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THE USE OF SEASONAL FOLIAR COLOR CHANGES TO DIAGNOSE STRESS IN EASTERN WHITE PINE

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Abstract. Eastern white pine is one of the most popular landscape trees in the Eastern United States, and its decline has been observed by the authors for over 20 years in Virginia. To the arborist, landscaper, and tree owner this disease is very hard to detect in its early stages because of the complex nature and variability of the decline syndrome. It might be easier to maintain trees grown in conditions favorable to decline if a simple method could be used to detect and monitor the health of white pines. One such possible method would be to monitor seasonal foliar color fluctuations, since leaf morphology (size, shape, color) is a prime indicator of tree health. The authors have tested a color analysis method which is simple and inexpensive. When perfected this method might be useful to protect white pine from the latent stages of decline through its use in early detection in combination with methods to modify certain site stress factors.
Keywords: *Pinus strobus*, decline, foliar color, disease diagnosis.

Résumé. Le pin blanc de l'est est un des arbres les plus populaires en aménagement dans l'est des Etats-Unis et son dépérissement a été observé par les auteurs depuis 20 ans in Virginie. Pour les arboriculteurs, aménagistes et propriétaires d'arbres, cette maladie est très difficile à détecter dans ses jeunes stades, à cause de la nature complexe et la variabilité du syndrôme du dépérissement. Ce serait peut-être plus facile de maintenir les arbres matures qui sont dans des conditions favorables au dépérissement, si une méthode simple pouvait être utilisée pour détecter et contrôler la santé des pins blancs. Si une telle méthode était possible, ce serait pour contrôler les fluctuations saisonnières de la coloration du feuillage puisque la morphologie des feuilles (grandeur, forme, couleur) est un premier indicateur se la santé de l'arbre. Les auteurs ont testé une méthode d'analyse des couleurs qui est simple et peu coûteuse. Quand elle sera perfectionnée, cette méthode pourrait être utile pour protéger le pin blanc à partir des stades latents du dépérissement jusqu'à son utilisation dans la détection précoce en combinaison avec des méthodes pour modifier certains facteurs de stress liés à l'emplacement

Eastern white pine (*Pinus strobus* L.) is one of the most popular landscape trees in the Eastern United States. The range of the species is from Canada to the higher elevations of the South and west from Maine to Michigan. The tree serves as an ornamental and in larger specimens as a shade tree. In Virginia, "white pine", as it is called, is a prime evergreen choice of arborists, landscapers and homeowners alike. It has been a relatively care-free and inexpensive species to grow; it is used primarily as screens along property lines or as windbreaks. White pine owes much of its popularity and low cost to the Christmas tree industry which has promoted white pine for years as a seasonal decoration and the use of balled and burlapped specimens for planting outside after the holidays. In the Washington National Capital Parks alone, Eastern white pine is a major planting in and around the memorials and parks in this historically focused landscape.

Although it has been easy to grow, many owners of white pines grown for landscaping have reported problems and losses during the past 20 years. Trees which seemed otherwise in good health would start to decline in health and die. After years of observation and investigation, this syndrome has been named, "white pine decline" (16, 17, 18, 19). Symptoms include foliar chlororis and necrosis, shortened internodal growth, reduced crown density, dehydration and eventual death. Studies (16, 17, 18, 19) have indicated that a number of associated factors stress the trees and we believe initiate the decline syndrome. With no intervention, the trees will eventually die. The length of time for death depends on the severity of the episode with some trees taking many years to die. The cause of this decline is usually a complex of factors which could include: heat stress, water stress, damaged and restricted root systems, numerous poor soil characteristics, large numbers of secondary biotic pests, and other abiotic stress factors. Man's modification of the natural habitat contributes in a large part to the decline syndrome; removing the natural needle mulch under trees, altering fertilization and pest control regimens, and planting trees in hostile environments all contribute to decline. The droughts of the late 1970's and 80's are also suspected as an initiating cause of this decline in some trees.

White pine decline is typical of other decline syndromes which are usually associated with environmental stress. Stressors include abiotic and biotic entities. Many workers have documented these specific stressors with this and other declines of tree species (2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19). This article will focus on a possible diagnostic tool which could be used to detect a decline in growth quality; i.e., seasonal foliar color fluctuation. For more details on this disease, please refer to an article entitled "White pine decline: A case study from Virginia landscapes," by Weaver and Stipes (16) published in the Journal of Arboriculture in May 1988.

The photograph in Figure 1 represents a comparison of the growth quality associated with decline conditions versus conditions favorable to good quality white pine growth. A limb from a tree growing in a good quality environment, in this case a forest, is represented by the sample on the left in the photograph. A limb from a white pine found growing on a highly disturbed site is represented by the sample on the right in the photograph.

