7.7 MONITORING FREEZE INJURY POTENTIAL TO U.S. WINTER WHEAT DURING DORMANCY

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1. INTRODUCTION

U.S. winter wheat, grown primarily across the Plains, Midwest, and Northwest, is an exceptionally hardy crop. Planted in the fall, winter wheat becomes vegetatively established—exhibiting root and leaf development—before daily average temperatures fall below 5 degrees C. Winter wheat is most resistant to freeze injury during the winter months, a period of crop dormancy in much of the U.S. Wheat that has become well established prior to dormancy can withstand temperatures to -20 degrees C or slightly lower without sustaining significant injury. Even lower temperatures are not harmful provided that winter wheat is blanketed with a protective snow cover. Therefore, it is useful to monitor potential freeze injury to the winter wheat crop using temperature and snow depth observations provided by the U.S. Cooperative Observer Network, managed and maintained by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce (DOC). Monitoring of winter wheat freeze injury potential and many other crop-weather assessments are provided by the Joint Agricultural Weather Facility (JAWF), jointly operated by DOC/NOAA and the U.S. Department of Agriculture's Office of the Chief Economist (USDA/OCE). Such assessments are conveyed to a broad audience in the *Weekly Weather and Crop Bulletin*, JAWF's flagship publication.

2. U.S. WINTER WHEAT BACKGROUND

Approximately 90 percent of the U.S. winter wheat crop is grown in 18 states across the Plains, Midwest, and Northwest (fig. 1). By far the nation's largest winter wheat producer is Kansas, which from 1996-2000 accounted for an average of nearly one quarter of the U.S. production.

2.1 Freeze Injury Potential

Freeze injury to winter wheat during dormancy is only one of many factors influencing yield potential. Nevertheless, it is helpful to examine temperature and snow depth observations during winter wheat dormancy, which coincides with the period of maximum resistance to cold weather (fig. 2). Although winter wheat can typically withstand mid-winter readings lower than -20 degrees C (-4 degrees F), a crop weakened by factors such as drought, high winds, or flooding may sustain damage at somewhat higher temperatures. However, even a weather-stressed crop can be protected from adversely cold conditions by a snow cover.

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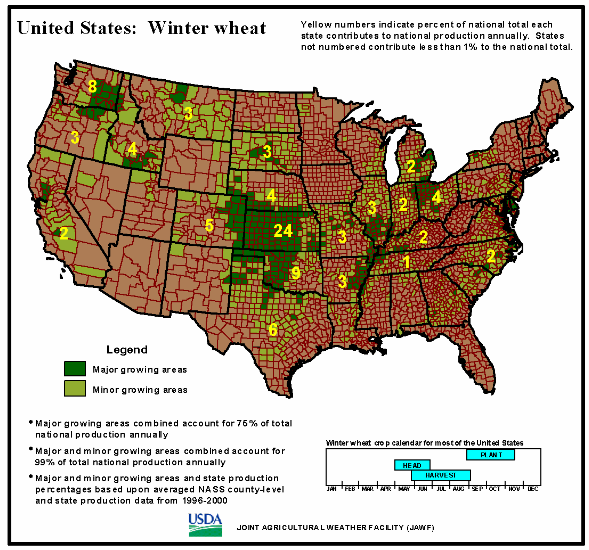

Fig. 1. Major and minor U.S. winter wheat areas.

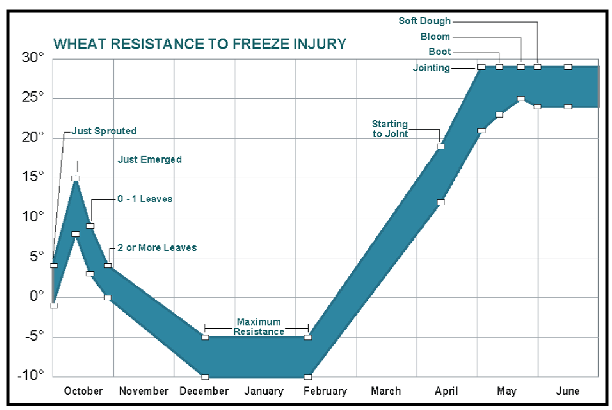

Fig. 2. Temperatures (degrees F) that cause freeze injury to winter wheat at different growth stages. (Graph from Agricultural Experiment Station and Cooperative Extension Service, Kansas State University; adapted from A.W. Pauli.)

