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Effects Of Potassium Fertilization In The Nursery On Survival And Growth Of Pine Seedlings In The Plantation

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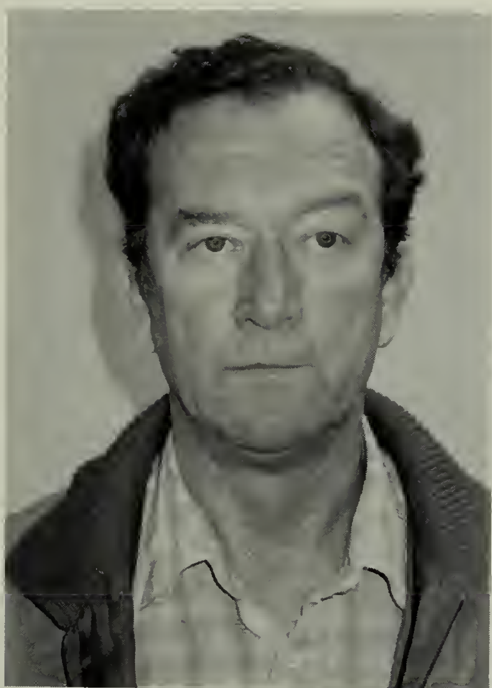

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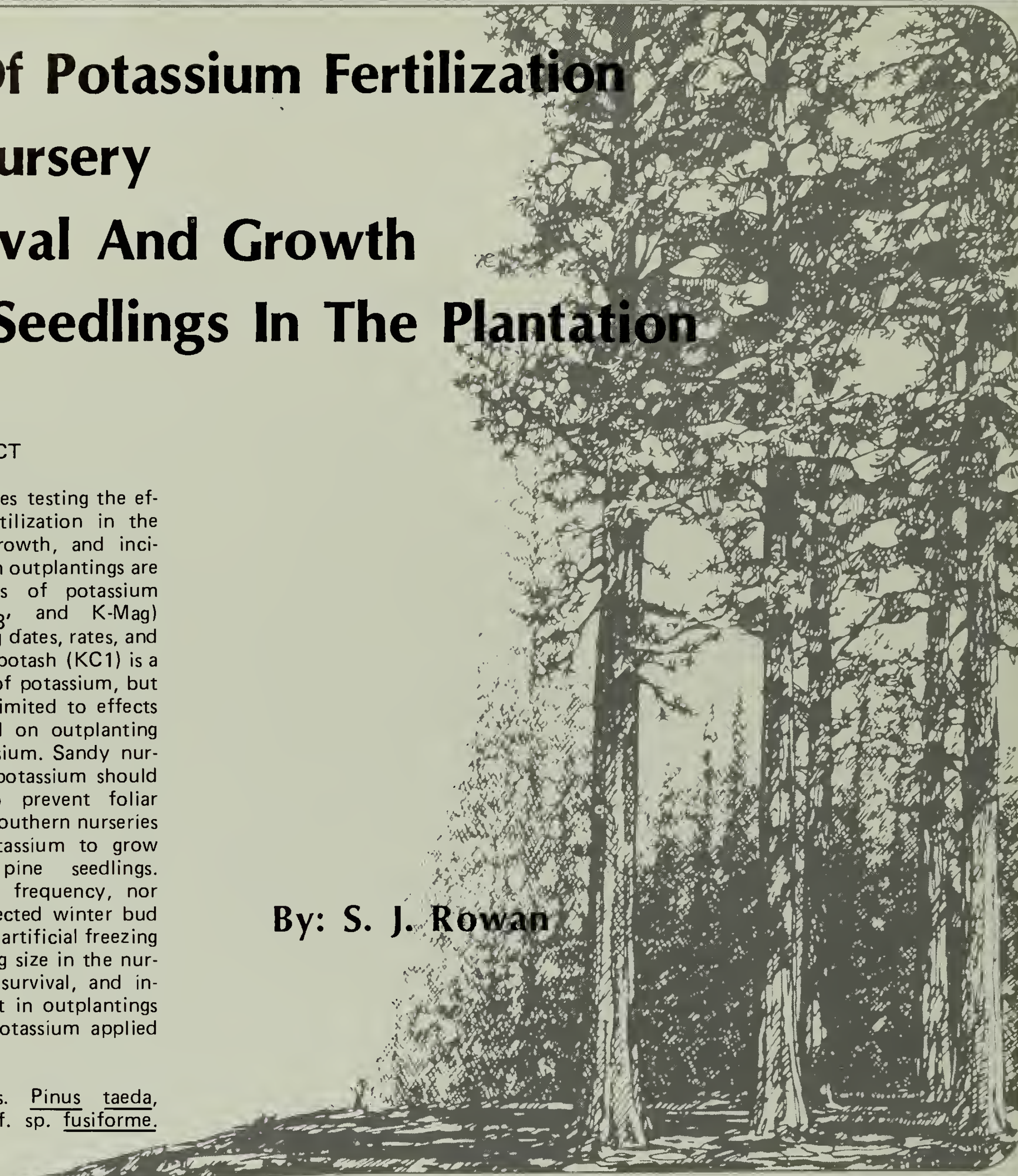