Seasonal foliar color fluctuation. It is obvious that the amount of foliage and the quality of foliar growth in Figure 1 represents a significant difference between the two trees. The color of the sample on the left in Figure 1 was the typical blue-green of a "healthy" white pine, while the foliage of the sample on the right was the yellow-green color so typical of trees on poor quality growing sites.

According to Parker (14), needle color tends to fluctuate slightly throughout the growth cycle of the white pine. However, in "healthy" specimens this color usually remains a blue-green, while our observations indicated that this is not the case with declining trees, which tended to turn a chlorotic yellow. Trees in the early stages of decline were particularly hard to diagnose; however, many of these trees exhibited drastic swings in foliar color especially during the winter months. Although the age of needles (leaves) may have played a role here, it was difficult to detect without a longer more extensive study. This phenomenon was addressed by Freeland (5) who studied the effects of age of leaves on the rate of photosynthesis in conifers.

If it were possible to evaluate accurately white pine foliage in such a way so that colors were represented by numerical data, then colors could be used to diagnose and monitor plant health. This capability would be especially valuable where trees were exhibiting the early symptoms of decline. A study was conducted to determine the feasibility of such a method.

Materials and Methods

In order to conduct such a study a standardized method would have to be developed to produce

Figure 1. Foliage of declining and "healthy" eastern white pine.

data which could be compared to a set rating scale. Preliminary studies involved extraction of chlorophyll from needles for comparison photometrically. This method would have worked very well, but the extraction process involving needles was very unreliable. Needles were much more woody than other leaves and the process could not be carried out without great difficulty. The resin and woody nature of the needles did not allow for complete extraction of the chlorophyll. The difficulty and time consuming nature of this process made it immediately evident that an alternative method would have to be developed in order to carry out the experiment. An alternative method was worked out in which needle color was compared with a plant color chart.

The study was conducted to determine the degree of change in foliar color that was associated with seasonal change and tree health over a 12-month period. Sample trees were selected for the study, six from a natural site located within the Jefferson National Forest (Virginia) and seven from "human-altered" sites on the Virginia Tech campus. The term "human-altered" is used to describe trees growing on sites managed by humans, and included rural, suburban and urban areas, along streets, around homes, along highways or anywhere the natural site conditions, especially soils, were disturbed by humans.

A 4.5 meter pole pruner was used to sample at about a 6.5 meter height from the periphery of each tree in the study. Needles were selected from all sides of the trees and then selected from the total sample to obtain an average sample for each observation. Needle samples from each observation (tree) were taken monthly over a period of 12 months. Old and new growth needles were measured if present on the trees. Old needles were those older than one year; new needles were the present year's growth.

Needles were compared, under a standard tungsten light source, with the Munsell plant (botanical) color scale (1). In order to prevent any variation in color vision, the same individual rated the colors throughout the duration of the experiment. Colors were designated according to the Munsell system which used a 3-part designation to give a color's hue, value and chroma. A sample designation; e.g., 7.0GY5/6, would include the following: where 7.0 = a specific hue subdivision, GY = green yellow hue names, 5/ = the value or degree of lightness, and /6 = the chroma or degree of saturation. These designations were converted to numerical ratings ranging from 0 to 40 to allow the authors to analyze the data. The numerical range increased from yellow-green in color to blue-green as the numbers increased; a numerical rating of 24 would equal the rating 5.0GY4/4.

Results and Discussion

The results of this study supported the hypothesis that there was a difference in foliar color ratings between white pines under stress and those grown under favorable conditions. The best evidence available was that of data taken from the old needle samples of trees from both data sets (stressed and favorable conditions). When charted using a numerical rating scale, these data showed an obvious sharp contrast in color ratings between the two sets.

The ratings for new needles did not provide such a reliable comparison. These ratings varied drastically from month to month and between observations. These qualities were also present with old needle measurements but they tended to be more consistent and stable in color when compared to new needles. The conclusion was made that new needles were not reliable as an indicator of foliar color change versus tree health.

Two data sets of old needles are represented by Figures 2 and 3. Five observations were selected from each data set which best represented the set. Each observation was charted as a vertical histogram ranking needle color values on a scale of 0-40 over a period of 12 months. By comparing Figures 2 and 3 one can make the following conclusions:

- There is an obvious color threshold of around 24 (5.0GY4/4 Munsell ranking) where observations in both sets remain in the blue-green color.
- This threshold tended to be the median in the data set in Figure 3; trees grown under favorable conditions.
- Although needle color was observed at or quite close to this threshold in Figure 2 (stressed trees), there were several periods over the 12

months where needle color "dipped" far below the 24 rating.

• In Figure 2, the months of January through April were critical months where the colors often dropped below 12(2.5GY5/2) and as low as 10(2.5GY5/6). These colors were in a totally different hue sub-division from the other data and to the human eye represented a marked change in color; a yellowish-green.

