PERFORMANCE AND SURVIVAL MODELS OF *PRUNUS VIRGINIANA MELANOCARPA* L. AND *CORNUS STOLONIFERA* MICHX. SOWN ON ABANDONED FARMLAND

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Campbell Gerrond Davidson

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ABSTRACT

Davidson, Campbell Gerrond, M.Sc., The University of Manitoba, April, 1979. Performance and Survival Models of Prunus virginiana melanocarpa L. and Cornus stolonifera Michx. Sown on Abandoned Farmland. Major Professor; Louis M. Lenz.

A study was made of the after-ripening requirements of Prunus virginiana melanocarpa L., Cornus stolonifera Michx., Amelanchier alnifolia (Nutt.) Nutt., Elaeagnus commutata Bernh. and Prunus pensylvanica L.F. Highest emergence values were obtained by after-ripening Prunus virginiana melanocarpa seed for 30 days at 20°C followed by 150 days at 4°C; by after-ripening acid scarified seed of Cornus stolonifera for 30 days at 20°C and 75 days at 4°C; by after-ripening Amelanchier alnifolia seed at 4°C for 150 days; by after-ripening Elaeagnus commutata seed for 30 to 45 days at 4°C. All treatments failed to stimulate emergence of Prunus pensylvanica.

Direct seeding field trials resulted in stands of Prunus virginiana melanocarpa and Cornus stolonifera being successfully established on abandoned farmland near Neepawa, Manitoba. Models of seedling performance and survival were generated. Performance and seedling survival were principally influenced by the degree of competition and the amount of snow cover. Competition reduced growth and survival. Lack of snow cover resulted in winter desiccation causing mortality. A band in the mid-portion of the hill maintained a significant seedling population.

INTRODUCTION

In March of 1972, the Whitemud River Watershed Conservation District No. 1 was incorporated. It was born from a common concern for effective management of land based resources. Some of the principal problems as viewed by those involved were soil erosion and gullying, flooding, drainage and water shortages (McKay 1971).

The Whitemud river watershed encompasses some 1,777,291 acres in south-central Manitoba. The relief varies from 2,250 feet above sea level in the Riding Mountain Upland to 825 feet in the south-western portion. In the Western Upland, water erosion can be very severe. The early settlers cleared much of the land which reduced the snow holding capabilities of the area. Spring runoffs are often very rapid and cause much damage. With the reduction of native vegetation increased erosion during the growing season has also been recorded (Veldhuis et al 1972).

This, as well as other concerns has lead to the development of an extensive conservation program. Approaches followed to date have concentrated on two major avenues. These are grass waterways, to reduce further gully erosion, and establishment of permanent cover with either forage crops or woody plant material. Permanent plant cover will help stabilize the erodible soil and conserve valuable moisture.

Utilization of woody plant material has been restricted to areas that are unsuitable for forage crop production. The choice of species and quantities planted has been largely dictated by the supply of material from the Federal government nursery at Indian Head, Saskatchewan and the Provincial government nursery at Hadashville, Manitoba. The area planted yearly is held in check by budgetary restrictions. In an overview, the impact of the tree planting program has been quite low.

In an attempt to offset the low impact, a direct seeding trial was initiated. Utilization of native shrubby material was considered of prime importance. The first trial was a failure. Few seedlings emerged during the first or second season. In an effort to obtain a greater understanding of what factors were influencing the populations an experimental site was selected for further studies. The eastern exposure of a hill was chosen. The site would present a variety of site variables. The most important considered at this time was soil moisture. The upper portion of the slope is much drier than the lower levels. The performance of the species chosen for seeding could be monitored in relation to the moisture regime.

In the initial proposal five species were considered; Prunus virginiana melanocarpa, Cornus stolonifera, Prunus pensylvanica, Amelanchier alnifolia and Elaeagnus commutata. However, it was soon evident that such a large undertaking was not feasible for an in-depth study. Two species were chosen for detailed study; Prunus virginiana melanocarpa and Cornus stolonifera. P. v. melanocarpa frequently is associated with dryer habitats while C.

stolonifera is associated with moister locations. It was felt that performance of these two species on the site could correspond to the soil moisture regime.

The purpose of this study was to develop models of the emergence and survival of P. v. melanocarpa and C. stolonifera under field conditions. After-ripening requirements were also investigated to allow both spring and fall sowing of seeds.

LITERATURE REVIEW

Throughout much of the world, plants have evolved some method of surviving unfavourable environmental conditions. The evolution of seed dormancy was instrumental in expanding the distribution of higher plants into temperate regions of the world (Porter 1967). Seed dormancy provides the plant with a method of surviving unfavourable conditions. The variety and importance of these mechanisms has resulted in intensive study of this field.

Viable seeds that fail to germinate in favourable environmental conditions are considered to be dormant (Villiers 1972). Dormancy as used in this discussion, is a state of suspended growth and reduced metabolism (Bidwell 1974).

One of the first investigators to categorize the occurrence of seed dormancy was Crocker (1916). Seven basic types were considered. The first was defined as seeds which have an immature embryo. The embryos are a mass of undifferentiated cells as in Ilex opaca Ait. (Ives 1923) or fully differentiated as in Fraxinus L. (Steinbauer 1937, Vanstone and LaCroix 1975) and Viburnum L. (Giersbach 1937), but need additional growth before germination can take place.

The second dormancy type considered was impermeability of the seed coats to water (Crocker 1916). The uptake of moisture is prevented by the testa. Rupturing of this layer is followed by quick imbibition of water and usually germination (Crocker 1916, Crocker and Barton 1953). This dormancy mechanism occurs in many members of the Leguminosae (Villier)

1972). Bacterial and/or fungal invasion of the seed coats has been hypothesized as a mechanism for terminating this dormant state under natural conditions (Crocker 1916, Pfeiffer 1934).

Mechanical resistance of seed coverings to embryo growth was the third dormancy mechanism (Crocker 1916). This is not a common occurrence. Investigations of Xanthium pensylvanicum Wally seeds have indicated that the embryos of small dormant seeds do not exert enough thrust to rupture the testa (Esashi and Leopold 1968). Embryos in larger seeds of this species could break the restrictive layers.

Low permeability of seed coats to gas exchange has been implicated as a dormancy mechanism (Crocker 1906, Crocker 1916). The embryo in this situation does not have free access to oxygen. Whether the oxygen deficiency is the cause of dormancy or only involved in maintenance in Betula L. sp. was unclear (Black and Wareing 1959). Brown (1940) observed a similar condition in Cucurbita pepo. L.

