PREVENTION OF INJURY TO TREE SEEDLINGS DURING CELLAR STORAGE ¹

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ABSTRACT

Survival of tree planting stock following cellar storage by various methods was consistently good when the storage method included packing the roots in damp peat. Manitoba maple and American elm needed such protection more than caragana and green ash. Prestorage treatments with various fungicides increased survival only slightly, or were injurious. It was demonstrated that injurious desiccation of stored plants may be determined by electrolytic methods.

INTRODUCTION

Nursery stock grown for distribution to Prairie farms is commonly stored in cellars during the winter before being shipped. Frequently, when planted in the spring many plants die. If the seedlings are heeled in out-of-doors in the fall, they are protected by the winter snow and survive well, but they cannot be handled early in the spring. Many of the cellar-stored plants become moldy before distribution. Weakly parasitic fungi are reported to cause molding and losses of nursery stock stored over winter under unfavorable conditions (1). Stock stored at 30 to 38° F. remains dormant, but relative humidity of 85 to 90 per cent is needed to prevent drying (2). At a uniform temperature of 28 to 30° F., drying is reduced and mold growth is decreased (4). Refrigeration is an excellent method of storing seedlings and cuttings (3, 6).

The object of this investigation was to establish a simple method for controlling winter storage injury. The study was designed to determine mainly

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if the low survival of the cellar-stored plants was caused by drying out or by molding.

MATERIALS AND METHODS

The experimental material consisted of seedlings of caragana (*Caragana arborescens* Lam.), green ash (*Fraxinus pennsylvanica* var. *lanceolata* Sarg.), box-elder or Manitoba maple (*Acer negundo* L.), and American or white elm (*Ulmus americana* L.). In one experiment (B), seedlings of Scots pine (*Pinus sylvestris* L.) and cuttings of cottonwood (*Populus deltoides* Marsh.) and Volunteer (a natural hybrid of *Populus* spp.) were also used. Five replicated bundles, 50 plants in each, constituted a sample of each species.

In accordance with usual practice, the planting stock was stacked during winter along the walls of a storage cellar at Indian Head, Saskatchewan. This is a nonrefrigerated, humid, concrete-walled cellar under a building. The temperatures were controlled by manipulating openings to outdoors when needed. During winter the cellar temperatures were maintained at approximately 30° F. in one compartment and 35° and 40° F. in others. Temperatures were somewhat higher in spring.

The plant samples were treated by various methods of storage (Expt. A) and by fungicides (Expt. B). In spring the plants were planted at 1-ft. intervals in random rows 9 ft. apart. Survival was recorded the following fall. The percentage data were transformed into angles before analysis.

In Expt. A, repeated for 4 years, the roots in each sample were either packed in moist peat or left without protection other than that provided by the surrounding bundles. The peat was partially decomposed acid *Sphagnum* moss, commonly sold as "peat moss". Heeling in out-of-doors in nursery clay loam served as a check treatment.

In Expt. B, conducted in only one year, the cuttings and roots of the seedlings were dipped for one minute in fungicidal water suspensions and then stored at 40° F. The fungicides compared were: Tersan (thiram 75 per cent), Orthocide (captan 75 per cent), and Manzate (maneb 70 per cent), each at 25 gm./gal., lime sulphur at 75 gm./gal. and Semesan at 14 gm./gal. Only pine and the poplars were packed in peat in Expt. B. At the end of the storage period, surface-sterilized pieces of plant tissues were plated on agar. The platings were incubated at low temperatures to isolate any low temperature pathogens which might be present.

Because elm was included in Expt. A in two years only, separate analyses were made on data with and without elm. However, very little difference was found in results. Therefore, data on elm are shown in Tables 1 and 2 as comparable to all the other data, but the significant differences given are those derived from the 4 years' data without elm.

The samples were weighed at the beginning and end of storage to determine any change in weight. The electrical conductivity of water extracts of all broadleaved seedlings, those stored with and without peat at the two cellar temperatures and those heeled in out-of-doors, was determined in 1954. The electrical conductivity method was the same as had been used to determine freezing injury in an earlier study (8).

EXPERIMENTAL RESULTS

Table 1 shows that the survival of all plants protected by damp peat was approximately equal to the survival of heeled-in plants, and survival of plants stored without this protection was much less. There was little difference in the survival of plants stored at the two temperatures.

