

## Needle and Twig Moisture Concentrations of Christmas Trees Displayed Indoors Over a 6-Week Period

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### Postharvest Biology

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*Additional index words:* fire risk, foliar water, proper care

*Abstract.* Balsam fir [*Abies balsamea* (L.)Mill.], Fraser fir [*Abies fraseri* (Pursh)Poir.], Douglas-fir [*Pseudotsuga menziesii* (Mirb.)Franco], Scots pine [*Pinus sylvestris* L.] and white spruce [*Picea glauca* (Moench)Voss] Christmas trees were cut from a variety of locations in New York during 20-22 November 1997. Sixty-three trees were displayed for 6 weeks in a heated building immediately after cutting (with butts in water or with butts dry) while another remaining 32 trees were stored outdoors without cover for 6 weeks prior to indoor display for 6 weeks. Needle and twig moisture concentrations (on a dry weight basis) of trees displayed with their butts in water were  $\geq 100\%$  for the entire 6-week display period, for both groups of trees (immediate display and 6-week outdoor storage prior to display). Needle and twig moisture concentrations of Christmas trees displayed out of water (butt resting directly on the floor) declined rapidly, falling below 60% 4 to 5 weeks after initial set up. Even in the absence of water, it took longer than 3 weeks for needle and twig moisture concentrations of displayed Christmas trees to reach hazardous levels that could support ignition. These results confirm that properly cared for Christmas trees displayed in water in a heated building maintain high moisture concentrations over a 6-week display period.

## INTRODUCTION

Fresh cut Christmas trees are commonly displayed in homes during the holiday season. According to survey data published by the American Christmas Tree Association, annual sales of live Christmas trees in the US ranged from 28 to 37 million between 1990 and 2002. Artificial tree use steadily increased during this period from 36 to 57 million, comprising 70% of indoor displayed trees in 2002, the most recent year for which data are available (NCTA, 2004).

One of the factors critical for aesthetically pleasing and safe indoor tree display is crown moisture concentration. If moisture is not adequately maintained, needles become brittle and lose their fragrance. In addition, dry trees are a fire hazard. Moisture concentration of the crown is the primary variable affecting potential for burning; Christmas trees with high foliar moisture concentration do not sustain a flame in the presence of an ignition source (Van Wagner 1963; White et al. 1997). Many consumers do not understand how trees function, resulting in the perpetuation of myths (e.g. Christmas trees displayed indoors are highly flammable and are subject to spontaneous combustion). Lack of understanding is one factor that has contributed to reduced display during the holiday season. The objective of this study is to document changes in needle and twig moisture concentrations of fresh Christmas trees over a 6-week display (indoor) period under two conditions: (a) displayed with proper care (butt in water); and (b) displayed improperly (butt out of water). In addition, we assessed moisture concentration of fresh cut trees that had been stored on an outdoor lot six weeks prior to indoor display in water. Storage of fresh cut trees outdoors prior to sale is common practice.

## METHODS AND MATERIALS

The study was conducted in the Youth Building at the New York State Fairgrounds, Syracuse, NY. Five species commonly produced in New York were evaluated: balsam fir (*Abies balsamea*), Fraser fir (*Abies fraseri*), Douglas-fir (*Pseudotsuga menziesii*), Scots pine (*Pinus sylvestris*) and white spruce (*Picea glauca*). Ninety-six trees obtained from 14 private growers distributed across New York were harvested during the period November 20-22, 1997. Donor tree farms, representing a sample of the Christmas Tree Farmers Association of New York (CTFANY), provided mature trees scheduled for harvest in the 1997 season. Not all species were grown at each individual farm. The CTFANY collected and transported the donated trees to Syracuse on 23 November by truck, which required two trips.

The trees were either displayed in a heated building or stored outside in an uncovered open lot for later display indoors, to emulate typical treatment by retailers. During the period of display, building temperature ranged from 17 – 21°C, typical for a commercial building. We did not monitor relative humidity.

Three treatments were evaluated over a 6-week indoor display period:

1. Immediate display (23 November, 1997) in a heated building with the butt immersed in a bucket of water;
2. Immediate display (23 November, 1997) in a heated building with the butt resting on the floor (dry);
3. Outdoor open lot storage for 6 weeks, followed by display (3 January, 1998) in a heated building with the butt immersed in a bucket of water.

The three treatments were replicated 6 times for each species except for white spruce, which was replicated eight times. One white spruce tree in treatment 2 inadvertently was not sampled, so that there were only 7 trees for that treatment. Immediately prior to display, sample trees were brought indoors and a fresh cut (10– 20 mm) was made at the butt. The tree butt was

then either placed in a 19-L bucket three-fourths full of water or was set directly on the concrete floor (dictated by treatment). Water level was maintained throughout the display period for watered trees.