Some seeds benefit from an exposure to light while others respond to a moist chilling treatment. This was defined by Crocker (1916) as endogenous dormancy. Light treatments are beneficial for increasing germination in a wide variety of species, although the responses to specific treatments varies considerably (Barton 1965). The light requirement may be low in terms of quantity or intensity. Light can cause promotion or inhibition of germination (Villiers 1972). Examples of seeds that are positively photoblastic are Nicotiana tabacum L. and Lactuca sativa L. (Villiers 1972, Borthwicket al 1952) while examples of

negatively photoblastic seeds are Phacelia tanacetifolia Benth. and Nemophila insignis Dougl. ex Benth. (Villiers 1972). Temperature changes may alter the light requirement of seeds. Sterns and Olson (1958) demonstrated that Tsuga canadensis (L.) Carr. germinates best under short day conditions in a temperature range of 17 to 20°C. If the temperature is increased to 27°C the best germination occurred under long day illumination. Black and Wareing (1959) achieved similar responses for Betula pubescens Ehrh. They also illustrated that the light requirement is unnecessary if the temperature is raised above 25°C.

Many seeds require moist chilling treatments to induce germination. This dormancy mechanism is most frequently associated with the presence of germination-inhibiting substances in the embryos or seed coats (Villiers 1972). The balance of endogenous inhibitors and promoters must be shifted in favour of the latter before the seed will germinate. It is generally considered that production of growth promoters are necessary rather than the removal of the inhibitors (Barton 1965, Villiers 1972, Bidwell 1974), although leaching of certain seeds has been an effective horticultural procedure (Schopmeyer 1974, Hartman and Kester 1968).

Seeds of this nature usually need to be placed in a cool moist environment. The process of placing seeds in a moist medium and exposure to 1 to 5°C temperatures for a period of one to several months is defined as stratification (Crocker and Barton 1953). The purpose of stratification is to after-ripen the seeds. Germination should be prompt after such treatment if all requirements have been met. Corns and Schraa (1962) demonstrated that growth inhibiting substances occurring in the

endocarp of Elaeagnus commutata Bernh. resulted in poor germination. Excision of the embryo or stratification removed the metabolic block and allowed germination to take place.

Inhibitors are believed to be the cause of dormancy in the following species: Prunus virginiana L.; Amelanchier alnifolia (Nutt.) Nutt. and Cornus stolonifera Michx. (Schopmeyer 1974, Hilton et al 1965, Krefting & Roe 1949). Cornus stolonifera seed has a dormant embryo but a hard pericarp may also restrict germination (Schopmeyer 1974).

Numerous types of seeds have a combination of dormancy types, as demonstrated in C. stolonifera. More than one type of treatment is required to terminate the dormant state of the seed. Examples are; Fraxinus nigra Marsh. (Vanstone and LaCroix 1975); Fraxinus excelsior L. (Villiers 1972) and Prunus pensylvanica L.F. (Schopmeyer 1974, Hilton et al 1965). Marks (1974) stated that an explanation of the germination behaviour of P. pensylvanica under natural conditions must account for two facts: (1) that the presence of the endocarp limits germination significantly in recently matured seed; and (2) that under natural conditions, germination occurs predominantly in response to a major disturbance. Marks (1974) was unable to recognize any specific environmental trigger(s) required before germination took place.

Seeds placed in unfavourable germination conditions often become dormant. This is defined as secondary dormancy (Crocker 1916, Crocker 1953). These seeds will not germinate when placed in favourable conditions. For example, high temperatures and restricted oxygen supply caused seeds of Ambrosia trifida L. and Xanthium L. to become dormant (Davis 1930, a,b).

Low temperatures and increased oxygen tension are required to break this induced dormant state.

After-ripening procedures have been investigated considerably yet technical problems still hamper practically orientated workers. Horticulturists, Foresters and Land reclamation specialists all have tried to overcome these problems as well as the difficulties which occur during seedling establishment.

Under protective nursery conditions, germination, emergence and seedling establishment may occur quite readily, but when trials are undertaken in the field, discouraging results generally ensue (Cayford 1973). With intensive nursery care, environmental variables affecting seed germination and seedling establishment are partially controlled. Under extensive field culture, manipulation of these factors is more difficult. The problems which arise during germination and establishment are not overcome.

Hughes and Post (1973) categorized environmental variables which interact with regeneration technique into three broad categories (Table 1). The fixed components affect all seeding operations while the variables controlled by the managers are manipulated to the best of their knowledge. Partially controllable factors are maintained at the necessary levels in nursery operations but maintenance is difficult in field trials.

Direct seeding of woody plants has increased in importance. Since 1900, approximately 137,360 ha were sown in Canada (Waldron 1973), two thirds of which was planted in the past ten years (Table 2). The increased interest has been due to economic considerations. The costs of reforestation can be lowered since the nursery operation is bypassed (Vyse 1973).

TABLE 1 . Environmental factors which interact with regeneration technique to influence success on a reforestation project area

Fixed	Partially Controllable	Varied by Manager
Climate:	Seedbed:	
Precipitation quantity	Moisture	Species
Precipitation timing	Temperature	
Temperature	Nutrients	Stocking
Humidity	Microorganisms	Seed Source
Radiation	Light	
Wind	Vegetation	
	Organic Matter	
Elevation	Insects	
Aspect	Disease	
Soil:		
Depth	Animals	
Texture		

(After Hughes and Post, 1973).

TABLE 2. Direct seeded area since 1903

Years	Hectares	Percent of Total
1903 - 1912	4,048.1	3
1913 - 1922	72.7	*[1]
1923 - 1932	10,799.3	8
1933 - 1942	236.3	*
1943 - 1952	9,825.7	7
1953 - 1962	11,376.2	8
1963 - 1972	99,780.7	73
Total	136,139.0	100

*[1] less than 1%

(After Waldron 1973)

A variety of seed placement methods are used. Spot seeding and mechanical seeders are used but aerial dispersal with helicopters and airplanes is most popular (Waldron 1973).

The condition of the seedbed is important to any seeding operation. Numerous difficulties arise in preparation of seedbeds under the conditions within which the Foresters work. Mineral soil may be lacking or occur only in small pockets. Thick organic matter and plant debris layers are not a suitable environment for seedling establishment (Arnott 1973). Although site scarification or preparation is used in the majority of trials, twenty-four percent still receive no preliminary preparation (Waldron 1973).

