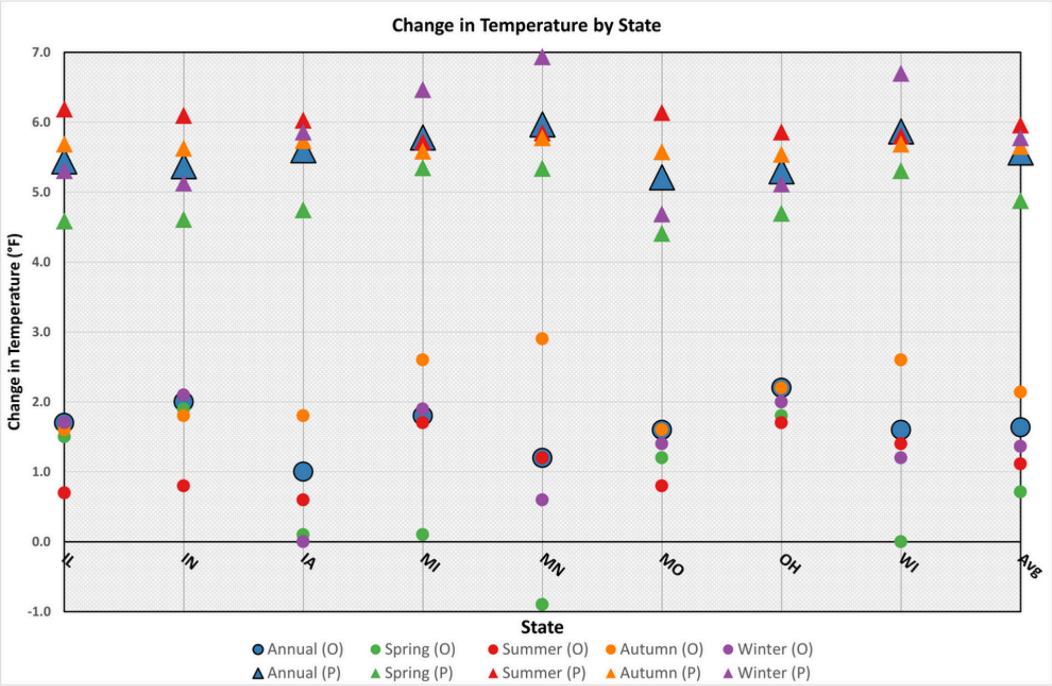

Figure 2: Mean observed and projected changes in average temperature (°F), annual and seasonal. Observed values are changes in annual/seasonal average between 1979 and 2021 (circles, "O"). Projected changes are based on the RCP 8.5 scenario, 2040-59 (triangles, "P"). The solid black horizontal line at 0.0 represents no change relative to 1979.

Extreme Cold and Heat Events

- The frequency of very cold nights (daily low ≤-4°F (-20°C)) has been decreasing across the Midwest since the 1960s (Figure 3).[4]
- Winter "rapid" cold snaps (≥45°F (25°C) drop over 48 hours) have shown no significant trends over the last several decades at most observing sites (Figure 4).[5]
- The number of days per year with a low temperature ≤0°F (-18°C) is projected to decrease by 6 days by mid-century. Days (per year) with daily low at or below freezing (32°F, 0°C) are expected to decrease by 36 days, on average (Table 1).
- The number of hot days (daily high ≥86°F (30°C)) per year is expected to increase, on average, by 81 days. On average, number of days with a hot night (daily low ≥80°F (27°C)) are projected to increase by 2 days per year (Table 1).