• Dips in color were observed at other periods, but the months of mid-winter to early spring were the most consistent. These other drops in color may have been caused by variations between sites or tree health. From August to October it may have been due to fall coloration while in the spring, it was probably due to a change in the tree physiology associated with new needle development. Also the samples were taken from the oldest needles on the trees at the time. As needles dropped in the fall, sampling was taken the next month from what was a different set of needles, yet still the oldest set of needles on the tree at the time. The selection of old needles would then have varied from tree to tree dependent upon the number of sets of needles on the trees during their growth cycle. To provide for consistency in sampling, the oldest and newest samples were taken each month.

• The observations in Figure 2 didn't all drop below the threshold level at the same time, but varied somewhat between each tree. This was probably due to differences in tree health, physiology and site condition.

• Even though observations in Figure 2 didn't all drop at the same time, each observation did drop sometime during the months of winter or early spring. During this period, the weather at the sites was cold (below freezing) most of the time, and photosynthesis was reduced due to low, seasonal light levels and inclement weather conditions.

These results lead one to conclude that more work needs to be done to investigate whether a qualitative visual rating system can be developed to monitor white pine health and to detect stress and possible decline in its early stages. Such a method could easily be linked to tree growth measurements (internodal measurements or tree ring analysis).

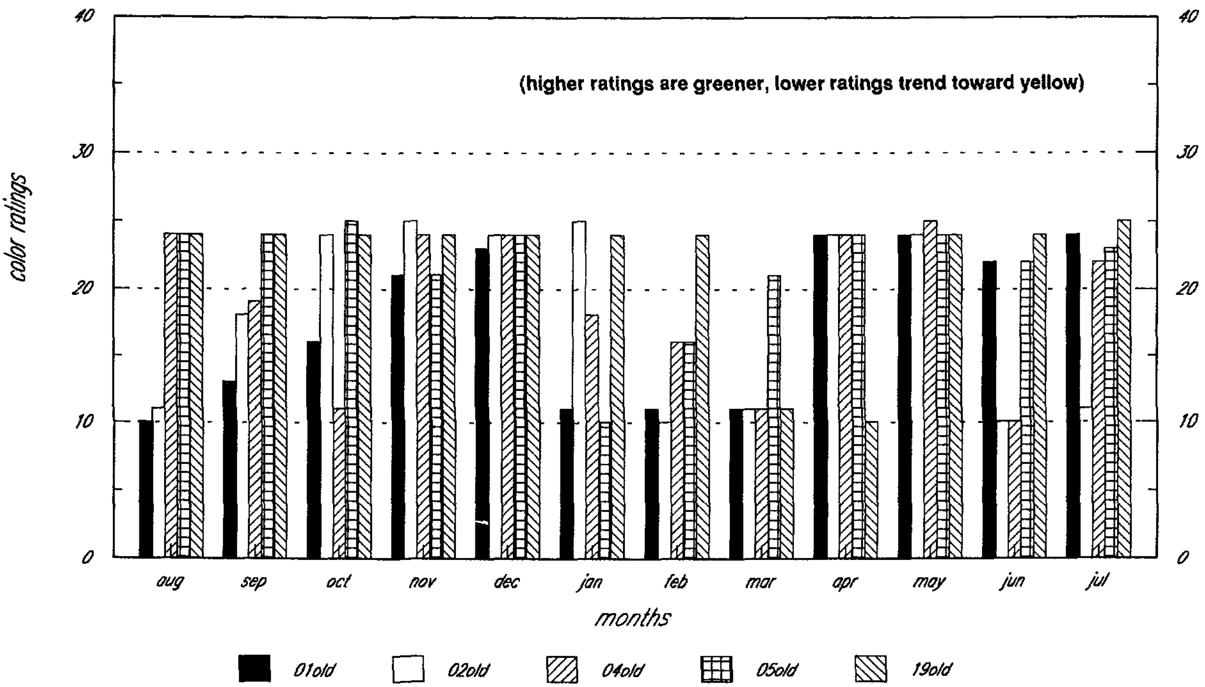

Figure 2. A comparison of seasonal foliar color change data taken monthly over a period of one year from observations of five white pines growing under stress conditions on "human-altered" sites. Notice the consistent dip in color during the winter months.

In addition, investigation needs to be done to determine if site conditions may have contributed to these color changes in stressed trees. It is suspected that rooting depth, water and nutrient levels, and perhaps root zone area may all be possible contributors to this phenomenon. Also, one can not rule out factors which could inhibit photosynthesis such as biotic agents, variations in tree physiology and possible abiotic agents such as air pollutants, herbicides, etc. Evidence in other studies (16, 17, 18, 19), mentioned earlier, supports a link to site conditions.