The experimental design was a randomized complete block with single trees as the treatment unit. Although we did not monitor temperature separately for each section, we recognized the potential for uneven air flow and heat distribution in our building, which is normally used for displays during the NY State fair. In order to minimize potential impacts, we partitioned the building into 6 blocks prior to tree display.

Moisture concentration on a dry weight basis (MC) of the branch and attached needles was the variable of interest. Except for Scots pine (for which separation was quickly accomplished), we did not separate needles from twigs. Separation would have required a significant expenditure of time (each sampling required an entire day) which may have affected our moisture concentration estimates by extending the time period between sample collection and determination of initial sample mass. Additionally, separation would have added only marginally to our understanding of crown moisture concentration over the 6-week display period. Since we measured moisture concentration directly, water potential was not assessed. Water potential is highly correlated with moisture concentration (Hinesley, 1984; Hinesley and Snelling, 1991).

Moisture concentration varies with age of branch and attached needles, therefore, the crown was partitioned into the outer sheath (current year twig and attached needles) and inner sheath (1-year-old twig and attached needles). Our sample unit consisted of 2 – 3 outer or inner sheath twigs (5 – 15 cm length, 5 – 15 g fresh weight) with attached needles. Sample mass required for a precise estimate of moisture concentration was based on our experience sampling conifer crowns. The outer needles of Scots pine were quite large, easily separated from the twigs, and comprised a large proportion of the total mass of twig and attached needles for the entire crown. Consequently, the Scots pine sample consisted solely of outer needles (without the associated twig).

Samples were collected at the time of tree display and again every seventh day for the next 6 weeks. Samples were weighed to the nearest 0.1 g immediately after collection, placed in brown paper bags, and transported to the Forest Soils Analytical Laboratory at the SUNY College of Environmental Science and Forestry. Samples were placed in a forced air oven for 48 h at 60°C and placed on a scale to determine mass to the nearest 0.1 g. Moisture concentration (MC) was calculated as a percentage of tissue dry weight as follows:

[1]  $MC = [(needle + twig \text{ fresh weight}) - (needle + twig \text{ dry weight})] * 100 / (needle + twig \text{ dry weight})$ . For Scots pine, MC was calculated for outer needles only.

In order to assess changes MC over time, we used a method of estimated coefficients for response curves as described by Meredith and Stehmen (1991). This eliminates the assumptions required for split plot and repeated measures analyses (spherically symmetric errors). Briefly, this procedure involves fitting a linear model (using the method of polynomial coefficients) to describe MC as a function of time for each tree. Model coefficients generated for each tree were treated as dependent variables in an analysis of variance to assess the effects of species on changes in MC over time. Utilizing the notation of Meredith and Stehmen (1991), twig MC ( $y$ ) for the  $i^{\text{th}}$  species ( $i=1$  to 5) for the  $j^{\text{th}}$  replicate ( $j = 1$  to 6 for all species except white spruce) of the  $m^{\text{th}}$  time period ( $m = 1$  to 7 weeks) can be expressed as:

[2]  $y_{ijm} = \mu_{im} + \varepsilon$ , where  $\mu$  = moisture concentration mean of twig and attached needles (either outer or inner) for species  $i$  and time period  $m$ , and  $\varepsilon$  = normally independently distributed error term with mean = 0 and constant variance.

Mean MC as a function of time can be expressed as:

[3]  $\mu_{im} = B_{i0} + B_{i1} (m - mbar)$  where  $m$  = week and  $mbar = 4$  (the mean for week). This model allowed us to assess whether moisture concentration increased, decreased, or remained constant during the 6-week display period. Week 1 refers to the beginning of the experiment when the trees were initially displayed and week 7 refers to the conclusion of the experiment at the end of the sixth week (beginning of week 7). Samples were obtained every 7 d from the time of initial display.

Coefficients for model [3] ( $z_i$  as an estimate of  $B_{i0}$ , and  $b_i$  as an estimate of  $B_{i1}$ ) were fit to each tree for the display period using orthogonal polynomials. Analysis of variance was used to test the following hypotheses about the coefficients for each of the five treatments:

- [i] mean  $\mathbf{z} = 0$  (intercept of 0 averaged across all species)
- [ii]  $z_i$  are equal for all species (intercept term constant among species)
- [iii] mean  $\mathbf{b} = 0$  (slope of 0 averaged across all species)
- [iv]  $b_i$  are equal for all species (slope term constant among species).

Following hypothesis tests, statistically significant coefficients were used to compute average twig moisture concentration for each week as follows:

[4]  $y_{ijm} = z_i + b_i * (\text{week} - 4)$ .