With the above difficulties in mind, the fluctuations of the stocking rate may be explained. Aerial seeding does not ensure proper placement of seed in a seedbed which is of variable quality.

Direct seeding of woody plants is not restricted to Forestry. Land reclamation specialists also have experimented with this method. The variability of results obtained by Foresters is apparent in reclamation trials. Experiments completed by Lesko, Etter and Dillion (1973) were indicative of this. They recommended against direct seeding woody plants, although sparse information was presented on this trial.

Brown (1973) direct seeded Robinia pseudoacacia L., Pinus strobus L. and Pinus rigida Mill. on coal mine spoils in West Virginia. He demonstrated that covering the seeds with soil or soil covering plus a mulch layer is beneficial for germination and establishment of all three species. Soil moisture was an important component as well as soil compaction and the amount of plant cover or competition present. A lack of moisture limited estab-

lishment on southwest facing slopes and areas that had cover present. Compaction of the soil prevented efficient root penetration, hence the seedlings expired due to heat and moisture stress.

The seeded material germinated successfully under selected conditions. The highest survival was obtained with scarified Robinia pseudo-acacia seed having both soil cover and mulch on a northeast ungraded surface with no additional cover present (Brown 1973). Survival curves illustrate constant losses of seedlings through the first growing season and the following spring. Final survival values averaged between 6 and 14 percent.

The importance of moisture or soil water cannot be overestimated. A good supply of water must be available for plant growth during the establishment phase of seedling development (Brown 1973, Cayford 1973).

Soil water can be measured by a number of methods (Salisbury and Ross 1969, Slavik 1974). The measurement of the chemical potential energy is widely accepted for reporting the water status of a system (Salisbury and Ross 1969, Taylor and Ashcroft 1972, Slavik 1974, Rosenberg 1974). This measures the amount of work a unit quantity of water can do when it moves into a pool of water in the reference state at the same temperature. The total potential of soil water is made up of the water and gravitational potentials (Taylor and Ashcroft 1972). Other external forces present which must be included are the pressure potential, matrix potential and solute or osmotic potential (Taylor and Ashcroft 1972).

Field capacity or maximum capillary water is a term used to define

the upper limit of water availability while the permanent wilting point is used to define the lower limit (Buckman and Brady 1970). Water in the potential range of 1/3 bar to 15 bars is considered to be available for plant growth. Experimental determination of the permanent wilting-point has resulted in values of 10 bars to 20 bars, thus the choice of 15 bars as a reference point has been arbitrary (Kramer 1969).

Water content, on a percent dry weight basis varies considerably. Determinations of field capacity and permanent wilting-point vary with different soils (Taylor and Ashcroft 1972). Parent material, organic matter content and particle size and distribution differences have been largely responsible for this.

The distribution of nutrients and water is variable. In relatively small areas, changes occur in the abiotic environment, hence variation in the biotic sphere have been observed. In fact, the study of these gradients has led to one of the many approaches used to understand the complexity, diversity and adaptability of nature (Whittaker 1973).

Gradient analysis, a method of measuring biotic complexity is implicitly related to continuous variation of the environment. This analytic method is utilized to study vegetation in terms of gradients of the environment, species population and community characteristics in relation to one another (Whittaker 1973). These can be investigated directly or indirectly (Shimwell 1971).

Direct gradient analysis commonly has been used with sequential sampling points along a transect, while indirect gradient analysis has been performed on data collected randomly throughout the research area (Shimwell

1971). Implicit with both investigations is the collection of data on distribution, composition and importance of the community or species as well as pertinent environmental variables such as soil moisture, nitrogen, phosphorous and pH (Whittaker 1973 b). With the use of complex statistical and mathematical procedures the data are ordered in relation to the variables measured (Mueller-Dombois and Ellenberg 1974).

Gradient analysis relies on two basic assumptions which were first described by Gleason (1926) and have been since modified by Shimwell (1971). These are: (1) Each species has a distribution which is related to a total range of environmental factors and which depends on the limits of its own genotypic adaptability: The Principal of Species Individuality. (2) There is a continuous intergradation of communities along environmental gradients with gradual changes in species populations and population interaction along the gradient: The Principal of Community Continuity.

Inherent with the study of gradients has been the exposure of results that have not been easily interpreted. Shimwell (1971) states, "... indirect gradients analysis involves the comparison of samples with one another, usually in terms of species composition, and then through arrangement along axes or in a three dimensional hyperspace based on these similarity measurements. The approach to environmental gradients is always abstract, inferred and indirect."

Direct gradient analysis has yielded results which have been more easily interpreted yet the final product often falls short of expectations (Poole 1974). In a simple single gradient transect investigated

by Shimwell (1971), the performance of selected species over the altitudinal gradient was clearly illustrated. In the discussion of the results he stated that along the altitudinal gradient, numerous and complex interactions occurred. Adaptation to temperature, precipitation, humidity, growing season length, wind aspect, exposure and evaporation exist. Therefore each component contributes to a complex climatic gradient for which altitude is a useful approximation. The role of each individual component in the causation of the gradient would be attainable only by extremely intensive and laborious experimentation. Thus the gradient relations must remain as a generalization relative to the altitudinal approximation. The term complex gradient, or as in this case complex - elevational - gradient has been appropriately coined. Where altitudinal gradients do not exist, topographical gradients are largely responsible for the patterns which exist in vegetation. For example, Whittaker (1973 b) reported on a complex topographical moisture gradient in cyptograms growing in a ravine.

In the Hubbard Brook ecosystem study, a very in-depth analysis of vegetation, nutrients and water quality on a watershed level, the dynamics of the tree stratum (Borman et al 1970, Whittaker 1974) as well as herbaceous productivity (Siccama and Borman 1970), were found to follow a complex elevational gradient.

Nutritional gradients also were implicated as causing vegetation patterns. Wikum and Wali (1974) found nutrients to be important in the presence and absence of many species in a gallery forest in North Dakota. Results of multiple regression analysis yield predictive models for many species.

Topographical, altitudinal, nutritional and climatic gradients are responsible for a great deal of the variation observed in the distribution of plants.