3. U.S. COOPERATIVE OBSERVER NETWORK

A primary source of real-time snow depth observations is the U.S. Cooperative Observer Network (COOP). According to a recent analysis performed by the Joint Agricultural Weather Facility (JAWF), more than 4,000 daily snowfall and snow-depth observations are available through the COOP (fig. 3). Unlike other meteorological parameters—such as precipitation and temperature observations—which have been automated with varying degrees of success in recent years, the accurate measurement of snowfall and snow depth requires human intervention. Ongoing efforts by the Department of Commerce (DOC) to modernize the COOP should continue to ensure the integrity of the unique, manual snow measurements, which will become part of a National Cooperative Mesonet (NCM). According to DOC's 2004 Program Development Plan, one of the goals is for the COOP to "be a modern network that can serve as the backbone of the NCM and...to support agriculture."

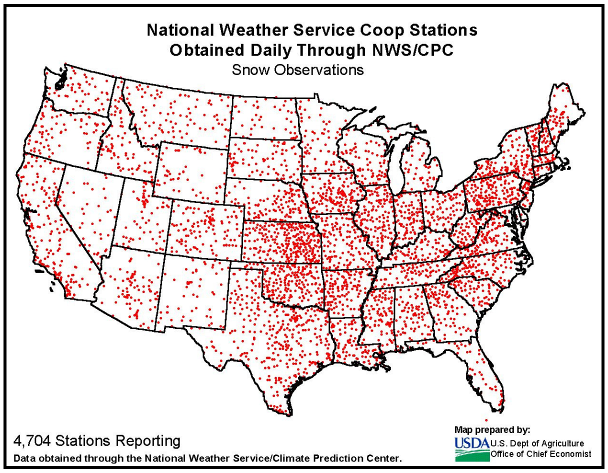

Fig. 3. Locations of daily snow observations available through the U.S. Cooperative Observer Network.

3.1 *Benefits of COOP Snow Cover Data*

The COOP snow cover data is particularly useful for crop assessments because the observations are mostly taken in rural, agricultural locations. COOP information contrasts with the data provided by the network of Automated Surface Observing Systems (ASOS), which are concentrated at suburban and urban airport sites. In addition, snowfall and snow-depth observations are provided at ASOS locations only when there is human intervention.

4. GIS DATASET COMBINATION

Using a geographic information system (GIS), three layers of data are combined to analyze the effects of cold weather on exposed winter wheat. First, county- and state-level winter wheat production data from USDA's National Agricultural Statistics Service are mapped to identify major and minor crop areas. Then, minimum temperatures from COOP and ASOS observations are layered atop the crop production data. Finally, snow-depth observations are added to the other two layers, providing a quick assessment of areas of concern for freeze injury potential. One of the most useful methods for mapping a multi-day cold outbreak involves plotting the number of "critical days" for dormant winter wheat (fig. 4) at all locations that observed both temperatures at or below -18 degrees C (0 degrees F) and coinciding snow depths at or below 2.5 cm (1 inch).

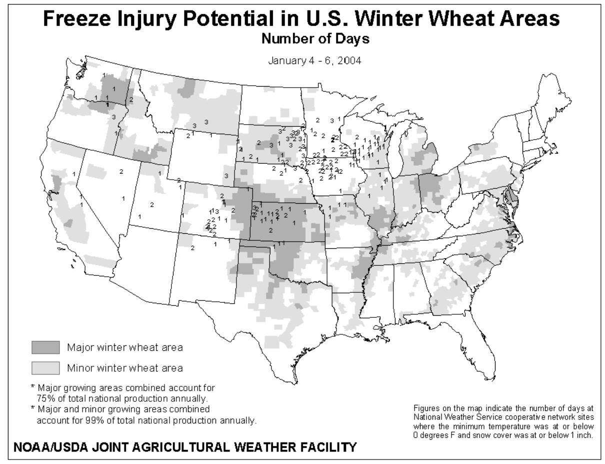

Fig. 4. Example of map featuring the number of "critical days" for dormant winter wheat due to low temperatures and little or no snow cover.

5. January 2004 Kansas Case Study

In January 2004, a pair of cold outbreaks threatened the central Plains' winter wheat crop. From January 4-6 and 26-29, a portion of the dormant but exposed winter wheat crop in parts of northern and western Kansas was subjected to temperatures at or below -18 degrees F (0 degrees F). Using the GIS dataset combination method described in Section 4, maps highlighting areas of concern for freeze injury to wheat were created and published in the *Weekly Weather and Crop Bulletin*. Both the January 4-6 and 26-29 cold outbreaks (fig. 4 and 5) showed an area of concern in northwestern Kansas.