## RESULTS AND DISCUSSION

At the time of tree display, twig moisture concentrations were near or well in excess of 100% for those trees displayed immediately as well as those stored outdoors for 6 weeks. Moisture concentrations of outer twigs generally exceeded those of inner twigs for all treatments and all species (Figure 1). The mean difference in moisture concentration (outer – inner), for the trees that were not stored prior to indoor display (treatment 1), ranged from a low of 0 for Fraser fir at the initiation of the experiment (week 1) to a high of 24% for Douglas-fir at week 6. The magnitude of the differences varied by species; Douglas-fir and white spruce consistently exhibited higher differences between inner and outer twig moisture concentrations than Fraser fir and balsam fir. The difference in MC between outer and inner twigs was not calculated for Scots pine because inner needle MC was not measured.

Statistical analyses assessing the effects of species on MC over time for each treatment are summarized in Table 1. The statistical model expresses moisture concentration as a linear function of time over the course of a 6 week period by species for each treatment. The null hypothesis that the intercepts ( $z$ ) are equal among species was rejected for each treatment (Table 1). The rate of change in MC over time differed by species for some of the treatments. The  $H_0$ : equal  $b_i$  among species was rejected for outer and inner twigs of treatment 1, inner twigs of treatment 2, and outer twigs of treatment 3. Rejection of  $H_0$ :  $b_i$  equal among species when the  $H_0$ : mean  $b = 0$  was not rejected indicates that MC changed significantly over time for some but not all species. Graphical summaries from the statistical analyses (below) clarify these results.

Mean outer twig MC of trees displayed immediately in water (treatment 1) ranged from 104 to 147% during the 6 week indoor display period (Figure 2a). Rejection of the four null hypotheses indicates that species affected both intercept and slope of the regression for MC over time (Table 1). Moisture concentrations for balsam fir, Fraser fir, and white spruce outer twigs

increased slightly over the 6-week period. Hinesley and Snelling (1984) reported that trees in water actually had greater MCs compared to when they were initially set up.

Moisture concentrations for Scots pine and Douglas-fir, which started out above 140% at initiation of the experiment, decreased over the 6-week period. Even with the decrease in MC over time, twig MC for those species remained above 100% at the end of the 6-week display period. Patterns of MC change for inner twigs were similar to those of outer twigs (Figure 2b). Failure to reject only the  $H_0$ : mean  $b = 0$  indicates that for some of the species (balsam fir, Fraser fir, and white spruce) MC did not change over the 6-week display period. This contrasts to outer twigs which exhibited slight MC increases. Douglas-fir inner twigs, which exhibited the greatest decrease in MC over the 6-week period, did not fall below 90%, which equaled that of WS at the end of the display period.

Twig MC for all species of trees displayed out of water exhibited sharp declines over the 6-week display period (Figure 3). Although there was no difference among species in the rate of decline in outer twig MC, intercepts did differ statistically (Table 1, Figure 3a). Scots pine, which had the highest initial MC compared to the other 4 species, had the highest MC after 6 weeks without water. The rate of decline for inner twig MC differed by species (Table 1, Figure 3b). Douglas-fir and white spruce exhibited slightly greater rates of moisture loss compared to balsam fir and Fraser fir (Figure 1). Although these slight differences were statistically significant, the magnitude of the reduction in moisture concentration over time overshadowed differences among species for all trees displayed out of water.

It is interesting to note that initial MCs for dry trees, measured towards the end of the day when the experiment was set up (Figure 3a, b), were slightly lower than those trees that were immediately placed in a bucket of water (Figure 2a, b). Even within the ten-hour period that it took to complete setting up the trees inside the display building, the impact of no water on needle and twig moisture was already apparent. This observation suggests that it is important to provide displayed trees with water as soon as possible after bringing them indoors. It is likely that trees placed in water toward the end of the day rehydrated in a short period. However, we did not collect samples on an hourly basis and cannot rigorously test that hypothesis.

Average MC of outer twigs from trees stored for 6 weeks outdoors prior to display in water did not drop below 100% for the 6-week display period (Figure 4a). Only Scots pine exhibited a statistically significant change in MC over time, declining over the 6-week period. Inner twig average MC for all species remained relatively constant over the 6-week period. Fraser fir and white spruce began and ended with the highest and lowest initial MCs, respectively. Buds were flushing on many of the trees at the end of the study.

