CHARACTERISTICS OF SITES AND TREES AFFECTED BY RAPID WHITE OAK MORTALITY AS REPORTED BY FORESTRY PROFESSIONALS IN MISSOURI

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Abstract.—A new syndrome was named rapid white oak mortality in 2011 to describe the rapid death of white oak trees (*Quercus alba* L.) within one growing season. A survey with 24 questions about stand and site characteristics, site history, and symptoms was distributed to forestry professionals to gather information about the new syndrome. Sixty-three reports were received. Most of the mortality was reported in the southeastern quadrant of Missouri. Site characteristics and the affected trees species were atypical of those usually associated with oak mortality in Missouri. The survey confirmed that rapid white oak mortality should be considered a new syndrome.

INTRODUCTION

Mortality of oak species in Missouri is typically attributed to oak decline and oak wilt. Both maladies disproportionately affect trees in the red oak group. An upsurge of white oak (*Quercus alba* L.) mortality that did not fit the descriptions of either malady was reported in 2011. Reports of new locations with mortality spiked during 2012 and declined during the following years. Most reports in 2015 included previously undetected pockets of mortality, along with those that continue to grow as declining trees die. Mortality patterns included the deaths of entire tree crowns followed by rapid bronzing of foliage at the beginning of the growing season or during late summer and an association with lower slopes and drainages. White oak and post oak (*Quercus stellata* Wangenh.) were the only species in the white oak group that were reported to be dead and dying; most dead trees were white oak. The phenomenon was named rapid white oak mortality (RWOM) to set it apart from oak decline until a regional study of causal agents could be performed.

A 1-year study was conducted during 2014 to investigate the distribution of RWOM and the site and stand characteristics associated with the disease. As part of this study, we compiled data from a survey form that agency employers had distributed to their forestry staff. The survey contained questions about locations of mortality pockets, land use, site and stand characteristics, symptoms, and site history.

METHODS

The Missouri Department of Conservation (MDC) forest health program requested that all MDC foresters fill out survey forms for any reported RWOM locations. Forms were also shared with and distributed by U.S. Forest Service (USFS) employees to its staff. The 1-page survey consisted of 24 questions grouped into five subject areas: location and description of land use, site characteristics, stand characteristics, visual symptoms observed on declining white oak trees, and known site history. Questions were categorical except for location information, elevation,

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slope aspect, and steepness. Foresters and forestry staff members were instructed to walk an area of approximately 0.2 ha that had white oak mortality before they answered the questions. (Throughout the remainder of this paper, these foresters and forestry staff members are referred to as respondents.)

The survey included five questions about location. Respondents provided the name of the surveyed location, the county, the geographic coordinates or the legal description, and the soil map unit from the soil survey. They also described how the public or private land was being used (e.g., forest).

The survey contained eight questions about site characteristics associated with dead and declining white oak trees. Respondents identified the aspects, elevations, average percent slopes, slope shapes, and positions of dead and declining white oak trees on the slope. They also indicated what they perceived as general soil moisture content, the presence of pooled water or drainages, and whether the water was seasonal or permanent. Information about soil characteristics at the site was later gathered from the Natural Resources Conservation Service Web soil survey (NRCS 2016) using the soil map unit information or geographic coordinates provided. A soil profile depth of 150 cm was used when gathering data from the Web soil survey for the following soil features: available water storage; the percentages of clay, sand, and silt; and the depth to restrictive layer. A soil depth of 80 cm was used to obtain coarse fragment data from the Web soil survey. The overall percentage of coarse fragments was calculated by multiplying the relative percentage of total coarse fragments for each soil horizon by the depth of each horizon and then dividing the sum for all horizons by the total soil depth.

Four questions were asked about stand characteristics. Respondents identified the dominant tree type, the relative percentage of the stand that was in the white oak group, the types of dead and dying trees, and whether white oak regeneration was evident. Respondents answered an additional five questions about dead and dying white oak trees in the stand. These questions included an estimate of the percentage of the dead and dying white oak trees, as well as the crown position, the severity of the crown dieback, and the size of dead and declining trees.

Respondents were asked eight questions about symptoms or signs associated with declining white oak trees. They were also asked to indicate if holes made by wood-boring insects were present and if so, the shapes and relative sizes of the holes.