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ABSTRACT

Results of four studies testing the effects of potassium fertilization in the nursery on survival, growth, and incidence of fusiform rust in outplantings are reported. Four sources of potassium (KC1, K_2SO_4, KNO_3, and K-Mag) were applied at differing dates, rates, and frequencies. Muriate of potash (KC1) is a recommendable source of potassium, but it's usefulness appears limited to effects on growth and survival on outplanting sites deficient in potassium. Sandy nursery sites deficient in potassium should receive fertilization to prevent foliar deficiencies, but many southern nurseries have sufficient soil potassium to grow loblolly and slash pine seedlings. Potassium source, rate, frequency, nor date of application affected winter bud formation, resistance to artificial freezing temperatures, or seedling size in the nursery. Seedling growth, survival, and incidence of fusiform rust in outplantings were not affected by potassium applied in the nursery.

Additional key words. Pinus taeda, Cronartium quercuum f. sp. fusiforme.

Although seedling quality is often said to be directly correlated with seedling survival and growth in the plantation, it is difficult to measure seedling quality and to accurately predict rates of survival and growth in the field. Switzer and Nelson (1963) found that seedling quality, when influenced by increasing seedbed fertility and decreasing bed density, was correlated with growth but not with survival in the field. Baule and Fricker (1970), on the other hand, concluded after a literature review that potassium fertilization may affect seedling cold hardiness and, consequently, survival rates under conditions of potassium deficiency, high pH, and nutrient imbalance.

Potassium is thought to play an important role in the process of frost-hardening of trees, involving sugar-starch conversion at the end of the growing season (Kopitke, 1941; Sato & Muto, 1953; Woback, 1930). The reduction of carbohydrate reserves in potassium deficient plants is probably related to decreased photosynthesis and increased respiration rates (Lawton & Cook, 1954; Mulder, 1956). Potassium is also involved in the synthesis of proteins from amino acids, which is related to nitrogen fertilization on potassium deficient sites and potassium fertilization on nitrogen deficient sites, resulting in depressing effects on tree growth (Xydias & Leaf, 1965).

Applying potassium fertilizer during late summer and early fall to increase seedling quality is routine in most forest tree nurseries. Most sites in the Southeastern U.S. are not subjected to extremes of cold and, therefore, fertilization with potassium to increase cold hardiness may be unnecessary. Potassium, on the other hand, is low and/or deficient in many sandy soils low in organic matter and is readily leached from such soils (Krause 1965). Its use throughout the growing season, but especially late in the season, may increase seedling survival and/or growth on sandy field sites low in potassium. This paper presents results of four fertilization studies in which the effects of nursery applied potassium on field survival and growth were monitored.

Materials and Methods

Study plots were first established in 1979 in both the Georgia Forestry Commission's Morgan Nursery near Byron, Georgia (study 1) and in Great Southern Paper Company's nursery near Cedar Springs, Georgia (study 2). In each nursery, plot size was 4 feet by 25 feet and each of nine fertilization treatments (Table 1) were replicated in three blocks in a randomized complete block design. Potassium was applied as muriate of potash (0-0-60) at a rate of 50 pounds potassium/acre/application. One group of seedlings was lifted from each plot in late November and stored under refrigeration for 14 days, after which (early December) a second group of seedlings was lifted from each plot. Both groups of seedlings from Great Southern's nursery were outplanted in Meriwether County, Georgia and both groups of seedlings from Morgan Nursery were outplanted in Baldwin County, Georgia. Again in January the same lifting, refrigerated storage, and outplanting procedures were repeated. The outplantings were made in randomized complete blocks with treatments assigned to single-row plots of 25 seedlings each and replicated 3 times. Tree height and survival were measured during each of 3 years after outplanting. Foliage samples were collected for chemical anaylses from the nursery plots in December prior to the first outplanting.

