ETHYLENE ACCUMULATION DURING COLD STORAGE OF PINE SEEDLINGS: IS IT A PROBLEM?

Jon D. Johnson[1]

Abstract.--Ethylene is a plant growth regulator that can inhibit root and shoot growth in plants. The atmospheres of two loblolly pine seedling cold storage facilities were sampled over a three month period during the winter of 1981-1982 to determine the extent of ethylene accumulation. Ethylene concentration reached physiologically significant levels (2300 ppb) in the storage facility which employed open seedling bales. The use of K-P bags for seedling packaging in the other facility precluded the accumulation of ethylene in the atmosphere during storage. There was evidence of ethylene addition by the operation of gasoline-powered forklifts in one of the storage facilities. Gas samples from within seedling bales and K-P bags indicate that loblolly pine seedlings do produce ethylene.

Additional keywords: *Pinus taeda*

Ethylene is a naturally-occurring plant growth regulator which has been implicated in a number of physiological processes (Abeles 1973; Galston and Davies 1970). Of importance to nursery operations are the reports of root growth and bud development inhibition by ethylene, and the stimulation of ethylene production as a result of mechanical injury such as occurs during lifting of seedlings from nursery beds (Burg and Burg 1968; Kramer and Kozlowski 1979; Wareing and Phillips 1973; Yang and Pratt 1978).

The effect of ethylene on tree seedlings has received increasingly more attention in recent years. Barnett (1980) reported a five percent increase in survival and a 75 percent increase in root regeneration potential of loblolly pine (*Pinus taeda* L.) seedlings stored for six weeks in the presence of an ethylene adsorbent. Fraser fir (*Abies fraseri* (Pursh) Poir.) seedlings exposed to 17.5 ppm ethylene for eight weeks in cold storage exhibited a 22 percent reduction in terminal growth (Hinesley and Saltveit 1980). Graham and Linderman (1981) found that lateral root growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings was inhibited at ethylene concentrations greater than 150 ppb.

This study examined the *in situ* changes in ethylene concentration during cold storage of loblolly pine seedlings.

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[1] Assistant Professor of Tree Physiology, Dept. of Forestry, V.P.I. & SU., Blacksburg, VA. Financial support was provided by USDA Forest Service, Southern Forest Experiment Station, Pineville, LA under cooperative agreement number 19-82-6. Cooperators were Jake Stone, Union Camp Hardwood Nursery, Capron VA, and Tom Dierauf, Bill King and Donald Hickson, Virginia Division of Forestry, New Kent Forestry Center, Providence Forge, VA.

METHODS

The atmospheres of the cold storage facilities at the Union Camp Hardwood Nursery, Capron, VA and the Virginia Division of Forestry, New Kent Forestry Center, Providence Forge, VA were sampled throughout the winter of 1981-1982 using Vacu-Samplers®. At the Union Camp facility monthly samples, replicated twice, were taken beginning 30 November 1981 prior to seedling storage and continued for three months. Biweekly samples, replicated four times, were obtained at the VDF facility also beginning 30 November 1981 prior to seedling storage and continued for 14 weeks.

The two facilities were chosen for their contrasting storage practices of loblolly pine seedlings. The VDF uses open-ended seedling bales and operates gasoline-powered forklifts in the storage facility. Union Camp employs K-P bags and uses only hand-operated lifts. Although the Union Camp facility is used primarily for storing hardwood seedlings, between 120,000 and 350,000 loblolly pine seedlings were present during the sampling period.

The samples were analyzed on a Bendix 2500 gas chromatograph equipped with a flame ionization detector and a six foot, glass Poropak N column. Column conditions were: carries gas (He) - 28 ml min^{-1}; hydrogen flame gas - 30 ml min^{-1}; column temperature - 60^{o} C. Ethylene was identified in the samples by co-chromatography with a known ethylene standard.

The data were statistically examined using analysis of variance and Duncan's Multiple Range test.

To further examine packaging differences between the two facilities, gas samples from within a VDF bale was obtained on 8 March 1982 and samples from within three K-P bags were taken on 27, 28 and 29 April 1982.

RESULTS AND DISCUSSION

Ethylene concentration in the VDF facility varied significantly (P=0.001) over the 14 week storage period whereas the variation in ethylene concentration in the Union Camp facility was not statistically different (P=0.05) (Figure 1). At the VDF facility ethylene accumulation apparently began immediately after seedlings were placed into cold storage with the maximum concentration of 2369 ppb being achieved on 28 December 1981. This maximum was followed by a precipitous drop in ethylene concentration to the minimum of 174 ppb on 25 January 1982. This minimum corresponded to cessation of seedling lifting due to extremely cold weather and frozen soils. The resumption of lifting and subsequent storage resulted again in an increase, although smaller, in the ethylene concentration to 431 ppb. Ethylene concentration then decreased to control levels on 8 March 1982. The ethylene concentration in Union Camp's facility remained virtually constant at or slightly above the control concentration (30 November 1981) of 200 ppb. This lack of change in ethylene concentration was attributed to Union Camp's use of K-P bags for seedling packaging. Any ethylene produced by the seedlings would presumably accumulate in the K-P bags and hence would not be detected in the atmosphere of the storage facility.