The site history category included 10 questions about management (e.g., timber stand improvement and fire severity), exceptional weather events, and insect outbreaks that had occurred since 2005. Respondents were encouraged to further describe the events and list the year or years of the events. Respondents were contacted with questions about their answers and to complete unanswered questions. Frequencies were calculated for answers to the 24 questions. The 55 reports that described the new pattern of mortality (e.g., lower slopes and drainages) were emphasized. Geographic coordinates supplied by forestry professionals or approximate coordinates from legal descriptions were used to generate maps in ArcGIS version 10.3.1 (Esri, Redlands, CA).

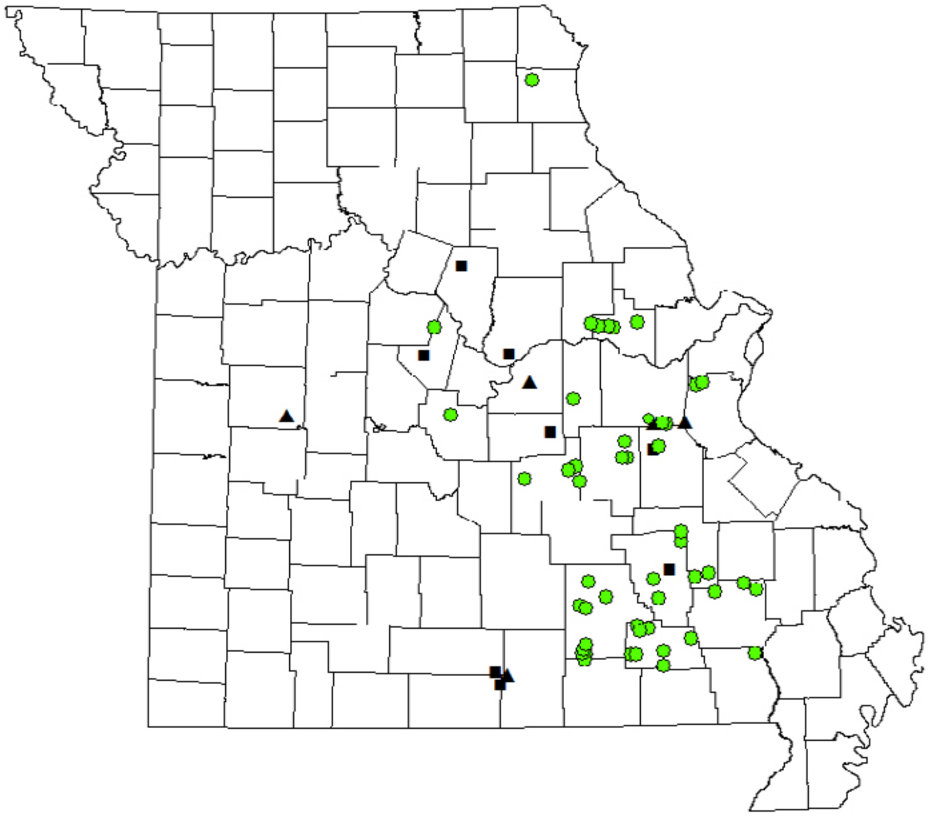

Figure 1.—Locations in Missouri that were surveyed between May and September 2014 and reported to have dead and dying oaks on an upper slope (black square), lower slope and drainage (green circles), or on the upper and lower slopes (black triangles)

RESULTS

Forestry professionals (the respondents) returned 63 survey forms, each for a separate location. Foresters from the MDC completed 94 percent of the survey forms, U.S. Forest Service employees completed 5 percent of the forms, and private industry completed 1 percent of the forms. Respondents reported white oak mortality at locations as far north as Lewis County, MO, and as far west as Henry County, MO (Fig. 1). Most surveys were completed for locations in the southeastern quadrant of Missouri and the counties immediately next to that quadrant. Forty-three of the described locations were public lands and 20 were private lands. Of the 43 public locations, 34 were state owned and 9 were federally owned. Respondents described one or more land uses for each location: 89 percent were listed as forest, 16 percent as riparian, 8 percent as roadside, 5 percent as pasture, and 2 percent as yard. No locations were park or urban, and no land use was reported for four locations.