Needle and twig moisture concentrations at the time of harvest were high for all of the trees in the current study. Had initial moisture levels been lower, storage might have had a negative impact. Work with Fraser fir has shown that if moisture concentration of cut trees drops below 75%, trees will not rehydrate when placed in water (Hinesley 1984). Moisture concentrations did not approach reported values for the damage threshold, defined as the moisture concentration below which cut Christmas trees experience irreversible damage such as accelerated needle loss after rehydration. The damage threshold for Fraser fir reported by Hinesley and Snelling (1991) is approximately 80% MC. None of our outdoor stored trees exhibited moisture concentrations below 98%. This underscores the importance of harvesting trees before the combination of frozen ground and dry, desiccating conditions combine to reduce moisture concentrations in tree crowns.

One of the key issues directly related to moisture loss is at what point a tree becomes a fire hazard. The fact that moist trees will not sustain combustion when a flame is introduced has been carefully established. In a recent study with Scots pine, red pine (*Pinus resinosa* Ait.), white spruce, Colorado blue spruce (*Picea pungens* Engelm.) and balsam fir displayed indoors in water for two weeks, White et al. (1997) documented that NONE of indoor displayed Christmas trees ignited when flame (simulating accidental fire source) was applied to the crown.

The moisture concentration below which a tree will ignite when a flame is applied is species dependent. Van Wagner (1963) reported needle MCs below which a flame would be sustained for Scots pine (65%), balsam fir (50%), and white spruce (43%), the latter being tentative because of low needle retention as trees dried. Extrapolating those results, balsam fir, white spruce, and Scots pine displayed OUT OF WATER would become fire hazards between 3 and 5 weeks after being set up indoors (Figure 3) under the conditions of our study (temperature range 14 – 22°C). Drier and/or warmer conditions would likely shorten that period. Hinesley and Snelling (1991) showed that the rate of drying for Fraser fir and eastern white pine (*Pinus strobus* L.) varied predictably with temperature, vapor pressure gradient, and light. When stored at 30°C and 25% relative humidity, trees dried to the critical moisture concentration in 3 – 4 days, compared to 25 days at 10°C and 90% relative humidity. Other species may dry at different rates. For example, fresh cut Arizona cypress (*Cupressus arizonica* Greene) Christmas trees displayed without water indoors in a study in Georgia at a temperature range of 22 - 22°C became dry and unsafe after only 1 week (Davis and Fretz 1972).

Our results are consistent with those reported by other researchers. Van Wagner (1963) followed moisture concentrations for three species of Christmas tree (Scots pine, balsam fir, and white spruce) in Ontario, Canada. He found that moisture concentrations of both fresh cut and stored (outdoors for 6.5 weeks) Christmas trees were maintained in excess of 100% for the entire 21-day indoor display period (average temperature range 20 – 26°C). Seiler et al. (1988) reported similar experience with eastern white pine and Norway spruce (*Picea abies* (L.) Karst.) in Virginia. Those trees, cut December 1 and stored outdoors through the following January, were displayed indoors in water and attained needle and twig moisture concentrations in excess of 100%. Cut trees stored outdoors for as long as 6 weeks in the current study maintained moisture concentrations in excess of 100% for the entire display period.

Collectively, these results underscore the importance of proper care (i.e. water) for long-term indoor display of Christmas trees given acceptable post-harvest handling. Even with no care, there is at least a two-week period during which fresh cut trees remain above 65% moisture for the conditions in our study. This period would be reduced in environments characterized by higher temperature and/or lower relative humidity. Van Wagner (1963) showed that moisture concentrations at which foliage becomes flammable ranged from 43% to 65%, depending on species. It is interesting to point out Van Wagner's (1963) findings that trees displayed in water remained at or above 100% moisture concentration for the entire study period and could NOT be ignited with matches. When a 20 cm Bunsen burner flame was applied to those trees, some foliage burned but ceased burning immediately upon removal of the flame. Flame persisted for a few seconds, then extinguished, in dry (but not in water) trees at moisture concentrations between 60 and 100%.

## CONCLUSION

Christmas trees cut in New York during late November and displayed indoors with the butt immersed in water for a 6-week period maintained moisture concentrations at or above 100%. This was true for all trees, fresh cut as well as those stored outside for as long as 6 weeks

after cutting. Some trees broke bud at the end of the study period. Flammability research by Van Wagner (1963) and more recently by White et al. (1997) has shown that foliage with moisture concentrations in excess of 65% does not ignite and support combustion. Trees displayed out of water for the 6-week display period rapidly lost moisture and dropped below safe moisture concentrations (susceptible to ignition by open flame) between three and four weeks after being set up.

The fact that dry, improperly displayed Christmas trees can and do ignite in the presence of an ignition source is indisputable. However, because of the notoriety associated with those fires that did involve dry Christmas trees (Damant and Nurbakhsh 1994), the fact that moist trees do not burn is often completely missed. Damant and Nurbakhsh (1994) noted that ignition was not achieved using either a match or ignited polyester fiber batting for the single fresh cut tree in their experiment. It is abundantly clear that watered fresh cut Christmas trees DO NOT represent a fire hazard.