After finding in 1979, that applications of up to 250 lbs/acre of potassium to seedlings did not increase foliar K in seedlings from the Morgan Nursery but significantly increased foliar K in seedlings from Great Southern's Nursery (Table 2), a third study was established in the Great Southern Nursery in 1980. In this study (no. 3), potassium source, rate, and frequency of application were varied. Sources of potassium compared were muriate of potash (0-0-60), potassium sulfate (0-0-34) and K-Mag (0-0-22).

Table 1. Potassium fertilization treatments applied in each of four studies.

Months applied	Frequency x K-rate (No. x lbs/acre)	Total K applied (lbs/acre)
Studies 1 and 2 using only KC1 (0-0-60) source:		
--	check	0
6	1 x 50	50
8	1 x 50	50
6,8	2 x 50	100
8,9	2 x 50	100
5,7,9	3 x 50	150
7,8,9	3 x 50	150
6,7,8,9	4 x 50	200
5,6,7,8,9	5 x 50	250
Study 3 using KC1, K_2SO_4 (0-0-34), and K-Mag (0-0-22) sources:		
--	check	0
8	1 x 50	50
8	1 x 100	100
6,8	2 x 50	100
8	1 x 150	150
5,7,9	3 x 50	150
6,8	2 x 100	200
6,7,8,9	4 x 50	200
5,6,7,8,9	5 x 50	250
Study 4 using KC1, K-Mag, and KNO_3 (13-0-44) sources:		
--	check	0
8	1 x 100	100
6,8	2 x 50	100
5,7,9	3 x 50	150
6,8	2 x 100	200
6,7,8,9	4 x 50	200
5,6,7,8,9	5 x 50	250
5,7,9	3 x 100	300
5,6,7,8,9	5 x 100	500

Table 2. Effects of potassium fertilization (KCL) in the nursery on foliar content of selected mineral elements at time of lifting from the seedbed.

Potassium rate (lbs/acre)	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Calcium (%)		Magnesium (%)	
	Morgan	Great Southern	Morgan	GS	Morgan	GS	Morgan	GS	Morgan	GS
0	1.627 a	1.243 a	.173 a	.143 a	1.936 a	.545 b	.255 a	.296 a	.063 a	.121 a
250[1]	1.575 a	1.253 a	.162 a	.140 a	1.887 a	.626 a	.221 b	.273 a	.058 b	.099 a

Means in each column followed by a common letter are not significantly different (P=.05) according to Duncan's multiple range test.

[1]The potassium fertilization rate treatment of 250 lbs/acre represents the samples from average plots of treatments in which potassium was applied (50 lbs/acre/application) in May, June, July, August, and September.

K-Mag is $K_2SO_4 \cdot 2\ Mg\ SO_4$. The nine treatments listed in Table 1 were assigned at random to plots in three randomized complete blocks. Seedlings were lifted from each 4 foot x 25 foot plot on November 15 and placed in refrigerated storage for 14 days, and in early December a second group of seedlings were lifted from each plot. Both groups of seedlings were outplanted in Marion County, GA in early December. The outplanting was made in randomized complete blocks with treatments assigned at random to single-row plots of 50 seedlings each in two blocks. Tree height and survival were measured during the first and second year after outplanting.