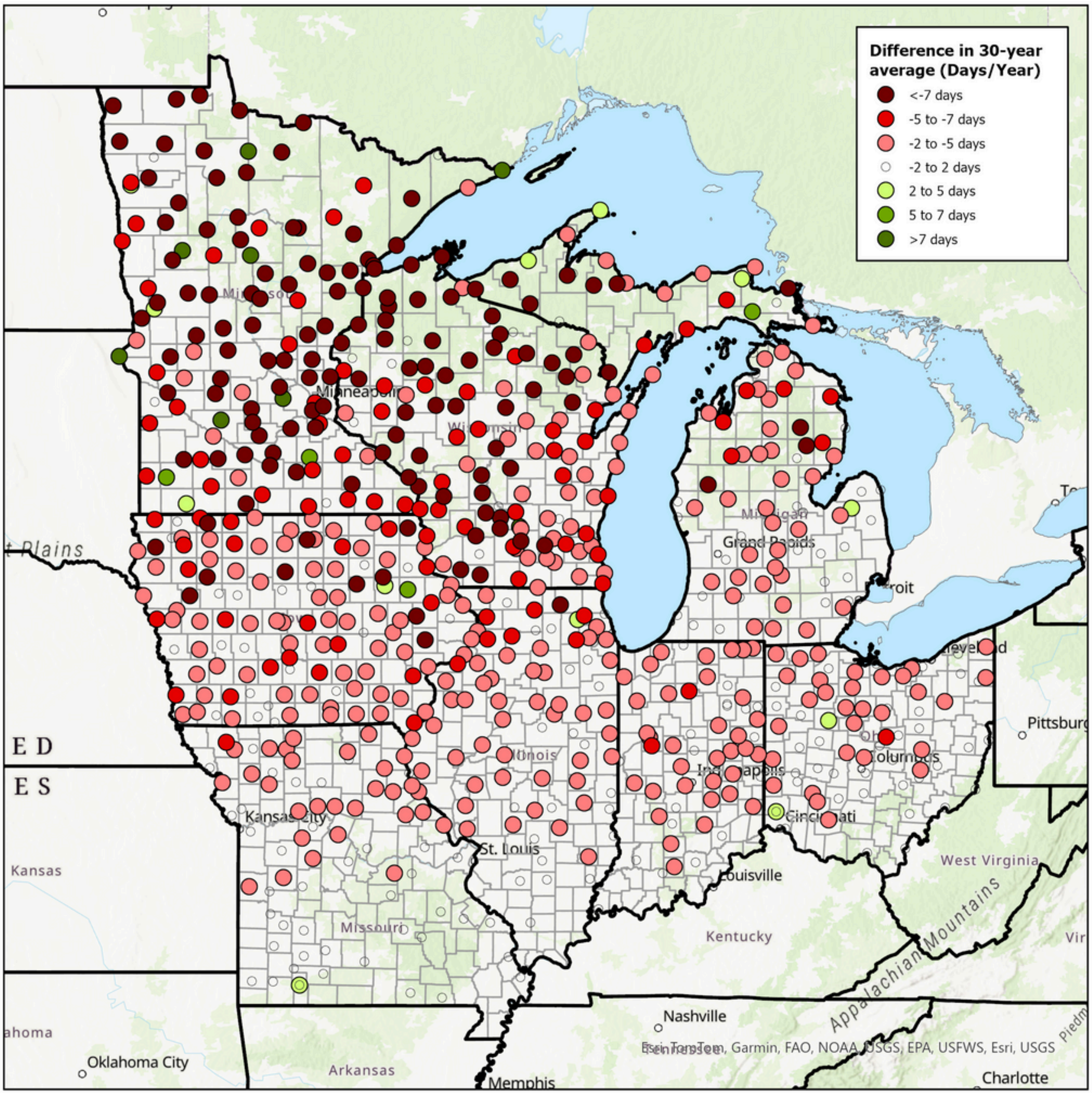

Figure 3: Change in the 30-year average number of days (per year) with a daily low temperature of ≤ -4°F (-20°C) between (1961-1990) and (1991-2020). Data source: Applied Climate Information System (ACIS), http://www.rcc-acis.org/.[4]
Data compiled with the assistance of the Midwestern Regional Climate Center (MRCC).

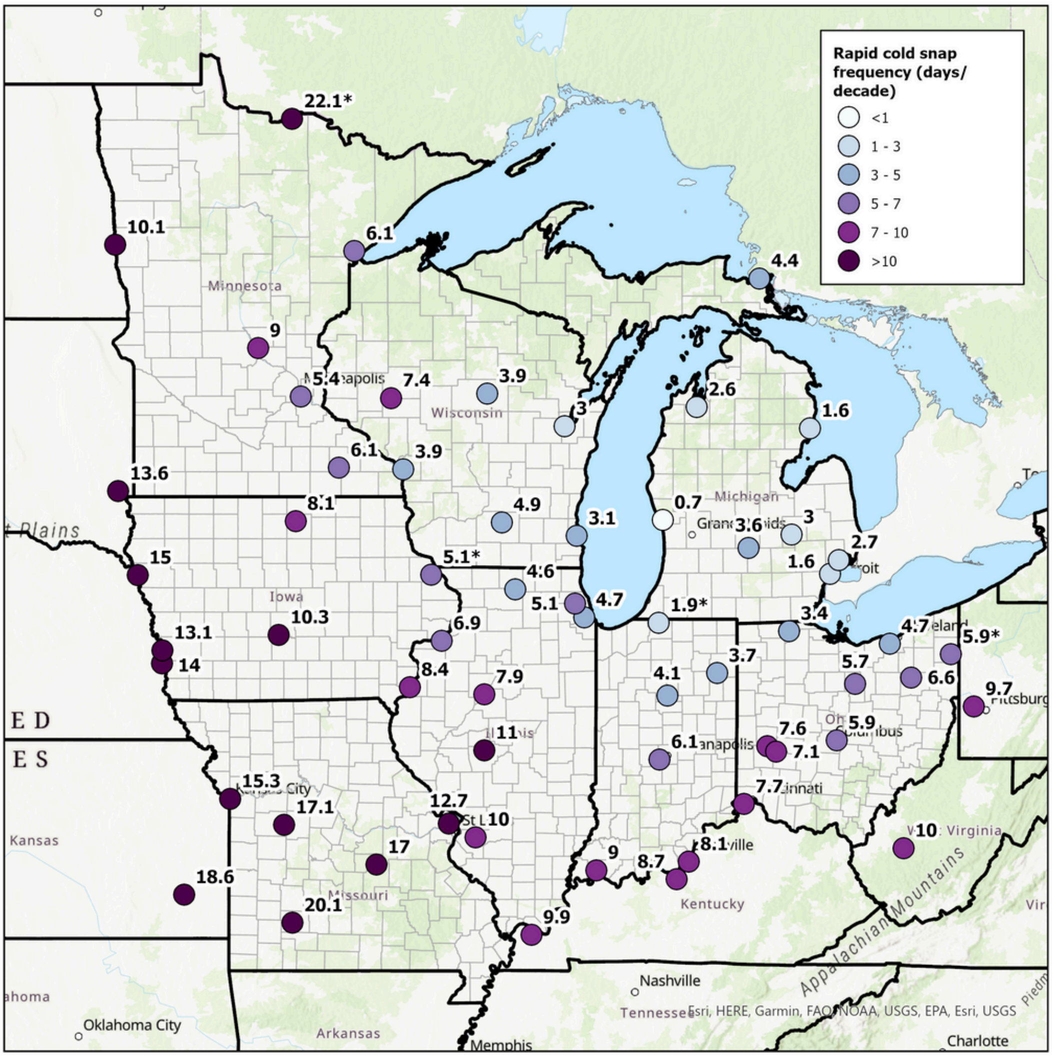

Figure 4: Frequency of winter "rapid" cold snaps (≥45°F (25°C) drop over 48 hours) at major airports, 1951-2020. Significant increase in cold snap frequency ($p<0.05$) is indicated by (*); no significant decreasing trends were observed. Data source: Iowa Environmental Mesonet (IEM), https://mesonet.agron.iastate.edu/request/daily.phtml.[5]