For the arborist, landscaper or tree owner, this color change in winter can be used as justification for altering the growing conditions of their white pines. One needs to be alert to color change throughout the year, but don't confuse this with the usual color changes associated with fall needle drop or spring new growth. Some suggestions which might help these professionals and amateurs alike to improve white pine growth include:

1. Preventative medicine is best! Select proper growing sites prior to planting which provide a more natural environment.
2. Prior to planting, alter soil texture with organic matter or coarser soils to eliminate soils with a heavy clay texture.
3. Aerate soils to encourage deeper root penetration and to reduce compaction. This, obviously, would be more feasible with smaller specimens or prior to planting, but it has been done with larger specimens as well.
4. Prevent soil disturbance and compaction (and root damage of existing trees) during construction activities at sites where trees are to be planted or presently exist.
5. Test soils and where necessary fertilize and maintain the soil pH below 6.0.
6. Maintain the natural needle mulch similar to conditions found under trees in their natural environment. This might require killing or removing sod in areas with tree feeder roots and covering these areas with mulch.
7. Remove competitors for light, water and nutrients where white pines are planted in dense plantings with other white pines or other trees or shrubs. Obviously, one would want to maintain a

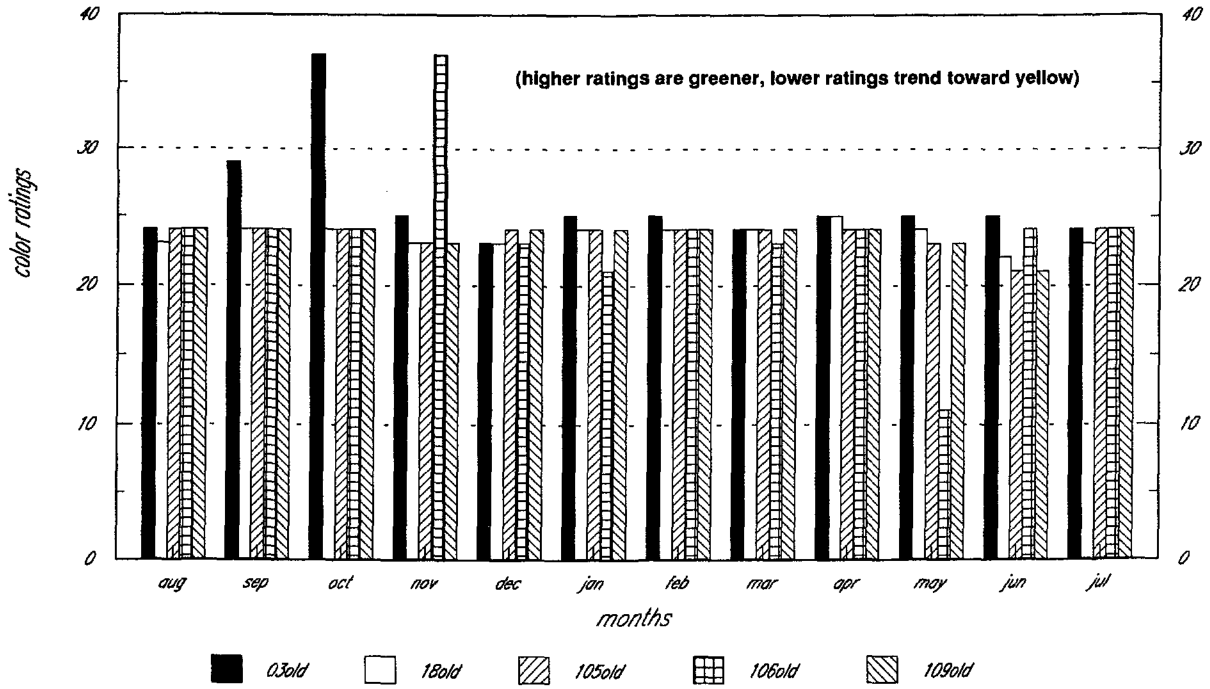

Figure 3. A comparison of the seasonal foliar color change data taken monthly over a period of one year from observations of five white pines growing under favorable conditions. Little change in color is noticed at any time during the year.

balance between this suggestion and an attractive landscape.

8. Irrigate trees during periods of drought, both winter and summer.

Species selection may be another important factor ignored by many people. Eastern white pine is not the optimal choice for all planting sites or geographical locations; our subjective observations of mixed plantings of pine species on stressed sites indicated that white pine is the most sensitive. Therefore, on poorer quality sites where evergreens must be used, one should consider other species.

Although these suggestions are not a cure-all, they can contribute to the proper maintenance of white pine. Corrective measures can not take the place of proper site selection and preparation prior to planting. All of these factors need to be assessed prior to landscaping.

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