A fourth study was established in 1981 in the Great Southern Nursery in which potassium source, rate, and frequency of application were again varied (Table 1). Sources of potassium compared were the same as those used in 1980 except that potassium nitrate (13-0-44) was substituted for potassium sulfate because of the hygroscopic nature of the latter fertilizer. Additional nitrogen was applied as ammonium nitrate to all plots not receiving potassium nitrate treatments at a nitrogen rate and frequency equal to that applied as potassium nitrate. The study was established as a randomized complete block design with three replicate blocks. Plot size was 4 feet by 35 feet. Study areas used in Great Southern's nursery during each of the three years were never established in the same location to avoid residual and unequal potassium levels in the soil. Chemical analyses of soil collected from each plot also proved the lack of influence of residual soil potassium on test results. Chemical analyses of soil collected from each of the four outplanting sites revealed that only two sites (Baldwin and Marion County) were deficient in potassium (Table 3). Seedlings with differing levels of foliar potassium due to fertilization treatment were outplanted on only one site (Marion County) deficient in potassium during the course of the 4 studies (Tables 2,3).

In an attempt to test for cold hardiness among potassium fertilization treatments, seedlings from study 3 (1980) were lifted from each nursery plot, transplanted to a depth 2 inches deeper than ground-line in styrofoam chests filled with sawdust, and placed in a freezer at -14 C for 0, 60, 120, and 240 minutes exposure. After thawing at 22 C, the seedlings were outplanted and their mortality was recorded one year later. Fifty seedlings from each (nursery) plot were exposed to each freezing treatment (50 seedlings x 9 treatments x 3 K sources = 1350). The freezer used was a walk-in unit precooled to the desired temperature in which fans circulated air and was not self-defrosting. Thus, the rate of freezing was constant for all treatments and that rate caused the surface 2 or 3 inches of sawdust to freeze when exposed 240 minutes.

In an attempt to determine if potassium fertilization affected the formation of winter buds, the percentage of seedlings with winter buds in late October of 1981 was recorded for each of the 8 nursery bed drills in random 1 foot x 4 foot plots within each treatment plot of study 4.

Approximately 28 seedlings/ft^2 were present at lifting in each plot in each of the four studies and numbers of plantable seedlings per plot was not affected by any potassium fertilization treatment. In studies 1 and 2, 25 random seedlings were outplanted from each nursery plot after exposure to two storage periods and outplanted on each of two dates on two field sites (2700 seedlings outplanted on each site from each nursery study). Seedlings from the Morgan Nursery (study 1) were hand planted but those from Great Southern's nursery (studies 2, 3, and 4) were machine planted.

Because of an error in fertilization application in study 3, only two replicates were outplanted. However, 50 seedlings were outplanted per replicate treatment. Seedlings were lifted in mid-November, stored 14 days under refrigeration and outplanted together with seedlings lifted in early December (14 days later). Thus, the outplanting included (50 seedlings x 2 lift dates x 2 blocks x 27 treatments) 5400 seedlings. In study 4 the outplanting included 50 seedlings from each plot lifted on each of two dates (14 days refrigeration vs no storage). Thus, the outplanting included (50 x 2 x 27 nursery plots x 3 replicate blocks) 8100 seedlings. Thus, growth and survival were monitored in 4 outplantings including (2700 + 2700 + 5400 + 8100) 18,900 seedlings from the 4 studies.

Table 3. Chemical analyses of soil from each of four outplanting sites.

Site[1/]	pH	Cation exchange capacity	Phosphorus	Potassium	Calcium	Magnesium	Organic matter %
			....	.lbs. per acre	....		
Baldwin	5.4	1.8	45	34	200	20	1.1
Meriwether	5.3	2.7	4	78	250	50	1.4
Marion	4.9	2.1	10	14	200	20	0.8
Early	6.8	4.0	74	105	550	100	1.1

[1/] The four outplanting sites are identified by the county in which they were located in Georgia.

Results and Discussion

Although fertilization with potassium during the late season is a common operational practice in many southern forest nurseries, such fertilization is not based on a proven need for seedling survival and growth in outplantings. Soil levels of potassium and other nutrients are monitored by frequent soil chemical analyses but it is rare that the effects of adding additional nutrients (including potassium) is determined in forest nursery crops by measuring levels in tree seedlings with and without the added fertilization. Such an analysis (Table 2) revealed that the Morgan Nursery was a poor site for conducting potassium fertilization studies because of the adequate amount of soil potassium to supply the needs of loblolly pine seedlings. Soil chemical analyses should also be used to select outplanting sites both deficient and with adequate levels of the nutrient tested (Table 3). Outplanting sites used in these studies were selected because of availability, although they did differ markedly in levels of soil potassium (Table 3).