	Projected Change, Number of Days (2040-2059)				
	Daily Low ≤ 0°F (-18°C)	**Daily Low ≤ 32°F (0°C)**	**Daily Low ≥ 80°F (27°C)**	**Daily High ≥ 86°F (30)°C**	**Daily High ≥ 95°F (35°C)**
Illinois	-3.1	-36.7	+5.3	+84.3	+26.4
Indiana	-2.5	-36.7	+3.0	+89.8	+20.6
Iowa	-7.3	-34.5	+2.2	+81.7	+17.3
Michigan	-7.1	-43.7	+0.3	+72.2	+6.8
Minnesota	-14.5	-32.8	+0.4	+68.4	+8.5
Missouri	-2.0	-32.0	+6.1	+82.5	+32.9
Ohio	-2.1	-37.4	+1.0	+92.1	+14.0
Wisconsin	-11.0	-37.2	+0.4	+73.4	+7.1

Table 1: Mean projected changes in days per year above/below temperature extremes. Projected changes are based on the RCP 8.5 scenario. Projected values are compared against 1979-2005 averages to calculate change.

Growing Season Length and Freeze Events

- Across the Midwest, growing seasons are getting longer (Figure 5) because of the last freeze (daily low ≤32°F (0°C)) happening earlier in the spring and the first freeze happening later in the fall.[6]
- Late-season freeze events (on or after May 1st) tend to occur at a higher frequency further north; see Figure 6 for county-specific frequency.[6]
  - Most counties with a significant trend in late freeze events between 1950-2023 observed a decline in frequency of <1 year/decade (data not shown).
- Models suggest that the last spring freeze will occur earlier in the spring by mid-century, but this date will become more variable from year-to-year.[7]
- By mid-century, under a very high scenario (RCP 8.5), the growing season length is expected to increase in the Midwest by an average of 32 days (compared to 1971-2010 average).[8]

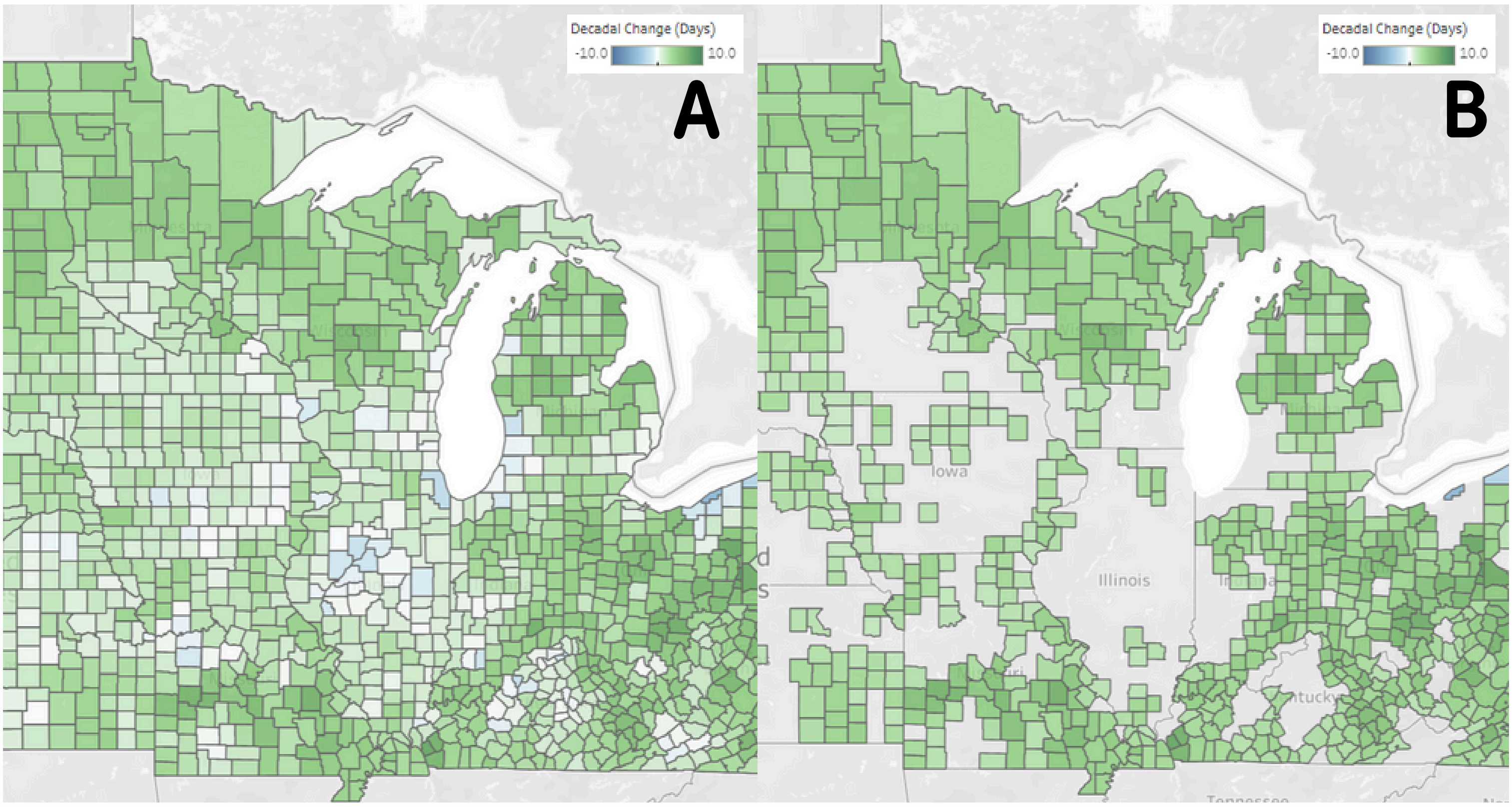

Figure 5: Trend in average annual growing season length for Midwest counties (a), 1950-2023 based on gridded ACIS dataset. The right-hand image (b) displays only those counties with a statistically significant trend (p<0.05). Image source: Freeze Date Tool, Midwestern Regional Climate Center, https://mrcc.purdue.edu/freeze/freezedatetool.html.[6]