Respondents reported white oak mortality mostly on lower slopes and in drainages throughout the southeastern quadrant of Missouri and in one location in northern Missouri (Fig. 1). In a few cases, respondents reported white oak mortality on lower and upper slopes. These few reports of mortality on lower and upper slopes tended to be in an east-to-west band just below the center dividing line of the state (Fig. 1). Respondents also reported white oak mortality only on upper slopes at eight locations. These reports were in the southeastern quadrant of the state and in nearby counties (Fig. 1). The eight reports of white oak mortality on upper slopes only were excluded from compilation of survey results because they fit the typical pattern of oak decline. The remaining 55 reports of RWOM on lower slopes and in drainages or on lower and upper slopes were used to develop a description of RWOM.

Table 1.—Surface soil textures typical of the surveyed areas at each of the 55 surveyed locations with white oak mortality on lower slopes and in drainages

Surface soil texture	No. of locations
Silt loams	
Extremely gravelly silt loam	1
Very gravelly silt loam	10
Gravelly silt loam	5
Silt loam	3
Loams	
Very gravelly loam	4
Gravelly loam	4
Loam	4
Sandy loams	
Very gravelly sandy loam	5
Gravelly sandy loam	1
Very cobbly fine sandy loam	2
Fine sandy loam	2
Silt clay	
Very channery silt clay	1
Other	
Slightly decomposed plant material	13

Forestry professionals reported that RWOM was occurring on 13 slopes with protected aspects (316°-134° azimuth) and 21 slopes with exposed aspects (135°-315° azimuth). Aspects for three locations with protected slopes and aspects for nine locations with exposed slopes were within a few degrees of the neutral line between protected and exposed aspects (315°-316° and 134°-135°, respectively). No slope aspect was reported for the other 21 locations, because either the mortality was in a flat area at the base of the hill or no information was reported. RWOM that was associated with hillslopes was reported most often on gentle and strong slopes. The average slope steepness was 12 ± 2 percent. Respondents stated that RWOM areas were associated with drainages 65 percent of the time, and those drainages had intermittent or ephemeral water flow 95 percent of the time. Forestry professionals reported no drainages in the surveyed area for the other 19 reports.

Soil information from the Web soil survey for the 55 locations indicated that surface soil textures included loams, silty loams, and sandy loams that typically had low water-holding capacities (12.6 ± 1 cm/cm) because of a high percentage of coarse fragments (Table 1). Approximately one-third of locations had soils with a restrictive layer of 31-150 cm depth.

Respondents described RWOM in a variety of stand types. Slightly more than half of RWOM-affected stands were dominated by trees in the white oak group or the white and red oak groups. The other 44 percent of RWOM-affected stands were a mixture of oak species with pine or a mixture of white oak with other non-oak hardwoods. These RWOM-affected stands had white oak group regeneration 75 percent of the time. Respondents reported that mortality ranged from fewer than 25 percent of white oak trees in the surveyed portion of stands to complete or nearly complete mortality. Stands with complete or nearly complete mortality were scattered