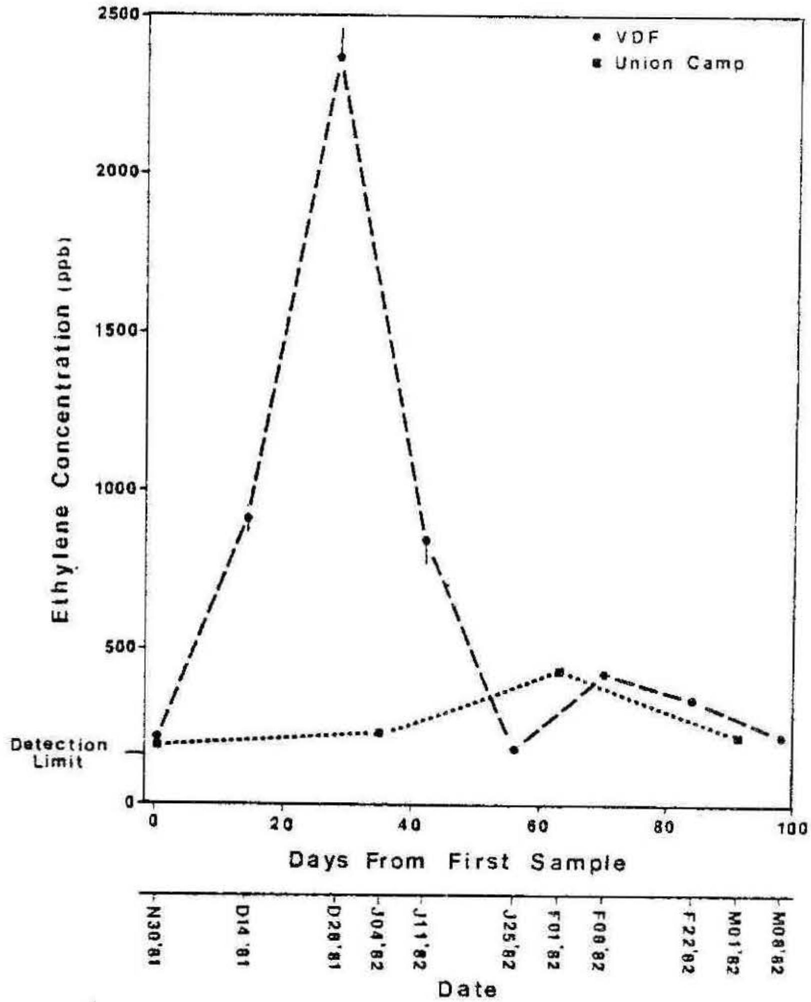

Figure 1.--Ethylene concentration in the VDF and Union Camp cold storage facility during the 1981-82 season. Standard errors are represented by vertical lines where they were larger than the symbols.

During the gas analysis all of the VDF samples with the exception of the controls (30 November 1981) exhibited a yet to be positively identified gas that was never detected in the Union Camp samples. A comparison of the retention time of the unknown gas with published values of hydrocarbons suggest that the unknown gas was acetylene. The significance of this finding is that both acetylene and ethylene are major components of engine exhaust (Abeles 1973). Thus, the VDF by operating gasoline-powered forklifts in their storage facility may be increasing the ethylene concentration to which their seedlings are exposed.

The pattern of ethylene accumulation in the VDF facility is difficult to explain based solely on the number of seedlings in storage. From personal observation the storage facility was about one-third full the first of January whereas it was completely full the first of March. The number of seedlings in storage would be reflective of forklift activity. Hence, one would expect more ethylene in March due to a greater number of seedlings present and to greater forklift activity. The ethylene concentrations at these two times do not support this argument (Figure 1). An alternative explanation is that the majority of the ethylene is seedling origin and that ethylene production is a function of seedling dormancy and hence varies with the time of lifting.

In order to verify that loblolly pine seedlings do produce ethylene, gas samples were analyzed from a VDF bale and three K-P bags containing loblolly pine seedlings (Table 1). Loblolly pine seedlings in the VDF bale exhibited a four-fold increase in the ethylene concentration over the K-P bags when expressed on a per seedling basis. This difference, however, is confounded by lifting time. The VDF seedlings were lifted in early February whereas the seedlings in the K-P bags were lifted in early April. These preliminary data support the above hypothesis that ethylene production changes with lifting time over the winter.

Table 1.--Ethylene concentration within loblolly pine seedling packages. The K-P bags contained 500 seedlings per bag and the VDF bale contained 1000 seedlings.

Package	ETHYLENE CONCENTRATION (ppb)			
	root region		shoot region	
	per bag	per seedling	per bag	per seedling
K-P Bag				
bag 1	76	.15	50	.10
bag 2	145	.29	136	.27
bag 3	98	.20	81	.16
VDF Bale				
bag 1	782	.78		

CONCLUSIONS

Ethylene can accumulate to physiologically significant concentrations during the cold storage of loblolly pine seedlings. Seedling packaging appeared to have a large control over the atmospheric ethylene concentrations. Ethylene accumulated to greater concentrations with seedling bales whereas K-P bags appeared to retain the ethylene. Lifting date tentatively appeared to strongly influence ethylene production from seedlings, regardless of packaging method. The operation of gasoline-powered forklifts within a storage facility appeared to add ethylene to the storage atmosphere.

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