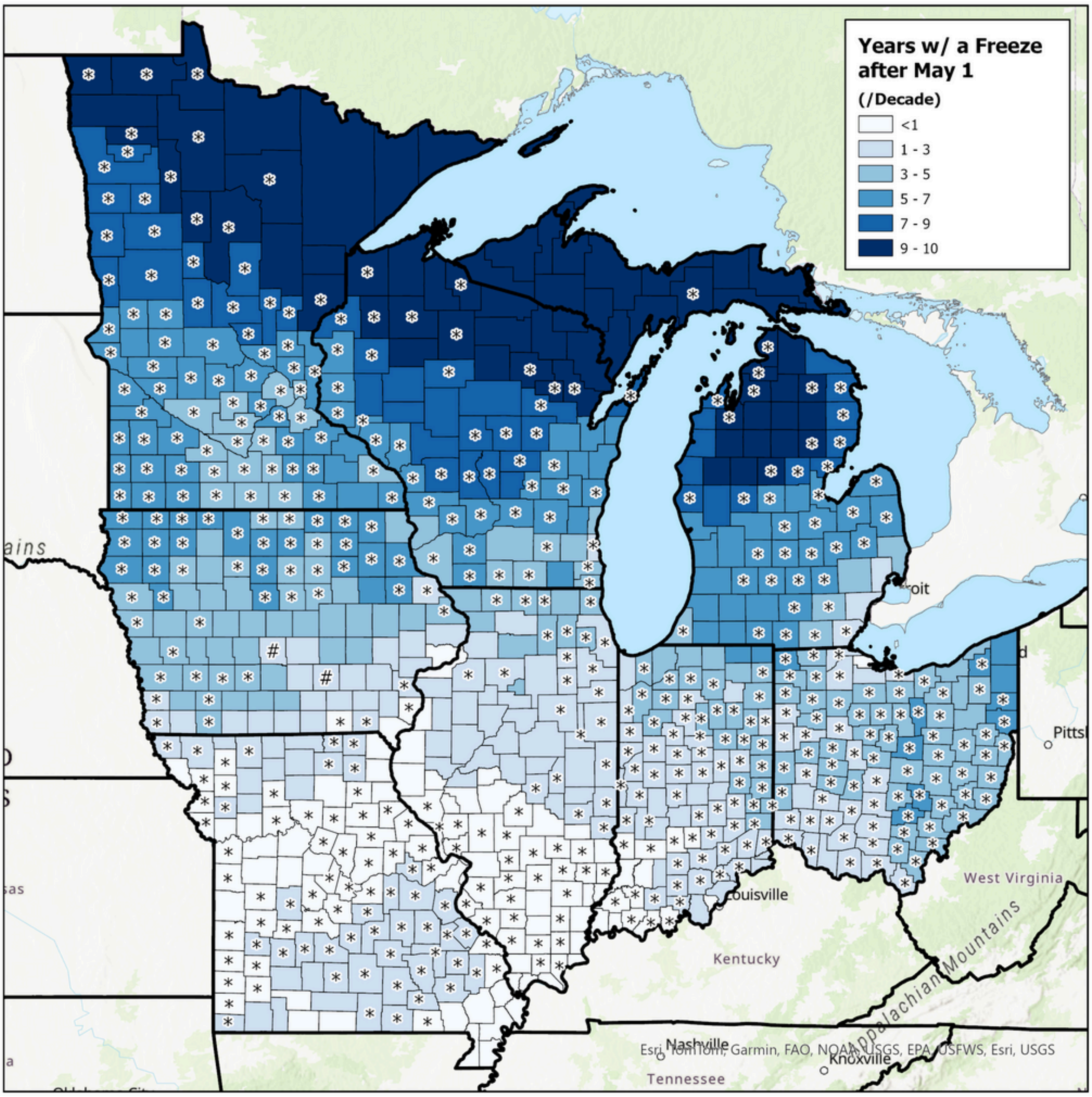

Figure 6: Frequency of years with a late-season freeze (May 1 or later, ≤32°F [0°C]) per decade, averaged by county, for 1951-2020. Symbols denote a significant change in freezes after May 1 ($p<0.05$; [*] = decrease, [#] = increase). Data source: Freeze Date Tool, Midwestern Regional Climate Center, https://mrcc.purdue.edu/freeze/freezedatetool.html.[6]

Precipitation

Annual and Seasonal Averages

- Annual precipitation totals increased across all seasons in the Midwest, ranging from +2.8" (~71 mm) in Minnesota to +7.0" (~178 mm) in Ohio (Figure 7).
- Winter and spring seasons have the largest increase in total liquid precipitation.
- Annual precipitation is projected to increase by an additional 1-2" (~25-50 mm) by mid-century (Figure 7).
- Total precipitation is projected to increase most in the spring, while summers are projected to have decreasing totals.