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Table 1. Summary of significance<sup>1</sup> for tests of hypotheses from analysis of variance for coefficients of the linear model<sup>2</sup> expressing needle and twig moisture concentration as a function of time.

Hypothesis	Statistical Significance By Twig Age and Treatment <sup>3</sup>					
	1		2		3	
	Outer	Inner	Outer	Inner	Outer	Inner
Mean $z = 0$	**	**	**	**	**	**
$z_i$ equal among species	**	**	**	**	*	**
Mean $b = 0$	**	ns	**	**	ns	ns
$b_i$ equal among species	**	**	ns	*	*	ns

<sup>1</sup> \*\* statistically significant, denotes rejection of null hypothesis at  $\alpha = 0.01$ ; \* statistically significant, denotes

rejection of null hypothesis at  $\alpha = 0.05$ ; ns denotes nonsignificant (failure to reject null hypothesis).

<sup>2</sup> Linear model:  $\mu_{im} = z_i + b_i(m - mbar) + e$  for species  $i$ , where  $m = \text{week}$ ,  $mbar = 4$ , the average value for week, and  $e = \text{error}$

term (normally, independently distributed with mean 0 and constant variance)

<sup>3</sup> Treatment 1, immediate display for 6 weeks with butt in water; Treatment 2, immediate display for 6 weeks with butt out of water; Treatment 3, 6 week storage on open outdoor lot followed by 6-week display with butt in water. Figure 1. Mean moisture concentration (MC) difference between outer and inner twigs ( $MC_{outer} - MC_{inner}$ ) for four species of Christmas trees (A) immediately displayed in water, (B) immediately displayed out of water, and (C) stored for 6 weeks outdoors then displayed in water. Order of species is balsam fir (white), Douglas-fir (lightly shaded), Fraser fir (horizontal hatch), and white spruce (dark shaded).

Figure 2. Average twig moisture concentration (MC) by species for treatment 1, trees immediately displayed in water over a 6 week period for (A) outer twigs and (B) inner twigs. Week 1 is the initiation of the experiment (tree setup indoors). Species denoted by BF = balsam fir (open squares), DF = Douglas-fir (open triangles), FF = Fraser fir (shaded squares), WS = white spruce (shaded triangles), SP = Scots pine (shaded circles).

Figure 3. Average twig moisture concentration (MC) by species for treatment 2, trees immediately displayed out of water over a 6 week period for (A) outer twigs and (B) inner twigs. Week 1 is the initiation of the experiment (tree setup indoors). Species denoted by BF = balsam fir (open squares), DF = Douglas-fir (open triangles), FF = Fraser fir (shaded squares), WS = white spruce (shaded triangles), SP = Scots pine (shaded circles).

Figure 4. Average twig moisture concentration (MC) by species for treatment 3, trees displayed in water over a 6 week period after 6 weeks of storage on an outdoor open lot for (A) outer twigs and (B) inner twigs. Week 1 is the initiation of the experiment (tree setup indoors). Species denoted by BF = balsam fir (open squares), DF = Douglas-fir (open triangles), FF = Fraser fir (shaded squares), WS = white spruce (shaded triangles), SP = Scots pine (shaded circles).