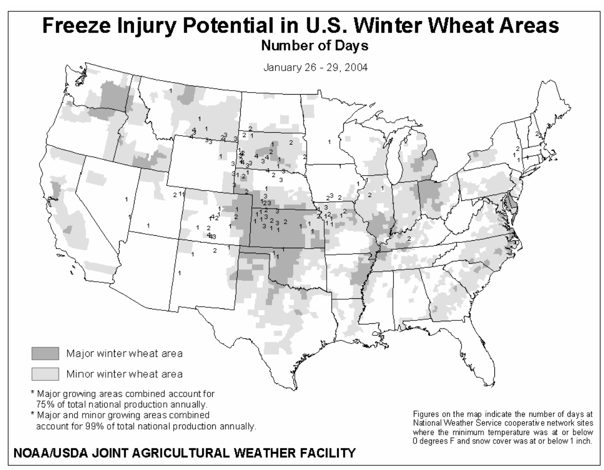

Fig. 5. Case study of a cold outbreak from January 26-29, 2004, showing the GIS dataset combination method of highlighting areas of potential freeze injury for winter wheat.

5.1 *Other Factors in Yield Reduction*

Freeze injury during dormancy is only one of many factors influencing winter wheat yield potential. Among the most critical times is the autumn development period, when the winter wheat crop becomes established. A poorly established winter wheat crop, with minimal root and leaf development, is especially susceptible to adverse winter weather conditions, such as high winds and bitterly cold weather.

The other critical period for determining final yield potential is spring, after winter wheat breaks dormancy. Just as wheat slides into dormancy when daily average temperatures fall below 5 degrees C, the crop becomes vegetative again when daily average readings rise above 5 degrees C. Vegetative wheat not only requires adequate moisture for proper development, but also becomes increasingly vulnerable to cold outbreaks.

5.2 *Assessment of 2004 Kansas Winter Wheat Crop*

According to USDA's National Agricultural Statistics Service (USDA/NASS), the 2003-04 Kansas winter wheat crop production was 314.5 million bushels, down 34 percent from the previous year (fig. 6). The 2003-04 wheat yield was 37 bushels per acre, down 23 percent from 2002-03 (fig. 7). Most of the 2003-04 reduction was due to adverse weather conditions, since the planted acreage was down just 5 percent from the previous year.

The season's first winter wheat condition report, on October 26, 2003, indicated that 16 percent of Kansas' winter wheat was rated in very poor to poor condition, 25 percent fair, and 59 percent good to excellent. The final autumn condition report, on November 23, rated the crop at 22 percent very poor to poor, 26 percent fair, and 52 percent good to excellent. Dry weather during crop establishment contributed to the decline in crop condition (fig. 8).

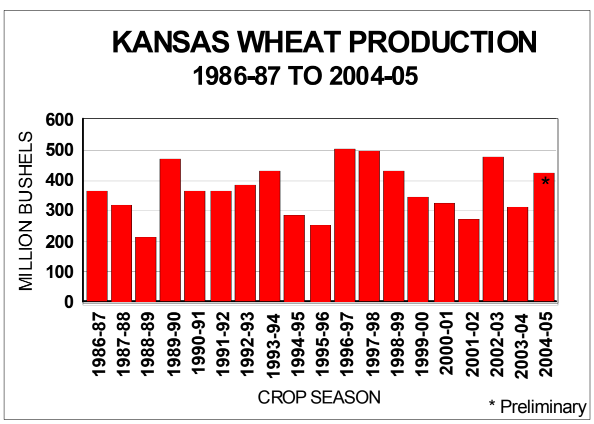

Fig. 6. Kansas winter wheat production, 1986-87 to 2004-05.

Following the January cold outbreaks, drier-than-normal winter and spring weather (fig. 9 and 10) in western Kansas continued to trigger a gradual decline in the state's wheat condition. On April 4, 2004, the Kansas wheat crop was rated 28 percent very poor to poor, 29 percent fair, and 43 percent good to excellent. Little more than a month later, on May 9, the crop was rated 36 percent very poor to poor, 29 percent fair, and 35 percent good to excellent. Finally, a mid-May freeze in parts of western Kansas (fig. 11) represented a final adversity for an already drought-stressed crop. Days after the freeze, on May 16, USDA/NASS reported that 90 percent of Kansas' winter wheat crop was heading. The winter wheat crop, especially vulnerable at the heading stage, can be damaged by temperatures at or below -1 degree C (30 degrees F).