METHODS AND MATERIALS

I. Introduction

Field plot and laboratory investigations were conducted during the study. The time scale of the studies is presented in Appendix 1. Field trials involved direct seeding Prunus virginiana melanocarpa and Cornus stolonifera as well as measurements of environmental variables related to plant growth and survival. Laboratory analysis consisted of a preliminary study of the after-ripening of Prunus virginiana melanocarpa, Cornus stolonifera, Prunus pensylvanica, Amelanchier alnifolia and Elaeagnus commutata. After-ripening procedures for P. v. melanocarpa and C. stolonifera were investigated in more detail during 1975 - 76.

All propagules utilized in these experiments were collected within the Whitemud Conservation District #1; primarily within townships 16-16, 17-16, 16-15, 17-15, 18-15 and 19-15, west of the prime meridian. Seeds for the 1974-75 experimental season were picked during August and September 1974 while seed required for the 1975-76 studies were picked during August and September 1975. Fruit colour and texture were used as indicators of maturity. After picking, the fruit was cleaned within 48 hours utilizing a Wareing blender at low speed. Damaged or unsound seed was removed by flotation. The seeds were then air dried for 3 to 4 days and stored in containers at $4^{o}C$. Seeds generally remained in storage for a period of one month before being placed in a series of treatments.

II. Preliminary Emergence Studies

An exploratory series of experiments were conducted to investigate the after-ripening requirements of P. v. melanocarpa, P. pensylvanica, C. stolonifera, A. alnifolia and E. commutata. Samples of 100 seeds, determined volumetrically, were used in each treatment. All seeds were after-ripened in small sealed plastic containers (Plastic-pak 6810, 10 ounce). Commercially available horticultural grade turface was used as a medium. After the recommendations of Kuch (1975) sufficient water was added to the medium to bring the water potential to 1.4 bars. To every 75 g of turface 40 ml of water was added. This was equilibriated in sealed plastic bags for 4 to 6 days at room temperature prior to use. Samples of P. v. melanocarpa, C. stolonifera, P. pensylvanica, A. alnifolia and E. commutata seed were after-ripened for 0, 30, 60 and 90 days at 20°C followed by 0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180 and 195 days at 4°C.

Trials also were conducted to determine what effect drying clean seed had on the after-ripening requirements of each species. One lot was not dried after cleaning (moist seed) while the other was dried for 3 to 4 days at room temperature. Both trials were held in 4°C storage until experiments were initiated (approx. 1 month). P. v. melanocarpa and C. stolonifera, of principal interest received an additional treatment of 15 days at 20°C followed by the sequential cold treatments.

Acid scarification was used to remove any seed coverings which could hamper the after-ripening or germination processes. The time period of treatment was determined by sequential observation. The best treatment was taken to be the one which removed the greatest amount of the covering without causing damage to the inner contents. Acid damage to the inner

contents of the seeds would adversely affect germination. A time period was selected on this basis and later utilized in scarification treatments.

Scarification was achieved by immersing the seeds in concentrated sulfuric acid which was constantly stirred by a magnetic stirring apparatus at slow speeds. The duration of the acid bath was variable between species. P. v. melanocarpa was scarified for 40 to 45 minutes, C. stolonifera for 25 to 30 minutes, P. pensylvanica for 65 to 70 minutes. Both A. alnifolia and E. commutata were destroyed during scarification. After completion of the treatment the seeds were washed for 30 minutes in cold running water to remove all traces of the acid. They were then air dried for 1 to 2 days and placed in a series of after-ripening treatments.

Scarified seed of P. v. melanocarpa and P. pensylvanica were stratified for 0, 30 and 90 days at 20°C followed by 15, 30, 60 and 90 days at 4°C. Additional treatments also included 120 days at 4°C and 60 days at 20°C followed by 30 days at 4°C. Scarified seed of C. stolonifera were stratified for 0, 15, 30, 45, 60, 90 and 120 days at 4°C as well as one treatment of 30 days at 20°C followed by 30 days at 4°C. A full range of treatments could not be conducted due to a shortage of propagules.

Upon termination of an after-ripening sequence each container was placed at a constant temperature of 20°C ± 2°C in a dark germination cabinet. Emerged seedlings were counted and removed every seventh day for a period of six weeks. Seedlings were considered emerged when seedlings appeared above the media surface. Any seedlings that emerged during the 20°C treatment were counted and removed.

III. Detailed Emergence Studies

Based on the results of the preliminary studies more detailed experiments were conducted the winter of 1975 - 76 to better define the after-

ripening requirements of P. v. melanocarpa and C. stolonifera. Seed was picked during August and September 1975 and was cleaned and stored as previously outlined. Media preparation, stratification procedure, emergence counts also remained as outlined. Each sample consisting of 100 seeds was replicated four times.

Based on the results of the preliminary trials, selected after-ripening treatments of P. v. melanocarpa were 0, 15 and 30 days at 20°C followed by 105, 120, 135, 150, 165, 180 and 195 days at 4°C.

C. stolonifera seed was scarified in slowly stirred conc. sulfuric acid for 25 to 30 minutes and after-ripened for 0, 15 and 30 days at 20°C followed by 15, 30, 45, 60, 90, 120 and 150 days at 4°C. Any seedlings that emerged during the 20°C treatment were removed and numbers were recorded.

IV. Seed Packaging Study

When after-ripening seed for sowings, outdoors, separation of the seed from the media is often difficult. To facilitate seed removal from the media small nylon bags were fabricated to contain the seeds during the after-ripening treatments. An experiment was conducted to determine if the nylon barrier had any effect on the after-ripening of the seed.

Thirty samples of 100 seeds of each P. v. melanocarpa and C. stolonifera were obtained from the sources as previously outlined. One half of the samples were enclosed in small nylon packages. Each sample was then placed in 10 ounce plastic-pak containers with premoistened turface and stratified at 4°C for 96 days in the case of P. v. melanocarpa and 63 days for C. stolonifera. The latter had been scarified for 25 to 30 minutes in constantly stirred conc. sulfuric acid. The duration of the treatments was the same as those used in the field trials. Upon termination

of this treatment those samples enclosed by nylon were opened, the seeds removed and the nylon discarded. The seeds were replaced in the container with the media. All lots were then placed at a constant temperature of 20°C ± 2°C in a dark germination cabinet. Emergence was recorded every seventh day for a period of six weeks. Seedlings were removed at the time of counting.