Fertilization with differing sources of potassium, at differing rates, differing frequencies, and on differing dates did not affect (data not shown) seedling size in the nursery nor rate of survival in outplantings. However, seedlings lifted in November and refrigerator stored 14 days did not survive as well as seedlings not stored and outplanted on the same date as the stored seedlings (Table 4). Seedlings lifted in mid-December and refrigerator stored for 14 days before outplanting in early January, however, did survive as well as non-stored seedlings in two of three studies (Table 4). The results of the Early County study (number 4) in

Table 4. Effects of refrigeration storage and planting date on survival and height growth of loblolly pine seedlings outplanted on each of four sites.

Site	Refrigeration storage (days)	First Year survival Dec	First Year survival Jan	First Year Dec	First Year Jan	Second Year Dec	Second Year Jan	Third Year Dec	Third Year Jan
				-outplanting date					
		-----%-----		---cm---					
Baldwin (Study 1)	0	56.6 a	44.6 a	28.7 a	28.4 a	53.9 a	46.5 b	128.5 a	110.0 ab
	14	28.4 b	26.5 b	26.1 b	27.6 a	46.7 b	43.3 b	117.6 b	102.7 c
Meriwether (Study 2)	0	90.2 a	94.1 a	30.0 a	32.2 a	62.3 b	67.5 a	115.0 b	125.0 a
	14	84.3 b	92.2 a	27.4 b	30.2 a	56.3 c	63.8 b	104.9 c	123.3 a
Marion (Study 3)	0	88.4 a	---	25.9 a	---	63.1 a	---	---	---
	14	95.3 b	---	24.0 b	---	59.4 b	---	---	---
Early (Study 4)	0	79.0 a	80.1 a	52.1 a	51.0 ab	---	---	---	---
	14	75.3 b	79.9 a	49.1 ab	49.6 ab	---	---	---	---

Means for each site and year followed by a common letter do not differ (P=.05) according to Duncan's multiple range test.

Table 5. Effects of fertilization in the nursery with different sources of potassium on seedling height in the plantation.

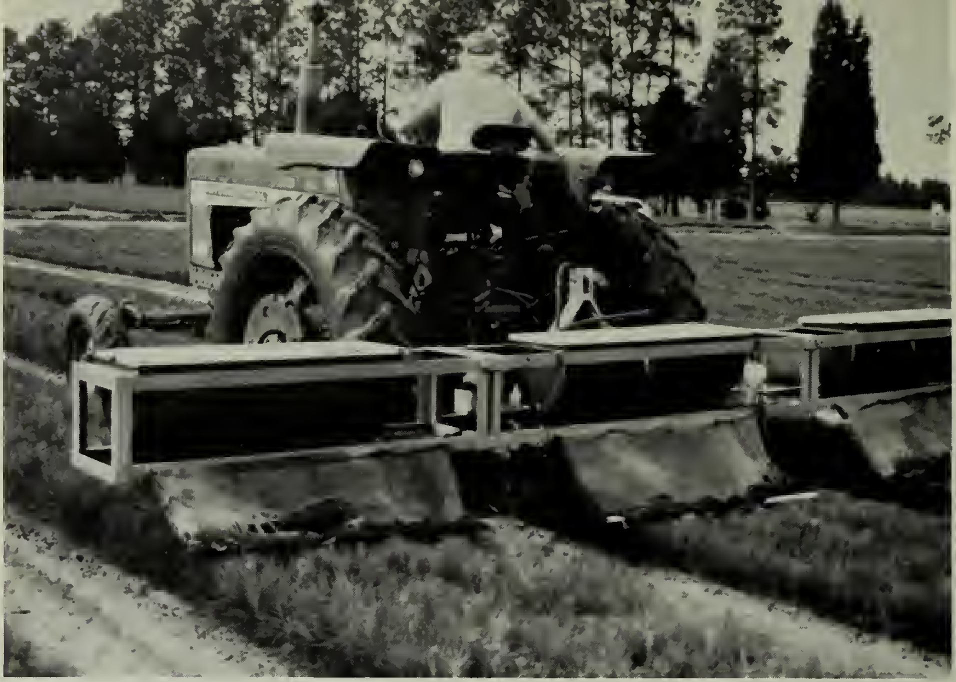
Source	Marion site First year (cm)	Marion site Second year (cm)	Early site First year (cm)
KC1	26.9a	65.8a	49.8a
K-Mag	24.9b	61.4a	50.1a
K_2SO_4	23.1c	56.6b	—
KNO_3	—	—	51.4a