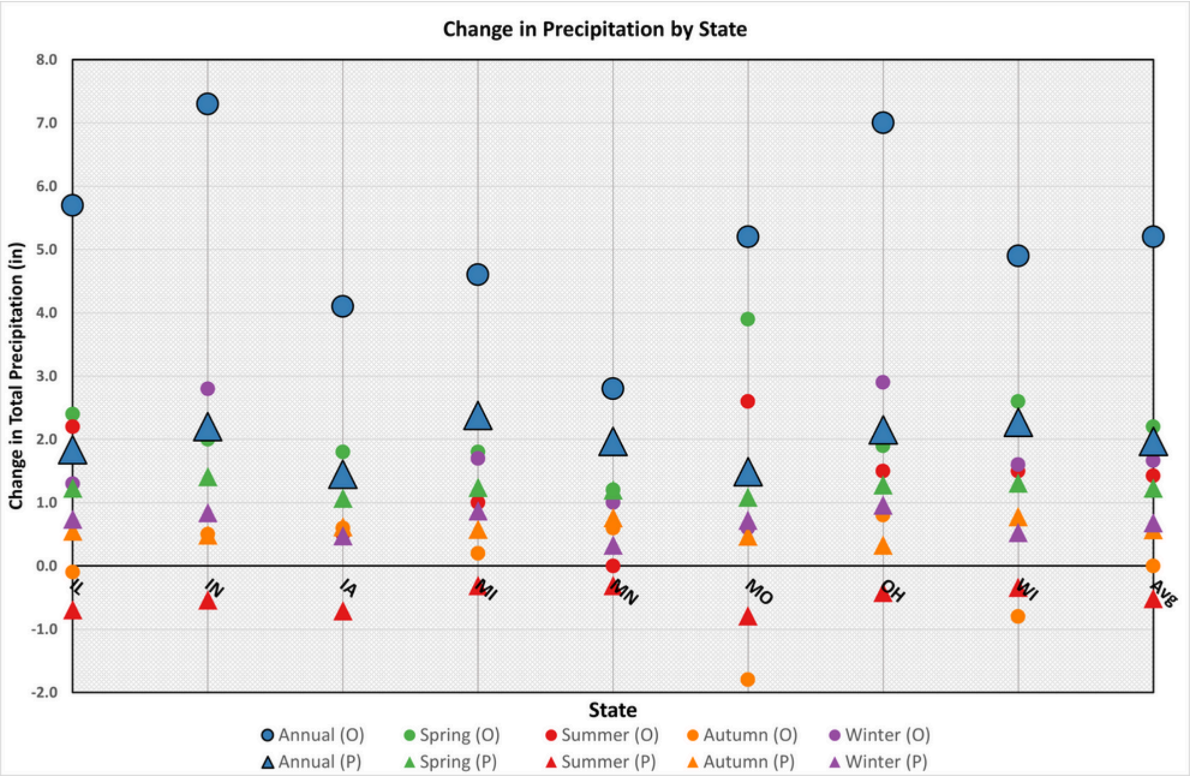

Figure 7: Mean observed and projected changes in accumulated precipitation (in.), annual and seasonal. Observed values are changes in annual/seasonal average between 1979 and 2021 (circles, "O"). Projected changes are based on the RCP 8.5 scenario, 2040-59 (triangles, "P"). The solid black horizontal line at 0.0 represents no change relative to 1979.

Extreme Events

- The number of days with heavier precipitation (≥2", 51mm) increased by approximately 1 per year.
- Precipitation has been becoming more variable[9]; this trend is projected to continue (Figure 8). Projections indicate an increase in both the number of heavy precipitation events and consecutive dry days.[10]
- May and June are the months with the highest amount of total crop insurance indemnity payments for hail damage to apples in the Midwest (Figure 9).[11]
- Severe hail reports from the early 1990s to present day have not shown significant trends across most months/states (Figure 10).[12]
    - See the "Hail Data Disclaimer" below for more information on this dataset.