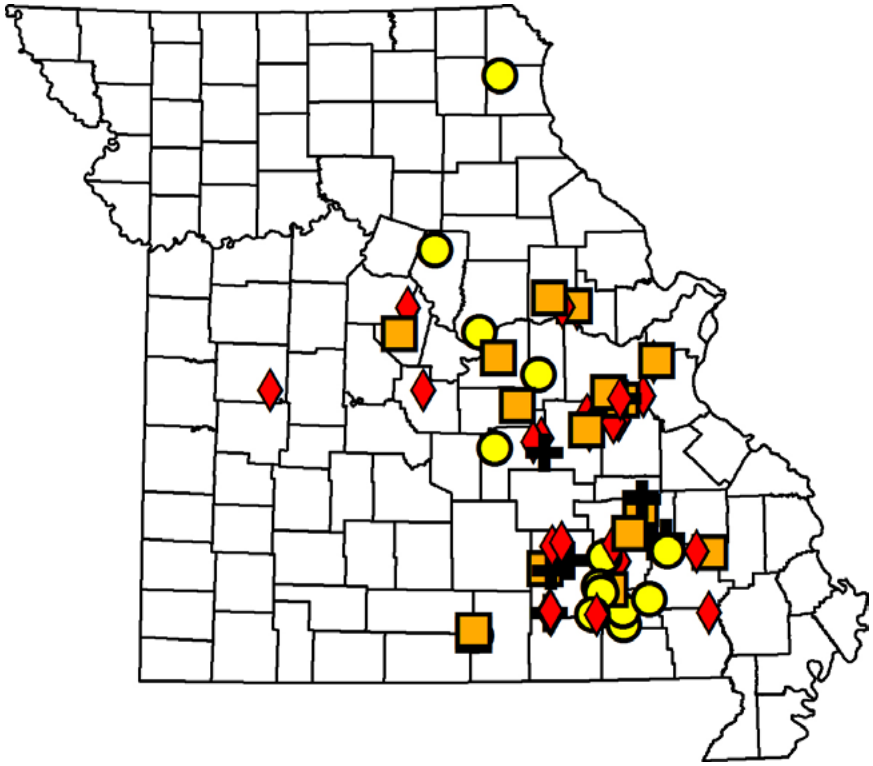

Figure 2.—Severity ratings for white oak mortality at each location surveyed between May and September 2014. Forestry professionals rated the severity as slight with <25 percent of white oak trees dead (yellow circle), moderate with 26–50 percent of white oak trees dead (orange square), severe with 51–75 percent of white oak trees dead (red diamond), or very severe with 76–100 percent of white oak trees dead (black plus sign). Map by Robbie Doerhoff, Missouri Department of Conservation, Forestry Division.

throughout southeastern Missouri (Fig. 2). These respondents also reported other dead and declining tree species in RWOM-affected stands. Trees in the red oak group were dead and declining at 20 percent of the locations and post oak trees were dead and declining at 22 percent of the locations. Respondents indicated that codominant and dominant white oaks larger than 25 cm diameter at breast height were dead and declining at nearly all locations, and that smaller codominant and dominant white oaks were dead and dying at one location. Fewer respondents stated that intermediate and suppressed trees were dead or declining at 40 percent and 16 percent of locations, respectively. Individuals also indicated that 71 percent of the surveyed locations still had declining white oak trees.

The four disease symptoms or signs most often associated with RWOM stands were upper branch dieback (80 percent of stands), Biscogniauxia (Hypoxylon) canker (56 percent of stands), fallen bark on the ground (55 percent of stands), and wilted leaves attached to trees (42 percent of stands). Respondents reported insect holes on declining trees at 13 locations. Round insect holes ≤ 2 mm wide were reported at 11 locations, and holes approximately 5 mm wide were reported at 6 locations.

Respondents described a number of weather and management events at RWOM locations since 2005. Respondents indicated that 95 percent of the RWOM locations experienced severe drought, 67 percent experienced the 2012 severe frost or the 2007 late spring freeze, and 45 percent experienced the exceptionally wet growing seasons of 2008 and 2009. Flooding was reported at 31 percent and severe winds at 25 percent of the locations. Respondents indicated that insect defoliation had occurred at 35 percent of the locations and often cited a looper

(Lepidoptera: Geometridae) outbreak during 2014. A jumping oak gall outbreak in 2010 was reported only 11 percent of the time. Respondents indicated that some sites had undergone active management since 2005, and timber stand improvement was reported at 31 percent of locations. Most timber stand improvement was performed to thin the understory and remove undesirable trees. Other timber stand improvements included timber sales and sometimes salvage sales. Respondents also indicated that 11 percent of the locations had been exposed to a moderate to severe burn.

DISCUSSION

This is the first summary of the distribution of RWOM in Missouri. The large number of reports of dead and declining white oaks on lower slopes and in drainages confirmed a large scale die-off of white oaks and showed that it is associated predominantly with the Salem Plateau of the Ozark Highlands. The Salem Plateau is a hilly, forested region formed mostly by the erosion of sedimentary, Ordovician rocks. The plateau also includes a smaller, rugged region of weathered igneous Cambrian and pre-Cambrian outcroppings associated with the St. Francois Mountains (Unklesbay and Vineyard 1992). The Ultisols and Alfisols in the region support vigorous white oak growth.

Six RWOM locations were also in the transition zone between the glaciated plains and the Salem Plateau in an area north of the Missouri River. Parts of this zone were not glaciated, and these locations may share some characteristics with the Salem Plateau and some with the glaciated plains.

Two survey locations with white oak mortality on lower slopes or in drainages were distant from other RWOM locations and should be investigated further. One location in Lewis County was in the glaciated plains and the other was in the Osage Plains. The soils and topographies of these two regions are very different from those of the Salem Plateau. If these two reports of RWOM are similar to those in southeastern Missouri, soils and some site characteristics might contribute less to this syndrome than other factors.