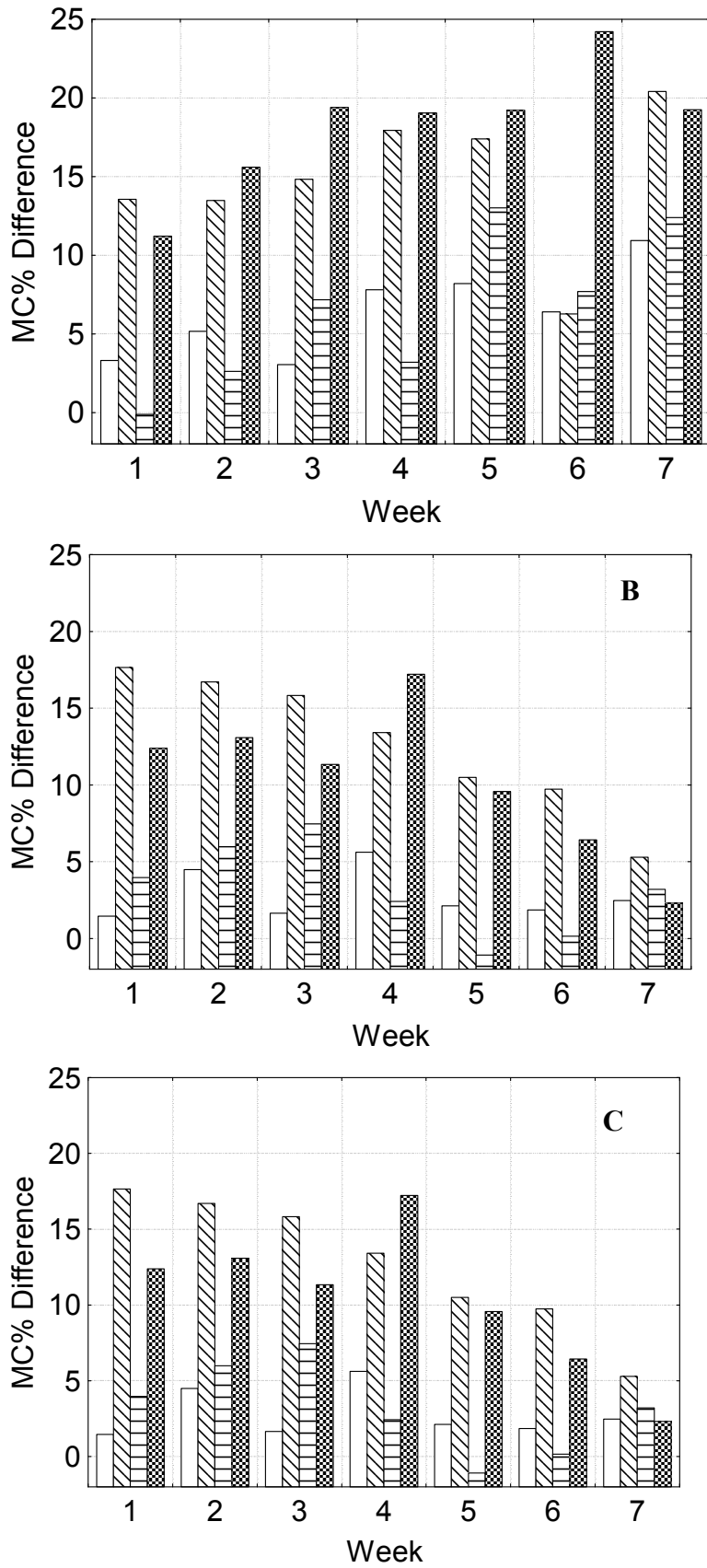


Figure 1