Means in each column followed by a common letter are not significantly different (P=.05) according to Duncan's multiple range test. Seedlings outplanted on the Baldwin and Meriwether sites are omitted because they were fertilized in the nursery with only one source of potassium (KCL).

which 8100 seedlings were outplanted confirms the detrimental effects of refrigerator storage of seedlings before they are acclimatized.

Seedling height growth in the outplantings did not differ because of date, rate, or frequency of application of potassium in the nursery (data not shown) but refrigeration storage reduced height growth (Table 4). Height was most reduced in seedlings lifted in mid-November and stored 14 days in a refrigerator indicating, again, the need for acclimatization before refrigeration. Muriate of potash proved to be a better source of potassium than did K-Mag or potassium sulfate when seedlings were outplanted on a potassium deficient (Marion) site (Table 5).

Source of potassium fertilization applied in the nursery did not affect the rate of mortality among seedlings exposed for differing time periods in a freezer (Table 6). Length of exposure did significantly affect mortality (Table 6). Rate, date, and frequency of potassium application did not affect freeze-induced mortality (data not shown).



Applying potassium fertilizer during late summer and early fall to increase seedliing quality is routine in most forest tree nurseries.

Table 6. Effects of fertilization in the nursery with different sources of potassium on resistance of seedlings to freezing (-14C) temperatures.

Exposure time (Min)	K_2SO_4	Potassium source KC1	K-Mag	Avg
	% Mortality			
0	8.7a	11.6a	8.2a	9.5a
60	20.3b	17.1b	15.7b	17.7b
120	21.5b	28.7c	28.1c	26.1c
240	52.8d	45.6d	42.9d	47.1d
Average	25.8A	25.8A	23.7A	

Columns means followed by a common lower case letter and row means followed by a common upper case letter are not significantly different (P=.05) according to Duncan's multiple range test. Each cell mean is the average percentage mortality among 1350 seedlings.

Rate of winter bud formation was also not affected by source, rate, date, or frequency of potassium application in the nursery (data not shown). Seedlings in the outside two drills on each bed set winter buds at an earlier date than did those in other drills (Table 7). This is probably related to their exposure to cooler air and ambient temperatures than seedlings from drills on the interior of seedbeds.

Although potassium is an essential plant nutrient, results of studies reported here do not support the need of this element for increased survival or growth in outplantings on Georgia sites not deficient in soil potassium. Results also indicate that some nursery soils have an adequate supply of soil potassium for growth of slash and loblolly pine seedlings. In southern nurseries with sandy soils deficient in potassium, fertilization with muriate of potash is a recommendable practice but real benefit from such fertilization may be realized only on potassium deficient outplanting sites.

Incidence of fusiform rust was not influenced by rate, frequency, source, or date of application of potassium fertilization in the nursery (data not shown). There was a numerical but nonsignificant decrease in rust incidence associated with November lifted, refrigerator stored seedlings in which growth rate was also slowed by the same treatment. Ferbam was applied to all nursery plots to control the disease and prevented testing the effects of potash fertilization on fusiform rust incidence in the nursery. A previous study (Rowan and Steinbeck, 1977) indicated that potassium fertilization did not change the susceptibility of loblolly seedlings to fusiform rust.

Table 7. Effects of seedbed drill location on frequency of winter buds in loblolly pine seedlings by late October.

Drill (No)	Winter buds (%)
1	35.7a
2	22.2b
3	18.8b
4	14.2b
5	18.5b
6	20.1b
7	23.8b
8	33.5a

Column means followed by a common letter are not significantly different (P=.05) according to Duncan's multiple range test. Cell means are the averages across all potassium treatments and replicates (about 1013 seedlings/cell).

Fertilization with differing sources of potassium, at differing rates, differing frequencies, and on differing dates did not affect seedling size in the nursery.

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