V. Field Trials

(a) Experimental Site

Direct seeding experiments were conducted on an experimental site near Neepawa, Manitoba. This location was chosen due to the Whitemud Watershed Conservation District #1's current interest in revegetation of reclaimed farmland. The site is located on a southerly portion of the southwest quarter of section 12, township 17, range 16, west of the prime meridian. It occupies the easterly slope of a hill. A survey determined that the 31 percent grade rose 51 feet over the 290 foot length. It is approximately 85 feet wide having a discernible downward slope on the north-south axis.

Shaley deposits and shale rock formed during the Upper Cretaceous period are an important soil and topographic feature of the surrounding area (Ehrlich 1958). Lacustrine and till deposits have helped in forming the soils. The surfacial horizons of the experimental site originally had a complex of both the Clarksville and Wapus grey wooded soil types. This soil is a shaley clay to shaley clay loam and characteristically susceptible to both wind and water erosion. In the natural state it is low in organic matter, low in carbonate content and is slightly acid in reaction (Ehrlich 1958).

The site had been under cultivation for at least ten years prior to

experimentation. Due to the steepness of the hill, erodibility of the soil and former agronomic practises, little top soil remained on the upper two thirds of the slope. The shaley subsoil formed the predominant feature of the substrate at these locations.

(b) Fall Seeding

Clean dry seed of P. v. melanocarpa and C. stolonifera which had been gathered and treated as previously outlined was sown on October 15 and 16, 1974. A "V" belt seeder was used. Seeding depth was two inches, however, variation occurred due to rough nature of the terrain. Six rows of each species were sown. The seeding rate was one seed per inch. Field plot design is illustrated in Figure 1.

(c) Spring Seeding

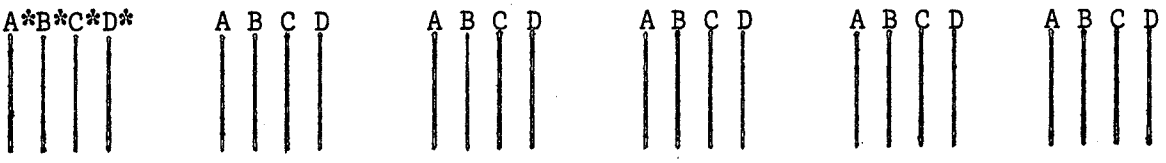
After-ripened seed of P. v. melanocarpa and C. stolonifera were sown on June 5 and 6, 1975. Results of the preliminary emergence studies were utilized to determine the length of after-ripening treatment for each species. In the case of C. stolonifera seeds were scarified for 25 to 30 minutes in concentrated sulfuric acid and placed in nylon packages in premoistened turface at 4°C for 56 days. P. v. melanocarpa was after-ripened in nylon packages in moistened turface at 4°C for 96 days. The nylon packages were used to facilitate separating the seed from the medium at the time of sowing.

Both species were sown with a "V" belt seeder. Seeding depth was two inches but variation occurred due to the rough terrain. The seeding rate was one seed per inch. Field plot design is illustrated in Figure 1. Additional data regarding intersampling station distance are presented in the Appendix 2..

(d) Soil Moisture Measurements

Figure 1. Field Plot Design - Elevations* and Planting Plan

1 (103.8)	2 (103.6)	3 (102.9)	4 (101.5)	5 (99.5)	6 (97.6)
7 (98.3)	8 (96.9)	9 (95.7)	10 (93.6)	11 (91.7)	12 (90.2)
13 (87.1)	14 (86.4)	15 (85.2)	16 (84.1)	17 (82.7)	18 (82.1)
19 (75.2)	20 (74.8)	21 (73.8)	22 (72.9)	23 (72.8)	24 (72.2)
25 (63.0)	26 (62.9)	27 (62.7)	28 (62.4)	29 (62.6)	30 (63.2)
31 (56.5)	32 (56.4)	33 (56.2)	34 (56.4)	35 (57.2)	36 (58.0)
37 (53.7)	38 (53.7)	39 (54.1)	40 (54.3)	41 (54.7)	42 (55.2)



A* - Spring sown C. stolonifera (rows extend from top to bottom)
B* - Fall sown C. stolonifera
C* - Fall sown P. v. melanocarpa
D* - Spring sown P. v. melanocarpa

*Elevation in feet above a reference point on Provincial Road 357

Soil moisture samples were collected to obtain an estimate of moisture available for plant growth. Samples were obtained nine times during the 1975 season; June 1, June 11, June 19, June 24, July 2, July 11, July 21, August 14 and September 24. Sampling was much more frequent during seedling establishment. Fluctuation of moisture was also much greater during this period. A 4" diameter soil auger was used to extract the sample at each of the 42 locations from a depth of 0 to 6". The soil was then quickly placed in a plastic bag, sealed and placed in cold storage at 4°C within 12 hours.

Soil moisture potential determinations followed the filter paper method of Fawcett and Collis-George (1967). Analyses were not completed until the winter of 1975-76. Periodic inspections were conducted to ensure all samples were properly sealed, hence loss of moisture was minimized.

(e) Plant Cover Estimates

Total plant cover was estimated at each of the 42 sampling stations on June 19, July 11, September 3 and September 24, 1975 to obtain a relative estimate of the competition present. Visual estimates of cover, including sown material were rated according to the following scale; 0, 1 to 5 percent, 5 to 10 percent, 10 to 25 percent, 25 to 50 percent, 50 to 75 percent or 75 percent and over. A list of all competing species also was compiled.

(f) Soil Chemistry

Soil samples were collected during May and September, 1975 for analysis of nitrate nitrogen, available phosphorous, exchangeable potassium and pH. Soil samples from each of the forty-two stations were gathered from a depth of 0 to 6 inches. All samples were air dryed and stored in dust proof bags at room temperature. All analyses were completed in dupli-

cate by the Provincial Soil Testing Laboratory during the winter months of 1975-76. A preliminary set of samples was also collected during September 1974 from stations 1 to 6, 13 to 18, 25 to 30 and 37 to 42. Analyses were as previously described.

(g) Seedling Height Measurements

On September 24, 1975, height and number of leaves were recorded for each of ten randomly chosen individuals of each species and seeding dates at all sampling stations to obtain an estimate of seedling performance. If the population was less than 10 seedlings at any station all were measured.

(h) Climatological Data

Maximum and minimum temperatures and rainfall data were obtained through the generosity of Dr. C. Shaykewich. These data were recorded from May to September 1975 on an experimental plot approximately ten miles away and were taken to be representative of the conditions in the area of the experimental site.