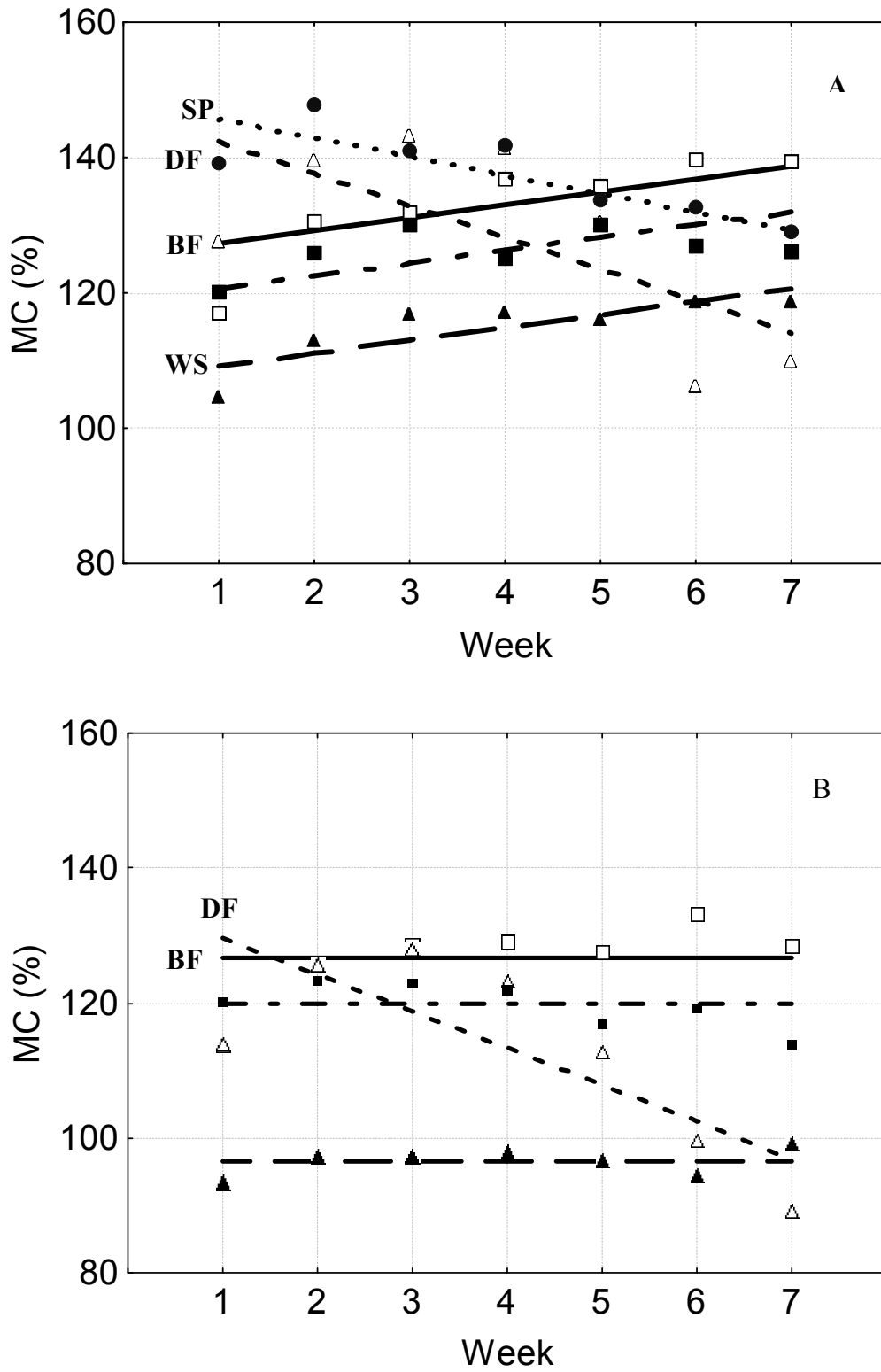


Figure 2

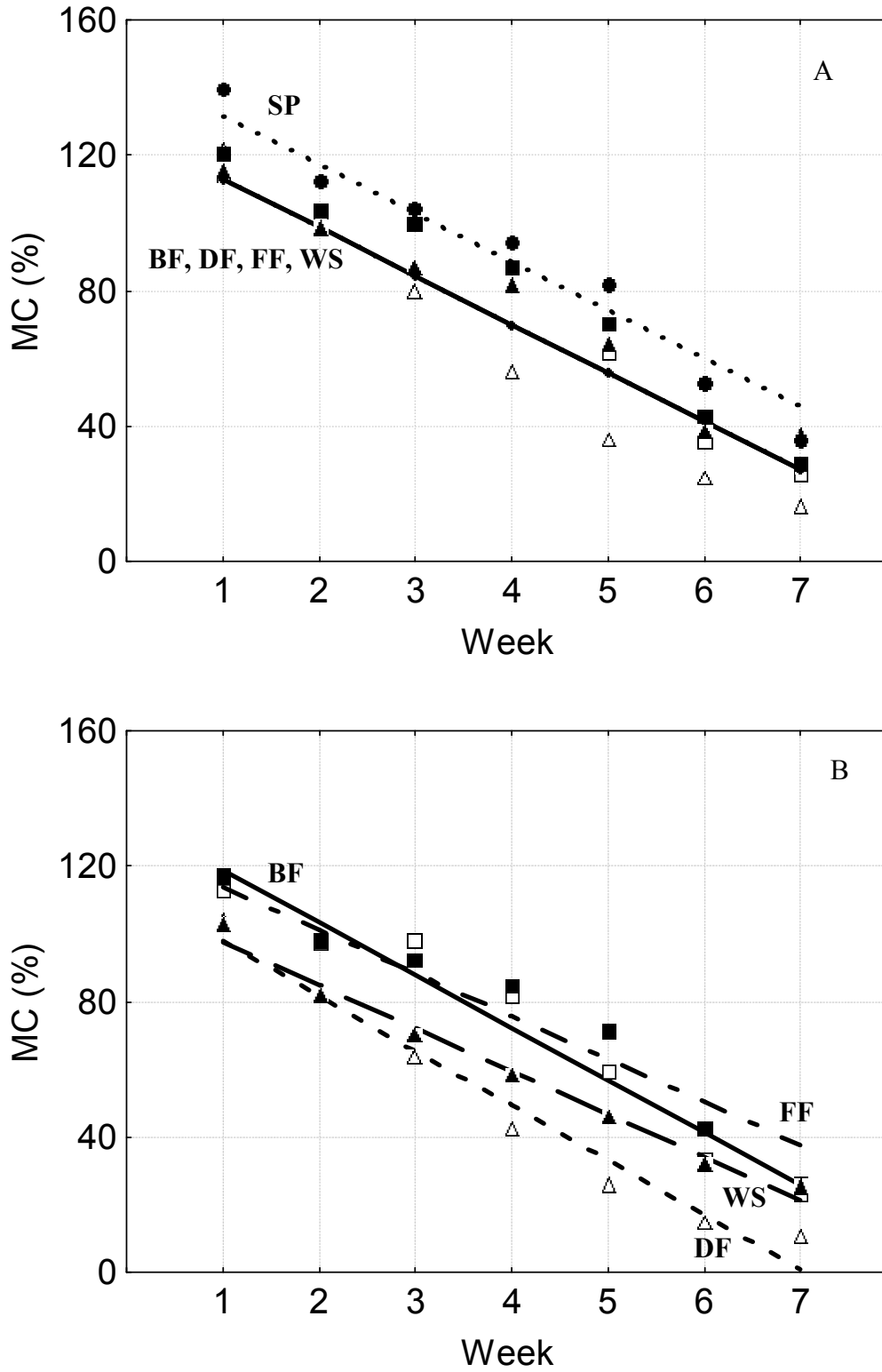