RWOM was associated with lower slopes and drainages in valleys with ephemeral and intermittent streams. The soils typical of these areas were sandy loams, silty loams, and loams derived from cherty dolomite and cherty sandstone residua that are characteristics of the Salem Plateau (Unklesbay and Vineyard 1992). The deaths of so many trees on these sites present a conundrum because white oaks are particularly well suited to these dry and mesic uplands, especially protected aspects on lower slopes (Johnson et al. 2009). Restrictive layers in soils can limit root growth and water availability, but these were present in soils at just one-third of the locations. One possibility is that trees affected by RWOM occurred in pockets with soils that are atypical of the general area. Trees in ephemeral or intermittent stream areas may also have been affected by root pathogens, such as *Phytophthora*, that are favored by these conditions. *Phytophthora* root rot is most severe when infected trees are exposed to too-wet and too-dry cycles because of abundant zoospore production and infection followed by host stress (Corcobado et al. 2013).

Respondents most frequently mentioned the 2012 drought (52 locations), when asked about exceptional weather events at RWOM locations. This historic statewide drought first developed in the southeastern and west-central sections of Missouri in April 2012 and spread through the rest of the state during May, with little relief until September. The hydrologic deficit was not made up until the following year. Only a small part of the RWOM affected area was affected by a short period of drought during late summer 2011. Some respondents also noted a late spring frost during 2012 and an April freeze during 2007. The spring frost during 2012 occurred in late April in the Ozarks, when vegetative growth began 3 weeks earlier than normal. Most of the early growth was observed in low-lying areas within steep valleys. The freeze during 2007 was an 82-hour event that occurred in early April and affected branch tips and leaves that had emerged 2-4 weeks earlier than normal. Fewer than half the respondents listed the record-breaking years of 2008 and 2009, when Missouri received more than 106 inches of precipitation in a 2-year time period. All these events likely decreased tree health; however, the role of drought reported during 2012 is particularly unclear. RWOM was first reported in 2011, a year before the drought entered southeast Missouri. Although white oak is considered a drought-tolerant species, the peak in reports during the spring and early summer of 2012 may indicate that many white oaks were of low vigor before the drought and succumbed quickly to the extreme heat and lack of water.

Respondents indicated that timber stand improvement (i.e., thinning) had been performed at nearly one-third of the locations between 2005 and 2014. Some of the reported management likely had little effect on RWOM because it occurred after or during the mortality event. For example, six respondents mentioned that mortality was already present in stands at the time of management. One question was whether active management would reduce or preclude mortality. Unfortunately, too few of the reported locations had active management before RWOM to assess this question. This would likely be worth pursuing in the future. RWOM was reported in only three locations despite thinning or harvesting 4 or more years earlier.

RWOM appears to be a new syndrome in Missouri, with a unique combination of characteristics shared across the Salem Plateau. Unique characteristics include high white oak mortality, especially in the absence of increased mortality of other oak species, as well as high numbers of dead trees on lower slopes and in drainages. These characteristics are the reverse of those associated with oak decline, which has been ongoing in Missouri for decades (Fan et al. 2012, Kabrick et al. 2008). The timing and time course of RWOM are also unique in relation to drought. RWOM was reported just before or during the early development of a severe drought at many of the surveyed locations. In contrast, oak wilt often peaks 2 to 3 years after a drought (Fan et al. 2012).

CONCLUSION

This description of RWOM was developed from 55 of 63 surveys that describe white oak mortality on the lower slopes and in drainages. RWOM is occurring on federal, state, and private lands and appears to be a regional phenomenon. It occurs on lower slope positions and in drainages. Although the die-off varies by location, it can be very severe. Soils typically found at these locations are gravelly and well drained and little available water is stored. RWOM occurs in stands that are dominated solely by the white oak group, as well as in more diverse stands. White oak trees of all crown positions can be affected, but most are large dominant and codominant trees. At some locations, dead and declining post oak trees and trees in the red oak group may be present. At any specific location, trees may die rapidly with leaves still attached within a single growing season; others decline over a longer time period. Biscogniauxia canker may be associated with some declining trees and may be the cause of bark piles on the ground and rapid deterioration of branches. Locations with RWOM have experienced severe drought, late spring freezes and frosts, and exceptionally wet weather that may have further weakened trees. Future research should aim to confirm the survey reports taken at each location and to scientifically test portions of the description in this paper to see if the description correctly describes this new syndrome.

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