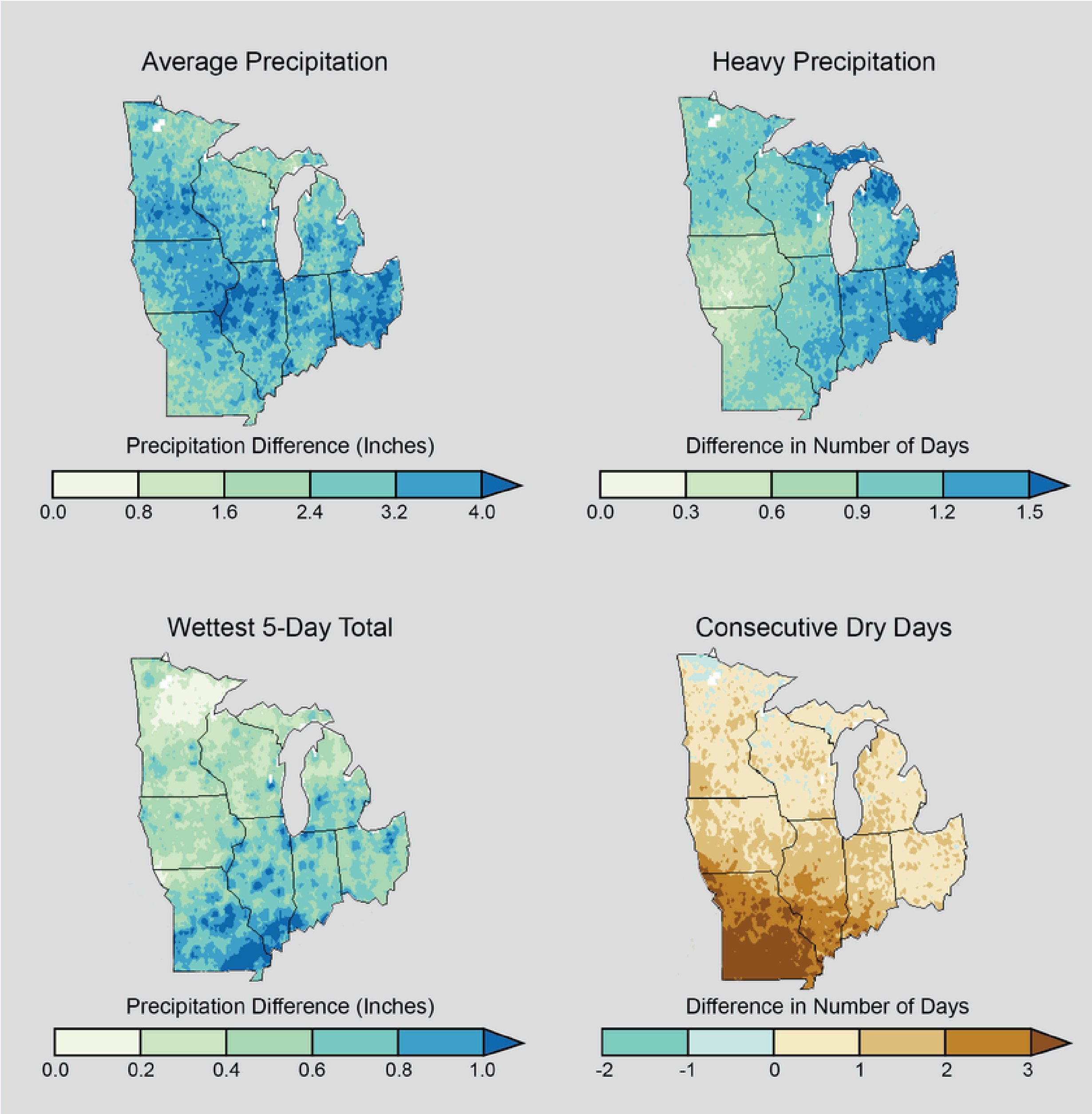

Figure 8: Projected change in precipitation by mid-century (2041-2070) under a very high scenario (RCP 8.5). Maps include changes in the average annual precipitation (top left), number of days with heavy precipitation events (top 2% of events, top right), rainfall total during the wettest-day period in a year (bottom left), and consecutive dry days (daily precipitation <0.01", bottom right). Image source: The 3rd National Climate Assessment, Midwest Region, Figure 18.6 (https://nca2014.globalchange.gov/report/regions/midwest).[10]

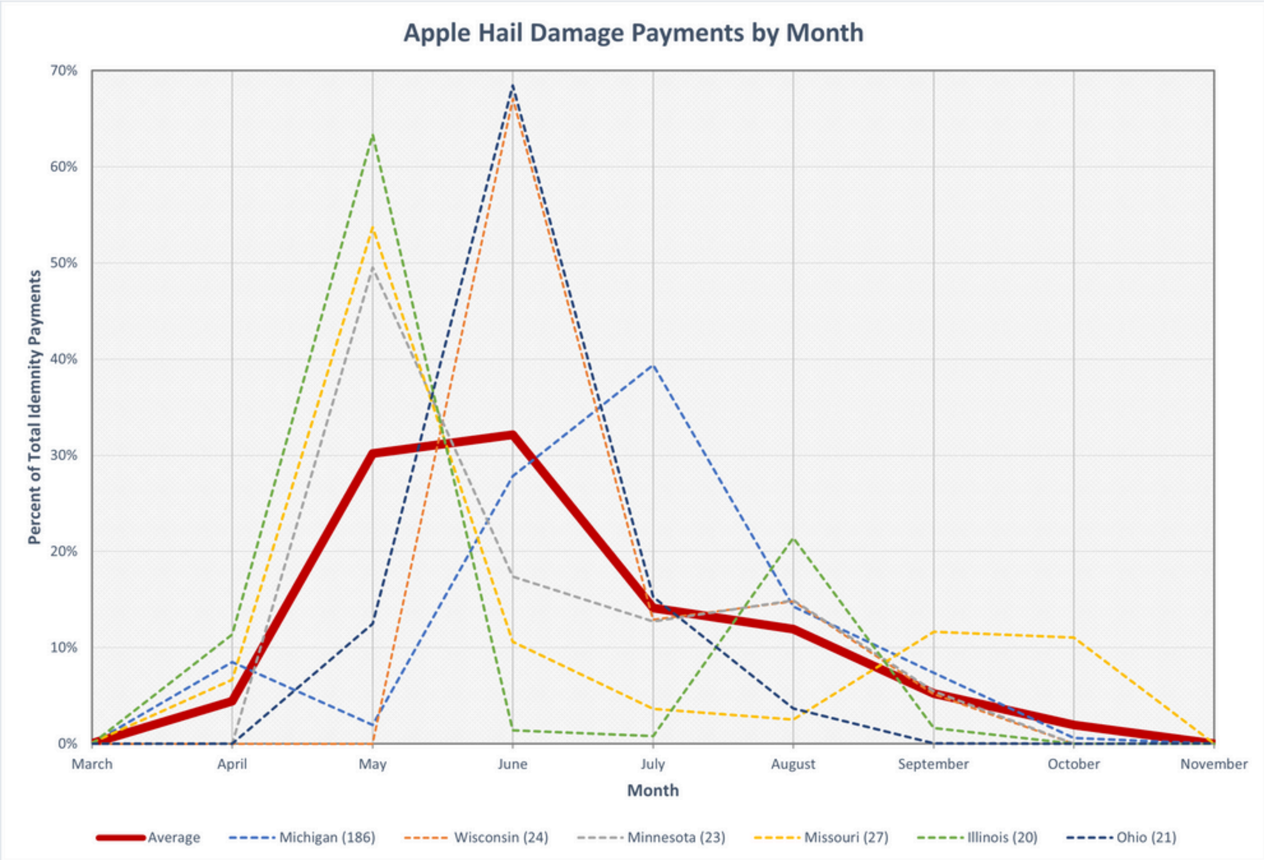

Figure 9: Crop insurance indemnity payments made to apple growers for hail damage, displayed as the monthly proportion of the 1989-2021 total payment amount. Data source: AgRisk Viewer (https://gallery3.jornada.nmsu.edu/rma/rma-data-viewer).[11]