(i) Winter Data Measurements

During both winters snow accumulation was measured to obtain an estimate of the quantity of snow held at the different levels of the site. Data from twenty-four stations were gathered during November, January, March and April, 1974-75 and from forty-two stations during October, January and February, 1975-76. Stakes with marked increments were driven into the ground at each sampling station to facilitate snow measurement.

During the winter of 1975-76 air, snow and soil temperatures were measured to obtain an estimate of the temperature variation at six stations on the experimental site. Stations 3, 9, 15, 21 and 26 were chosen to be representative of different elevations on the site. Thermo couples

were installed at seven levels; +60"; +30"; +6"; 0'; -1"; -3" and -5" during September 1975. Snow accumulation was recorded at each sampling station. Sampling dates were October 29, 1975 and February 13, 1976.

(j) Seasonal Population Measurements

Forty-two locations on the hill were designated as sampling stations to monitor population fluctuations (Figure 1). The number of seedlings at each station was recorded for a ten foot section of each row. Using the station as a reference point 5 feet were measured up the hill as well as down the hill to obtain the ten foot overall length. Frequency of seedling counts was greatest during the first six weeks of the growing season. Seedling counts were conducted June 11, June 19, June 24, July 1, July 11, July 21, July 30, August 14, September 3 and September 24, 1975. On June 4, 1976 spring survival was estimated. Counting procedures were as previously described.

Throughout the sampling season erosion played an important role in plant survival since many washouts occurred. Because of this, seedlings in the selected ten foot section of each row could not always be counted. If a damaged row was encountered the undamaged distance was recorded and the seedling count later corrected to the standard row length.

The converse of erosion, burial also was observed. Seedlings on the lower portion of the hill were subject to soil deposition. Plants lost due to burial were recorded as dead..

RESULTS AND DISCUSSION

I. Preliminary Emergence Study

(a) Prunus virginiana melanocarpa

Interpretation of the data in Tables 3 and 4 indicates that after-ripening at 20°C and 4°C was beneficial to stimulate germination of seed that had been stored dry or moist from the time of harvest. Fifteen days at 20°C if followed by a 4°C period enhanced germination in both cases. The apparent need for a 20°C treatment is not as significant for seed that was stored moist prior to treatment (Table 4). The moist stored seed possibly after-ripened during the 4°C storage period.

As the 20°C treatment duration increased, the response to increasing 4°C treatments remained relatively constant. After the 15 days at 20°C and 150 days at 4°C treatments, emergence percentages were stable. Emergence of the radicle was noted in samples that were in 4°C treatment for greater than ninety days.

Seedlings also emerged during the 20°C treatment. This was most pronounced in seed stored moist from the time of harvest where an average of 6 percent occurred. A small proportion of seeds which were stored in a moist condition after-ripened during the storage treatment. This is exemplified in Table 4. The requirement for 4°C treatment after the 20°C treatment to induce emergence was reduced. Seedlings emerged in each treatment whereas delays up to 60 to 75 days were needed to initiate emergence of seed stored in a dry condition.

Acid scarification of P. v. melanocarpa was unsatisfactory.

TABLE 3 . Percent emergence of *Prunus virginiana melanocarpa* seed stored clean and dry prior to treatment[△]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	0	0	0	1	10	12	30	40	45	42*	61*	3*	33
15	0	0	0	1	1	14	32	47	62*	89*	48*	89	82
30	0	0	0	0	4	15	36	61*	64*	72*	88	81	90
60	0	0	0	0	7	21	32*	54*	79*	91	82	91	91
90	0	0	0	1	2	29*	38*	63*	79	77	87	89	80

*Treatments in germinator when temperature rose to 26-29°C
△Germination temperature 20° ± 2°C

TABLE 4 . Percent emergence of Prunus virginiana melanocarpa seed stored clean and moist prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	18	28	36	56	65	70	52	71	77	78*	72*	1*	74
15	12	5	11	29	37	57	47	60	91*	84*	56*	88	88
30	2	16	7	11	27	27	47	62*	91*	39*	92	77	87
60	13	13	8	6	14	25	27*	66*	81*	78	88	90	95
90	5	7	8	9	10	34*	56*	59*	71	69	82	77	80

*Treatments in germinator when temperature rose to 26-29°C
[Δ]Germination temperature 20° ± 2°C

No seedlings emerged after scarification and cold stratification. The acid treatment had damaged the embryos of the seeds.

Thirty samples of seed were present in the germinator when the temperature rose to 26 to 29°C due to equipment malfunction (Tables 3 and 4). This depressed emergence in the following treatments for both moist and dry seed: Warm 0 days - cold 180 days; warm 15 days - cold 165 days and warm 30 days - cold 150 days (Tables 3 and 4). The high temperatures could have induced a secondary dormancy. Secondary dormancy was caused by high temperatures and restricted oxygen supply in Ambrosia trifida and Xanthium (Davis 1930 a,b).

(b) Cornus stolonifera

After-ripening at 4°C or in combination with 20°C failed to significantly stimulate emergence (Table 5). Highest emergence percentages were observed in the acid scarification trials in combination with 4°C and 20°C treatments (Table 7). Storing seed in a moist state had little effect on the emergence percentages compared to seed stored dry prior to treatment (Tables 5 and 6). Interpretation of the data indicates that acid scarification assisted in removal of an impermeable seed covering. Similar results have been observed in other species (Crocker 1906, Crocker 1916, Villier 1972).

Emergence of two seedlings from a single seed was observed throughout the duration of this experiment. This has increased the emergence values. Two embryos were fertilized and developed in the fruit. Rickett (1944) briefly mentioned a similar situation in his study of Cornus sp.

(c) Amelanchier alnifolia

Highest emergence percentages were observed in seed lots receiving 4°C after-ripening treatments for at least 150 days (Tables 8 and 9).