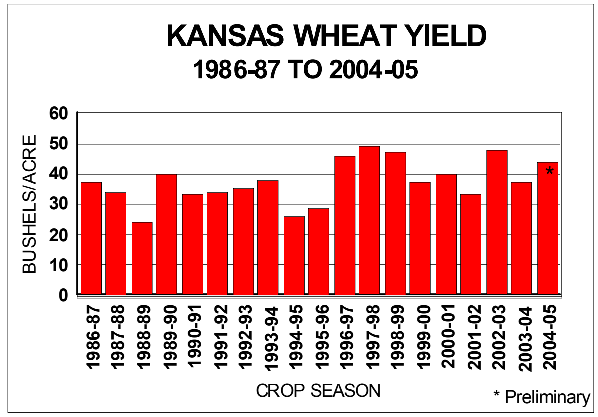

Fig. 7. Kansas wheat yield, 1986-87 to 2004-05.

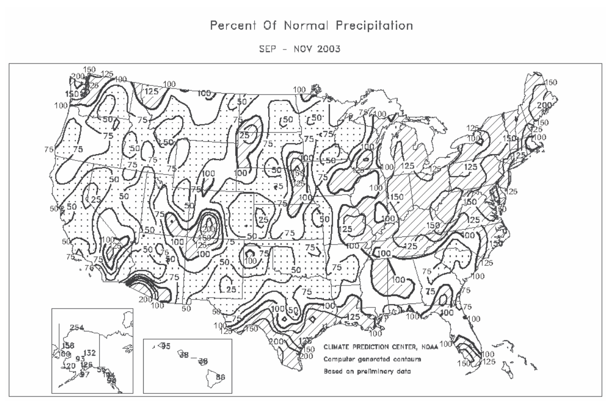

Fig. 8. Percent of normal precipitation map for September-November 2003, showing dry conditions in parts of Kansas during the autumn establishment season.

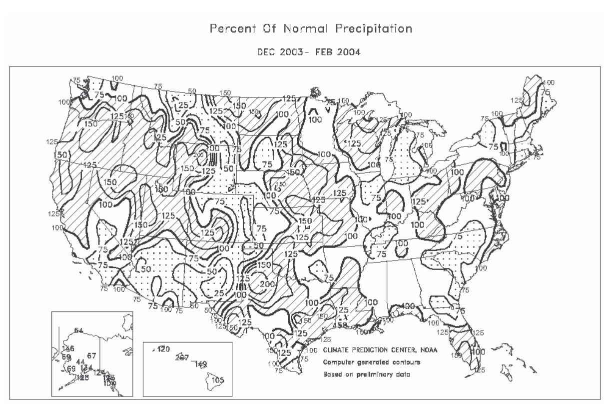

Fig. 9. Percent of normal precipitation map for December 2003 - February 2004.

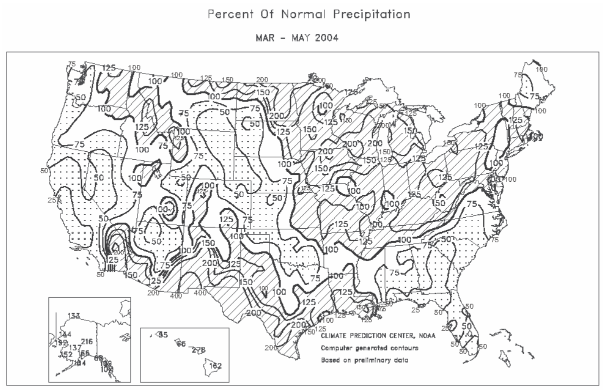

Fig. 10. Percent of normal precipitation for March-May 2004, showing persistent dryness in western Kansas.

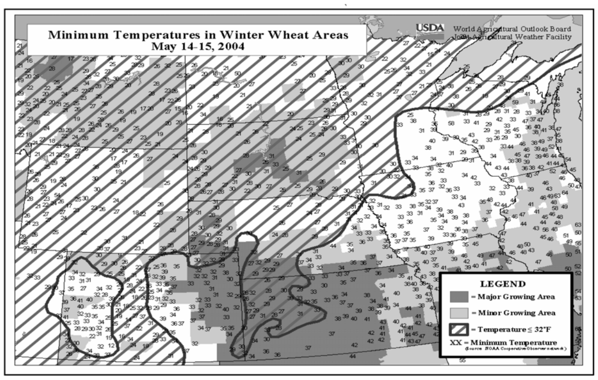

Fig. 11. A mid-may freeze was the final blow for some of the 2003-04 winter wheat crop in western Kansas.

By the time of the final crop condition report of the season, on June 27, Kansas' winter wheat was rated 44 percent very poor to poor, 27 percent fair, and 29 percent good to excellent (fig. 12).