	1955-1990								1991-2020								2001-2020							
	M	A	M	J	J	A	S	O	M	A	M	J	J	A	S	O	M	A	M	J	J	A	S	O
Illinois		0.3	0.4	0.3	0.2	0.1						1.6												
Indiana	0.2		0.3	0.4	0.3	0.2	0.1		1.2											-1.8				
Iowa	0.1	0.3		0.5		0.2	0.3		0.9	1.8		3.5									-3.1			
Michigan			0.2	0.1	0.4	0.1	0.1													-3.3				
Minnesota		0.3	0.5	0.5	0.4	0.4	0.2											-2.9		-4.8				
Missouri	0.2	0.5	1.2		0.2	0.1		0.1	2.7															
Ohio	0.2		0.6	0.4	0.3	0.1			1.2								1.5							
Wisconsin		0.1		0.2	0.3	0.1	0.2	0.01					1.1											

Figure 10: Trends in severe hail reports (reports/year) to the National Weather Service, 1955-2020. Significant trends ($p<0.05$) are highlighted by state and month. Data Source: NCEI Storm Events Database (https://www.ncdc.noaa.gov/stormevents/).[12]

Impacts and Management Strategies

The impacts of observed and projected changes in Midwestern climate on tree fruit and grape production are already occurring; these impacts are expected to continue and potentially increase in the future. The following sections cover specific climate-related impacts to tree fruits and grapes and management strategies to adapt to the change and mitigate the effects of the impacts.

Warmer Springs and Increased Growing Season Length

Climate projections in the Midwest region include warmer spring temperatures, longer growing seasons (e.g., frost-free period), and the last spring freeze occurring earlier in the spring. This will impact tree fruit and grapevines in meaningful ways:

Problem: Early bud break and increased risk of frost damage
Warmer temperatures during spring will accelerate the loss of cold hardiness of fruit trees resulting in earlier bud break, which renders plants more susceptible to spring frosts.

Strategies to mitigate spring frost damage include:

- The use of wind machines and heaters to mitigate cold events
- Overhead sprinkler irrigation
- Planting cultivars that break bud later in the season to mitigate the potential risk of trees and vines breaking dormancy during late-winter warm spells (i.e., loss of cold hardiness).

Problem: Shifts in phenological periods
Phenological models examine temperature data to create indices to predict the appearance, peak, and end of activity of various insects. Based on updated data trends, insect phenological models will need to be adapted to climate change parameters to ensure they continue to provide reliable information on the phenology of key pests of tree fruit.

Problem: Extension of period of insect and disease activity
The increase in length of the growing season means that insects, diseases, and weeds may have a longer period of activity, possibly an increase in the number of pest generations, or both. The result is a greater potential pest impact on fruit crops in Wisconsin and the larger Midwest region. For example, codling moth, a significant insect pest of apple and pear, has two generations per year with an occasional third generation (Figure 11). Increases in the length of the growing season will likely lead to a more consistent pattern of three generations per year. This will result in increased chemical treatments to address these longer periods of activity and may lead to increases in pesticide resistance.

Strategies to mitigate will include:

- Increasing the use of IPM strategies and delaying pesticide resistance via the rotation of pesticide chemistries.

Figure 11: Codling moth (left) and the damage they cause to apples (right). Image source: Christelle Guedot, UW-Madison.

Fungal pathogen spore production may extend beyond typical dispersal and depletion ranges. This could lead to earlier onset and prolonged epidemics in the growing season and extend for as long as susceptible tissue remains. This will inevitably lead to intensified fungicide programs to protect plants.

Problem: Range expansion

The increases in temperature in Wisconsin and the larger Midwest region may lead to shifts and expansion in the range of insects, diseases, and weeds. This will include increased ranges of insects not currently present in the upper Midwest due to the cold temperatures, including pests but also beneficial insects such as natural enemies and pollinators. For an example, see the expansion of the brown marmorated stinkbug's range.

Strategies to mitigate range expansion will include:

- Scouting and implementing IPM strategies that were successful in the original range of the pest.

Increased Spring Precipitation Followed by Drier Summers

The projected future climate in the Midwest will likely include higher precipitation during spring, with drier summers. This will impact tree fruit and grapevines in meaningful ways:

Problem: Fruit set

Rain or any direct source of water in open blossoms will reduce pollen availability for pollination. Pollen grains in direct contact with water will hydrate and lose viability. Water droplets in receptive stigmas can also wash out pollen grains, with the consequential reduction in effective pollination.

Problem: Fruit trees and vines development and fruit quality
Increased precipitation in spring will result in extended periods of soil saturation affecting nutrient uptake in spring, root development, and overall tree growth. Saturated soils during springtime will delay establishing new fruit trees and grapevines potentially resulting in limited growth during the first year of establishment. Alternate periods of extended drought, especially during the summer, will limit nutrient uptake, fruit development (small size and higher incidence of physiological disorders as well as fruit drop; Figure 12), and return bloom for the following growing season.

Figure 12: Grape cluster dehydration caused by summer drought stress. Image source: Amaya Atucha, UW-Madison.

Strategies to mitigate the effects of wet and dry soil cycles include:

- The use of cover crops that can help increase soil drainage, and
- Use of mulches such as wood chips on the tree rows that will increase water infiltration while also conserving moisture during the dry periods.