Figure 3

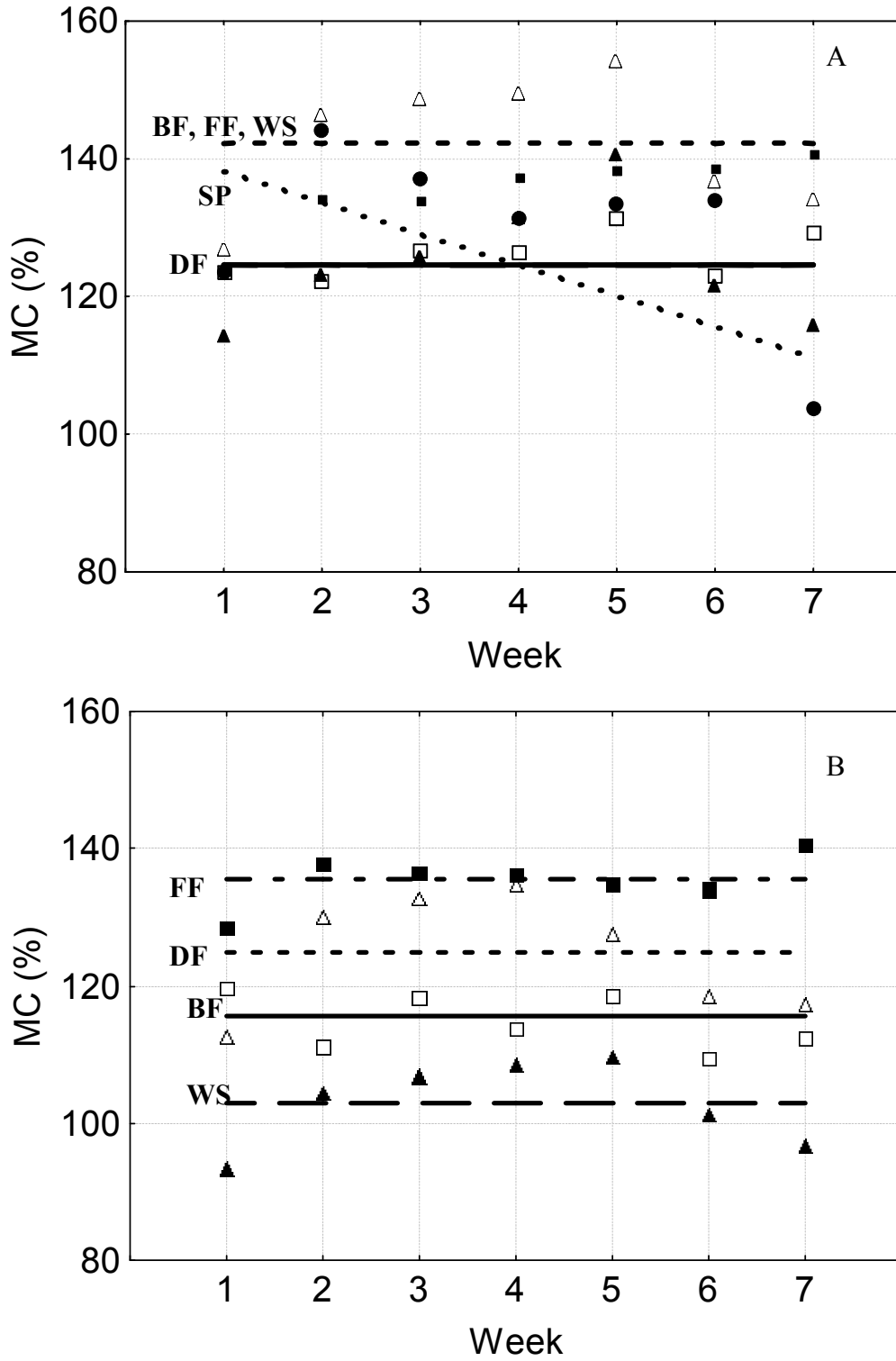


Figure 4