Table 2 shows that there was little difference in loss of weight between seedlings heeled in out-of-doors and those stored with peat around their roots. All seedlings without peat lost six to seven times as much weight as the protected seedlings. Weight loss at the two temperatures differed little.

Of the five fungicides, only Orthocide significantly increased plant survival (Table 3). However, as compared with the effect of peat (Table 1),

TABLE 1
FIELD SURVIVAL (PER CENT) OF SEEDLINGS AFTER WINTER STORAGE IN CELLAR

Species	Year of planting	Winter cellar storage					
		Heeled in out-of-doors	Peat around roots		No peat		Mean
			40°F.	35°F.	40°F.	35°F.	
Caragana	1951	63	96	96	82	89	85
	1952	98	100	100	98	86	96
	1953	100	99	100	98	96	99
	1954	95	95	93	60	76	84
	Mean	89	97	97	84	87	91
Ash	1951	98	100	98	92	94	96
	1952	99	100	100	98	97	99
	1953	100	100	100	81	55	87
	1954	95	94	97	13	39	68
	Mean	98	98	99	71	71	87
Box-elder	1951	95	97	96	32	37	71
	1952	97	97	90	48	19	70
	1953	100	100	100	13	2	63
	1954	96	89	71	2	12	54
	Mean	97	96	89	24	17	64
Elm	1953	96	96	98	37	34	72
	1954	92	98	96	6	21	63
	Mean	94	97	97	21	27	67
Mean		94	97	95	54	54	77
					P. .05	P. .01	
L.S.D. between means of species					2	3	
" " " " treatments					3	4	
" " " " within each sp.					5	7	
" " " " years within each sp.					4	6	
" " two determinations					23	30	

TABLE 2
LOSS OF WEIGHT (PER CENT) OF SEEDLINGS DURING WINTER STORAGE
IN CELLAR

Winter cellar storage									
Species	Year of planting	Heeled in out-of-doors	Peat around roots		No peat		Mean		
			40°F.	35°F.	40°F.	35°F.			
Caragana	1952	5.2	1.1	3.1	18.6	29.6	11.5		
	1953	2.4	9.5	3.4	29.7	28.2	14.6		
	1954	2.3	8.7	12.5	25.6	24.2	14.7		
	Mean	3.3	6.4	6.3	24.6	27.3	13.6		
Ash	1952	1.8	0.0	0.1	14.5	17.3	6.7		
	1953	2.8	0.6	4.6	25.8	27.8	12.3		
	1954	1.6	9.3	10.1	23.4	21.0	13.1		
	Mean	2.1	3.3	4.9	21.2	22.0	10.7		
Box-elder	1952	4.9	0.0	0.4	26.8	34.7	13.4		
	1953	8.6	4.2	4.9	29.6	35.9	16.6		
	1954	4.4	8.2	8.7	34.5	35.8	18.3		
	Mean	6.0	4.1	4.7	30.3	35.4	16.1		
Elm	1953	2.1	2.7	4.1	30.3	30.0	13.8		
	1954	1.1	6.5	10.4	29.0	28.9	15.2		
	Mean	1.6	4.6	7.2	29.6	29.4	14.5		
Mean		3.4	4.6	5.8	26.4	28.5	13.7		
						P. .05	P. .01		
L.S.D. between means of species						1.6	2.1		
"	"	"	"	treatments			2.0	2.7	
"	"	"	"	within each sp.			3.5	4.6	
"	"	"	"	years within each sp.			1.6	2.1	
"	"	two determinations						6.1	8.0

this increase was small. Table 3 also shows marked survival differences between the closely related cottonwood and Volunteer.

Fungicides did not prevent molding. Isolations indicated that the molds were mainly species of *Penicillium*, *Trichoderma*, and *Fusarium*.

The data in Table 4 reveal that low survival of planted seedlings was associated with (i) high loss of weight during storage and (ii) increase of electrical conductance of water extracts during the storage period.