Problem: Increased insect pressure
Increasing spring precipitation will result in some insects thriving in these conditions. For example, spotted-wing drosophila, a major pest of small fruit, lay more eggs and are more active in high relative humidity conditions. Thus, this pest could be getting a head start in ramping up populations in the spring, leading to the infestation of earlier fruiting fruit such as strawberry and to larger populations over the summer and fall. Another example would be with the Japanese beetle, a major insect pest of grapes and other fruit crops. Japanese beetles preferentially lay eggs in moist soil and larvae do best in moist soil, thus increases in precipitation could lead to increased populations and damage from this pest.

Decreasing moisture totals in the summer will negatively impact some insects such as those mentioned above (spotted-wing drosophila and Japanese beetle) but will be conducive to other insects, such as mites, which thrive in dry conditions. Mites are small arthropods that affect fruit trees and small fruit; dry conditions usually lead to increasing mite outbreaks.

Strategies to mitigate the increase in pest pressure include:

- Adapting scouting frequency for insects known to thrive in more extreme conditions,
- Increasing use of degree day models to more accurately track insect phenologies, and
- Enhancing the use of Integrated Pest Management techniques.

These strategies will help prepare growers for the potential outbreaks that these conditions may foster.

Problem: Early emergence of pathogens and shifts in primary diseases observed

With increased precipitation in the spring, often coupled with warmer temperatures, conditions more favorable for fungal pathogen growth and spread may be observed. Many fungal pathogens affecting fruit crop production overwinter in the woody parts of the plants or in the buds. During spring precipitation, these pathogens release spores, potentially leading to earlier and increased spore dispersal events. If these fungal spore release events coincide with bud break and subsequent growth stages of the plants, infections may begin earlier in the season. Consequently, adjustments to preventive fungicide spray schedules may be necessary.

With increasing precipitation amounts, diseases like anthracnose, which thrive under wetter conditions, may pose an increasing threat in vineyards. As such, fungicide spray programs will need to adjust to accommodate this shift. Additionally, other fungal diseases that typically emerge early in the growing season following spring rain events, such as Phomopsis, downy mildew, and black rot, may also become more prevalent in the initial stages of the growing season. However, if drought conditions persist throughout the summer these fungal pathogens may not persist as conditions will not be favorable.

Powdery mildew outbreaks may become more common in both apple orchards and grape vineyards (Figure 13). With a changing climate, higher humidity during the day and night can lead to powdery mildew becoming a more prevalent concern for growers to manage. While warmer temperature can also influence powdery mildew development and spread, germination of the spores can be inhibited by temperatures exceeding 95°F (35°C). Unlike other fungal pathogens affecting apples and grapes, powdery mildew does not require free water (i.e., rain) for spores to germinate and spread. For this reason, this pathogen can persist in fruit cropping systems despite less precipitation. Furthermore, in northern Midwest apple orchards the powdery mildew pathogen has not traditionally overwintered well in the buds due to more consistently cold temperatures (below -11°F or -24°C), but with milder winters this pathogen may survive in buds and become an increased problem in orchards.

Figure 13: Severe powdery mildew infection on grapes. Image source: Leslie Holland, UW-Madison

Summer Heat Stress

The projected future climate in the Midwest will include an increase in the number of days with temperatures at or over 86°F (30°C). This will impact tree fruit and grapevines in meaningful ways:

Problem: **Plant heat stress and fruit sunburn**

An increased number of hot and dry days during the growing season, in particular closer to harvest, can result in an increased incidence of sunburn or sunscald. Sunburn can be expressed as browning of the fruit skin, but in some cases, damage can also appear during post-harvest storage (Figure 14).

Figure 14: Sunburned apples. Image source: Amaya Atucha, UW-Madison.

Strategies to mitigate fruit sunburn include:

- The use of evaporative cooling through over-head irrigation applied in cycles to wet the fruit to reduce surface temperature,
- Use of protective netting over the tree canopy to provide shade, and
- Use of kaolin clay, calcium carbonate, or other chemical compounds that when applied directly to fruits can block or dissipate solar radiation.

Hail Data Disclaimer

A trend in hail reports does not necessarily reflect a similar trend in hailstorm frequency. An increase in hail reports is subject to some non-meteorological factors that can bias the reported data[13,14]:

- Spotters have become more numerous over time; reports are biased towards areas where there are more spotters (e.g., urban areas, major roads, etc.)
- Telecommunication technologies, like cell phones, that have become more common since the early 1990s that make reporting from the field easier.
- Increased popularity of storm chasing since the early 1990s, especially in the Great Plains states.

Based on when most of the changes that affected reporting occurred, it has been suggested that the hail reports provide a relatively reliable record of hail incidence from the early 1990s to the present[13]. Thus, our analysis on hail report trends separates the periods before and after the early 1990s.

State Climate Assessments

For more information on observed and projected climate data in your state as well as how these changes are expected to impact agriculture, read your state's *Climate Change Impacts on [State] Agriculture* bulletin. View or download a copy at https://www.climatehubs.usda.gov/hubs/midwest/topic/assessing-impacts-climate-change-midwest-agriculture.

Fruit Crop Extension Programs by State

- Illinois https://extension.illinois.edu/fruit-trees
- Iowa https://www.extension.iastate.edu/ag/commercial-horticulture
- Indiana https://ag.purdue.edu/department/hla/extension/fruit-crops.html
- Michigan https://www.canr.msu.edu/fruit/
- Minnesota https://extension.umn.edu/find-plants/fruit
- Missouri https://extension.missouri.edu/topics/fruits
- Ohio https://southcenters.osu.edu/horticulture/fruits
- Wisconsin https://fruit.wisc.edu/

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