TABLE 5*. Percent emergence of Cornus stolonifera seed stored clean and dry prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	15	13	27	32	22	36	25	27	21	24*	16*	20*	34
15	0	22	33	32	62	21	20	15	21*	15*	19*	17	12
30	0	18	30	72	23	43	48	33*	25*	16*	35	12	9
60	0	10	15	63	34	36	29*	17*	23*	15	16	11	12
90	0	2	12	23	26	22*	36*	24*	49	50	8	26	9

*Treatment in germinator when temperature rose to 26-29°C

[Δ]Germination temperature 20° ± 2°C

TABLE 6 . Percent emergence of Cornus stolonifera seed stored clean and moist prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	39	25	12	11	11	26	10	19	13	5*	8*	15*	22
15	14	22	21	33	47	20	24	20	22*	15*	20*	20	15
30	8	16	14	30	20	23	25	23*	17*	15*	21	16	23
60	7	13	20	25	19	26	33*	22*	19*	18	16	16	11
90	7	18	16	10	18	35*	32*	23*	15	24	26	19	12

*Treatment in germinator when temperature rose to 26-29°C

[Δ]Germination temperature 20° ± 2°C

TABLE 7 . Percent emergence of acid scarified Cornus stolonifera seed[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)						
	0	15	30	45	60	90	120
0	0	31	49	71	73	72	64
30	*	*	90	*	*	*	*

*Insufficient seed to conduct trials
[Δ]Germination temperature 20° ± 2°C

TABLE 8 . Percent emergence of Amelanchier alnifolia seed stored clean and dry prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	0	1	4	5	7	14	26	39	40*	65*	62*	50	67
30	0	0	0	0	0	2	8	7*	17*	21*	40	39	44
60	0	0	0	0	0	1	0*	7*	32*	35	29	32	15
90	0	0	1	0	11	21*	23*	19*	35	27	32	41	36

*Treatment in germinator when temperature rose to 26-29°C

[Δ]Germination temperature 20° ± 2°C

TABLE 9 . Percent emergence of Amelanchier alnifolia seed stored clean and moist prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	7	9	6	17	24	41	42	36	31*	52*	40*	15*	37
30	2	1	6	5	5	13	9	11*	19*	49*	36	49	45
60	5	3	1	3	8	3	5*	9*	17*	21	32	38	16
90	3	8	7	4	3	5*	1*	13*	7	20	34	13	29

*Treatment in germinator when temperature rose to 26-29°C
[Δ] Germination temperature 20° ± 2°C

A 20°C treatment prior to the 4°C failed to improve emergence values. Storing seed in a moist condition prior to treatment did not prove to be beneficial (Table 9). It was observed, however, that seedlings emerged during warm treatment indicating that a small proportion of the population was not dormant or the requirements to initiate emergence were met during the moist storage period.

Acid scarification proved to be unsatisfactory. The concentrated sulfuric acid destroyed the seed in a very short period.

(d) Elaeagnus commutata

Clean, dry seed was not dormant. Seedlings emerged during 20°C after-ripening treatments. After 90 days at 20°C, 85 percent of the seeds had germinated. Emergence was very slow. After-ripening at 4°C increased the speed and capacity of emergence (Table 10). These results are in agreement with those obtained by Corns and Schraa (1962), however, these researchers did not try to germinate seeds without after-ripening. Corns and Schraa (1962) reported that an inhibiting substance was present and theorized that this reduced germination. The 4°C after-ripening treatment was required to break down this inhibiting substance.

Moist storage and acid treatment were unsatisfactory. Seed stored in a moist state decayed quite rapidly and as a result emergence was adversely affected (Table 11). The concentrated sulfuric acid destroyed the seed in an extremely short period.

(e) Prunus pensylvanica

Seedlings of this species did not emerge significantly after any treatment. Of the 6,000 seeds treated only twelve seedlings were observed. Conditions were obviously not conducive for after-ripening. Deterioration of the propagules was not apparent. Cutting tests revealed

TABLE 10. Percent emergence of Elaeagnus commutata seed stored clean and dry prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	61	77	89	95	76	84	82	88	89	83*	89*	80*	86
30	81	74	83	80	91	83	93	86	82*	84*	73*	88	88
60	84	86	91	84	86	87	86	82*	81*	83*	82	82	81
90	88	92	90	90	87	77	86*	90*	83*	82	99	80	85

*Treatment in germinator when temperature rose to 26-29°C
[Δ]Germination temperature 20° ± 2°C

TABLE 11. Percent emergence of Elaeagnus commutata seed stored clean and moist prior to treatment[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)												
	15	30	45	60	75	90	105	120	135	150	165	180	195
0	1	4	2	6	12	2	3	5	16	0*	6*	13*	8
30	56	0	6	1	16	12	43	5	37*	31*	20*	8	61
60	13	1	13	8	35	3	1	2*	31*	35*	2	7	28
90	4	45	1	1	1	4	1*	34*	1*	4	13	4	4

*Treatment present in germinator when temperature rose to 26-29°C
[Δ]Germination temperature 20° ± 2°C

that the seeds had not physically deteriorated.

II. Detailed Emergence Studies

(a) Prunus virginiana melanocarpa

Emergence of P. v. melanocarpa seed was increased by stratification at 20°C prior to 4°C stratification (Table 12). Differences between the mean percent emergence of the two different 20°C treatment periods were slight; however, 30 days at 4°C did increase mean values (Figure 2). Mean emergence values were stable after 150 days of cold stratification (Figure 2).

As indicated in earlier experiments, radicle emergence was observed during after-ripening treatments. The data in Table 13 illustrates the mean percent radicle emergence at the termination of each treatment. Root appearance was slight in those replicates not receiving 20°C treatment prior to 4°C. Emergence of the radicle increased after seeds were first after-ripened at 20°C. This was particularly apparent after seeds had received at least 150 days at 4°C following the 20°C treatment.

Interpretation of the data indicates that after-ripening at 20°C for 30 days followed by 150 days at 4°C to be the best treatment in relation to the trials conducted. Emergence of the radicle should not interfere to any large extent in direct field sowings.

Emergence of P. v. melanocarpa seed collected in 1975 did not attain the same maximums as seed tested the previous year. As all variables in terms of picking, cleaning and after-ripening method were maintained as constant as possible, variation due to season or year of collection is a possible source of the variability observed.