DISCUSSION

The results in Table 1 demonstrated that seedlings of several broad-leaved species can be successfully stored over winter in cellars. Weight loss of seedlings may be small, and subsequent field survival high, if the roots are kept packed in moist peat during storage. When the roots were not packed in

peat (Table 1), weight loss of the seedlings was high and subsequent survival low. This may have been caused by metabolic processes, killing of plant tissues by pathogenic fungi, or by desiccation. Metabolic processes are not

TABLE 3

FIELD SURVIVAL (PER CENT) OF SEEDLINGS AND CUTTINGS AS AFFECTED BY FUNGICIDAL TREATMENTS PRIOR TO WINTER CELLAR STORAGE

Species	Tersan	Orthocide	Manzate	Lime sulphur	Semesan	Water (check)	Mean
Caragana	79	78	70	64	75	70	72.7
Ash	72	64	62	27	46	59	55.0
Box-elder	3	1	1	0	1	0	1.0
Elm	10	17	9	3	19	7	10.8
Scots pine	2	10	0	0	2	4	3.0
Cottonwood	7	13	2	3	7	4	6.0
Volunteer	28	31	48	20	24	31	30.3
Mean	28.7	30.6	27.4	16.7	24.8	25.0	25.5
						P. .05	P. .01
L.S.D. between means of treatments						4.6	6.0
" " " " species						4.9	6.5
" " two determinations						12.1	16.0

TABLE 4

RELATION BETWEEN FIELD SURVIVAL, WATER LOSS, AND ELECTRICAL CONDUCTANCE OF WATER EXTRACT IN SEEDLINGS STORED DURING WINTER (1953 - 54) UNDER TWO TREATMENTS

Species	Storage treatment ¹	Field survival (per cent)	Moisture loss (per cent)	Elec. conductance (micromhos)	
				Shoot	Root
Caragana	Peat around roots	94.0	10.6	319	1045
	No peat	68.0	24.9	505	2181
Ash	Peat around roots	95.5	9.7	185	405
	No peat	26.0	22.2	226	536
Box-elder	Peat around roots	80.0	8.4	336	1340
	No peat	7.0	35.1	617	2123
Elm	Peat around roots	97.0	8.4	280	432
	No peat	13.5	28.9	389	842
Mean	Peat around roots	91.6	9.3	280	805
	No peat	28.6	27.8	434	1420

¹ All data are averages of two temperatures, 35° and 40°F., shown for 1954 in Tables 1 and 2.

a likely cause since no differences occurred between the two temperatures tested. Metabolic processes are very low in dormant seedlings at temperatures lower than 40° F. (5). The results of the fungicidal treatments (Table 3) suggest that the importance of pathogenic fungi was limited. The main factor obviously was water loss.

It was not determined in which part of the storage period the weight loss was greatest, i.e., whether loss of weight during the later warmer weeks of storage was proportionally greater than during the almost constant 30° to 35° F. winter temperatures. However, it was found in another, similar study (7) that molded box-elder grew very well if the stock was removed, moistened, wrapped as for shipping, and re-stored two weeks before planting. This indicates that desiccation in the latter part of the storage was critical. The porous peat may also have served as a thermal insulator at this critical period in spring. In lieu of the controlled uniform storage temperatures of 28° to 30° F. suggested by Kains and McQuesten (4), covering the roots with moist peat, *Sphagnum*, or other similar materials, may be used as a means of improving storage facilities. A frozen condition of the peat packing during winter storage was commonly observed, and this may be beneficial to the species tested. The better winter storage survival of Volunteer poplar compared with cottonwood, and of caragana and ash compared with box-elder and elm, also suggests that species and varieties of plants with ability to survive winter storage conditions could be selected.

Of the five fungicidal treatments, only Orthocide increased the survival of the plants. Apparently phytotoxicity of some of the fungicides reduced the survival. Nevertheless, even the least phytotoxic fungicide did not give survival equal to that of plants protected with peat. It appears that protection with peat without fungicidal treatments is a satisfactory storage method. The need to use fungicides with peat is lessened by the fact that acid peat suppresses fungal pathogens either directly or by encouraging certain saprophytes antagonistic to pathogens (9). Further investigations are needed to determine the importance of common antagonistic saprophytes such as *Penicillium* spp. and *Trichoderma* spp. (9), and the action of *Fusarium* spp. as a possible facultative pathogen on stored seedlings (10). Further studies will be required also to determine the effect of certain other low temperature fungi which, although of minor importance in the present instance, might adapt themselves to the special environment and become serious in cold storage.

Since electrical conductivity of the water extracts increased directly with plant weight loss (Table 4), increased electrical conductivity is a measure of drying out. High electrical conductivity has been correlated with freezing injury (8). This study shows that it is also correlated with desiccation injury. This suggests a simple and rapid method of determining the amount of desiccation that is occurring during winter storage.

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