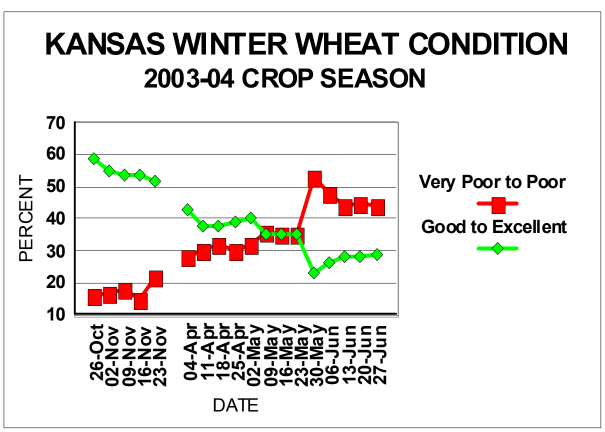

Fig. 12. Percentage of Kansas winter wheat rated very poor to poor and good to excellent during the 2003-04 crop season.

6. OTHER PRODUCTS FROM JAWF

Freeze assessments such as the one presented in this paper are part of JAWF's routine assessment program. JAWF meteorologists monitor global weather conditions and prepare real-time agricultural assessments. These assessments keep USDA commodity analysts, USDA's Office of the Chief Economist, and the Secretary of Agriculture apprised of worldwide weather-related developments and their effects on crops and livestock. When integrated with economic analyses, these crop-weather assessments provide critical information to decision-makers formulating crop production forecasts and trade policy. They also help analysts identify potential agricultural markets for U.S. products worldwide.

JAWF, located in Washington, D.C., was created in 1978. Among the most prominent JAWF publications is the *Weekly Weather and Crop Bulletin*, which has not had a name change since 1924 and has a storied history dating to 1872. Policy governing the two-agency publication of the *WWCB*, unwritten when the Weather Bureau was transferred from USDA to DOC on July 1, 1940, was formalized in 1958 and solidified by the establishment of JAWF.

Many of JAWF's crop-weather assessments appear in the *WWCB*. A common theme of the assessments is the blending of agricultural and meteorological information to provide a detailed analysis (fig. 13). Weather data are provided to JAWF by the World Meteorological Organization's Global Weather Observing System and the DOC/NOAA Cooperative Observer Network. Information on U.S. agriculture is obtained for each state through a network of county extension agents, farmers, and volunteer crop reporters, and summarized at the State Statistical Offices of the National Agricultural Statistics Service (NASS). This information is then forwarded to USDA/NASS headquarters in Washington, D.C.

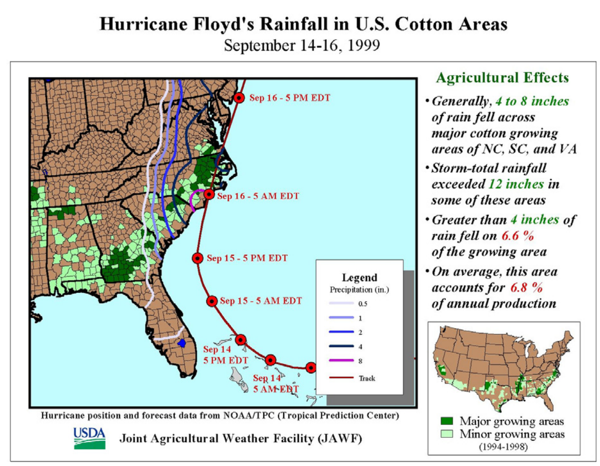

Fig. 13. Example of a crop-weather assessment generated by the Joint Agricultural Weather Facility. Such assessments are typically conveyed to a broad audience via the *Weekly Weather and Crop Bulletin*.

7. CONCLUSIONS

Freeze injury to winter wheat during dormancy is only one of many factors influencing final yield potential. However, when combined with analyses of autumn and spring growing conditions, assessments of potential freeze injury are a useful tool for crop analysts.

Winter wheat freeze-injury assessments rely on a unique blend of agricultural and meteorological data, collected and analyzed by the USDA/NOAA Joint Agricultural Weather Facility. JAWF, in existence for more than a quarter century and an important component of a two-agency agreement, combines data from USDA's National Agricultural Statistics Service (NASS) and DOC/NOAA's U.S. Cooperative Observer Network (COOP) to provide such assessments. Both the NASS and COOP programs rely on a cadre of mostly volunteer observers to serve as the backbone for a national network.

8. REFERENCES

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9. INTERNET REFERENCES

Cooperative Observer Program
http://www.nws.noaa.gov/om/coop/

Joint Agricultural Weather Facility
http://www.usda.gov/agency/oce/waob/jawf/

National Agricultural Statistics Service
http://www.usda.gov/nass/

World Agricultural Outlook Board
http://www.usda.gov/agency/oce/waob/index.htm