The nylon package experiment, comparing packaged versus non-packaged seed was terminated prematurally. Seeds and seedlings in both treatments

TABLE 12. Mean* percent emergence of Prunus virginiana melanocarpa seed after different after-ripening sequences[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)						
	105	120	135	150	165	180	195
0	3.75	6.75	7.00	9.50	6.50	9.50	6.25
15	13.00	21.25	24.00	34.50	34.80	32.30	34.80
30	12.80	25.80	41.00	45.80	46.00	46.50	46.80

*Means of 4 replicates of 100 seeds each
[Δ]Germination temperature 20° ± 2°C

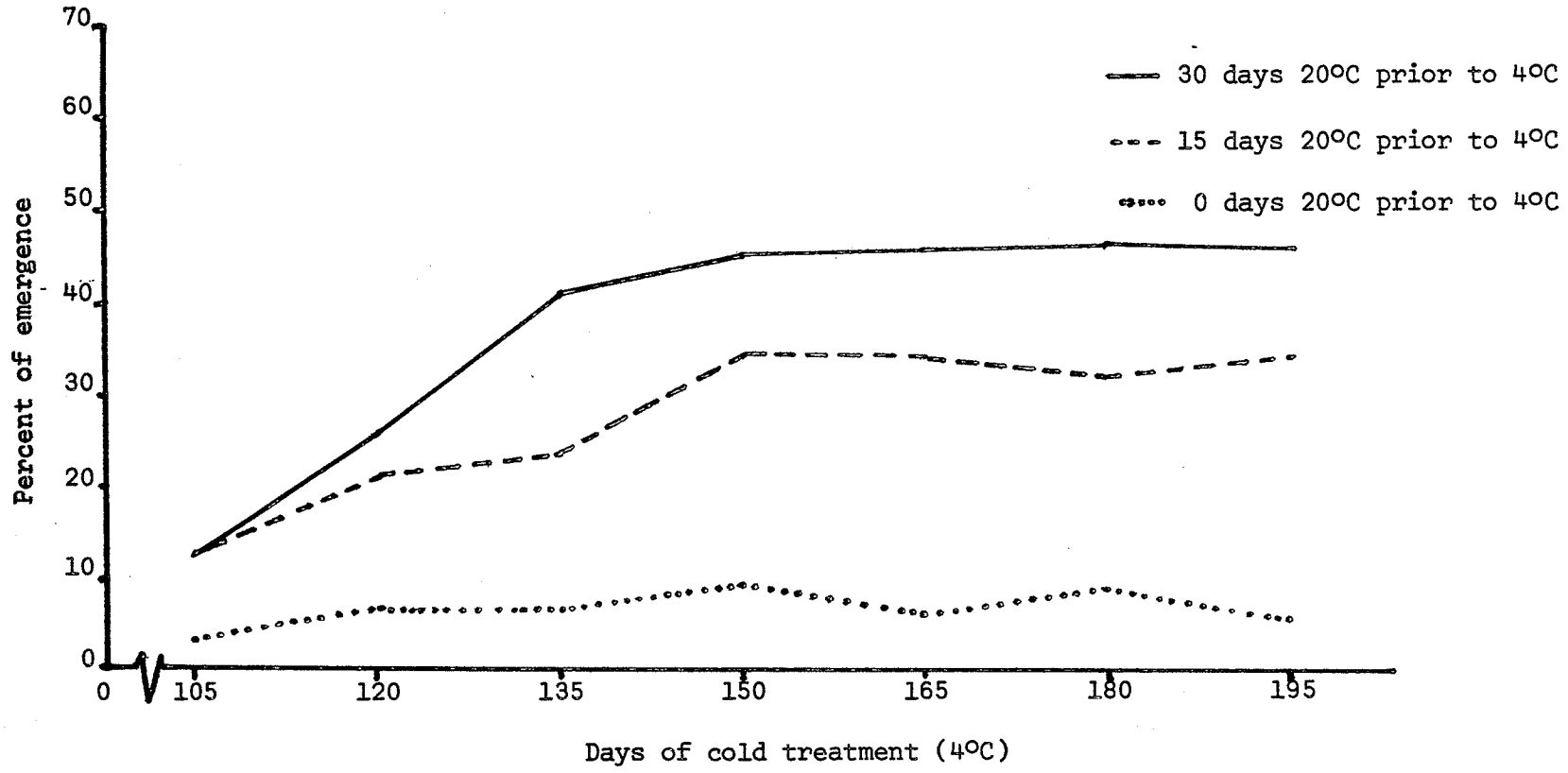


Figure 2. Mean percent emergence of Prunus virginiana melanocarpa seed at 20°C

TABLE 13. Mean* percent radicle emergence of Prunus virginiana melanocarpa after 4°C treatment**

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)						
	105	120	135	150	165	180	195
0	0	0	1.5	3.0	2.5	7.5	5.0
15	0	1	3.0	9.5	17.5	22.0	32.5
30	0	0	3.3	6.3	19.3	32.3	41.3

*Means of 4 replicates of 100 seeds each
**Counts conducted upon termination of cold treatment

were attacked by fungi which caused substantial mortality. Results were not indicative of expected values as only 2 to 5 seedlings emerged in any treatment.

(b) Cornus stolonifera

As illustrated in Table 14 acid scarification in combination with 20°C and 4°C after-ripening increased emergence. Emergence was lower if 20°C treatments were not conducted prior to the 4°C period.

Little difference was evident between the two different durations of warm treatment; however, in all but one trial a 20°C treatment for thirty days was most beneficial (Figure 3).

Emergence of seedlings was lower than those reported for earlier exploratory trials. Variation of seed handling technique was minimal. All seed was treated as it was the previous year. Dormancy strength as was found with P. v. melanocarpa must vary between growing seasons. Environmental factors may affect the strength of dormancy.

Emergence of C. stolonifera was not affected by after-ripening in nylon packages (Table 15). A "T" test revealed that there was not a significant difference between the two trials. The nylon material did not influence the after-ripening of the seed.

III. Field Studies

(a) Soil Moisture

The distribution of soil moisture was uneven. The upper half of the hill definitely was dryer than the lower portions (Table 16). Localized wet spots occurred as well. Stations 7, 8, 33 and 41 all remained moist throughout the season as the soil moisture potential did not drop below the permanent wilting point during the experimental period. These localized wet spots were due to lateral drainage or springs. All remaining

TABLE 14. Mean* percent emergence of scarified** Cornus stolonifera seed after different after-ripening sequences[Δ]

Days of Warm Treatment (20°C) Prior to Cold Treatment	Days of Cold Treatment (4°C)						
	15	30	45	60	90	120	150
0	4.50	14.25	21.0	31.5	36.8	35.8	29.8
15	28.80	43.50	56.3	59.0	57.5	53.0	43.0
30	39.25	49.00	61.3	65.0	56.8	57.5	54.8

*Means of 4 replicate samples of 100 seed each
**25-30 minutes in constantly stirred conc. H_2SO_4
[Δ] Germination temperature 20° ± 2°C

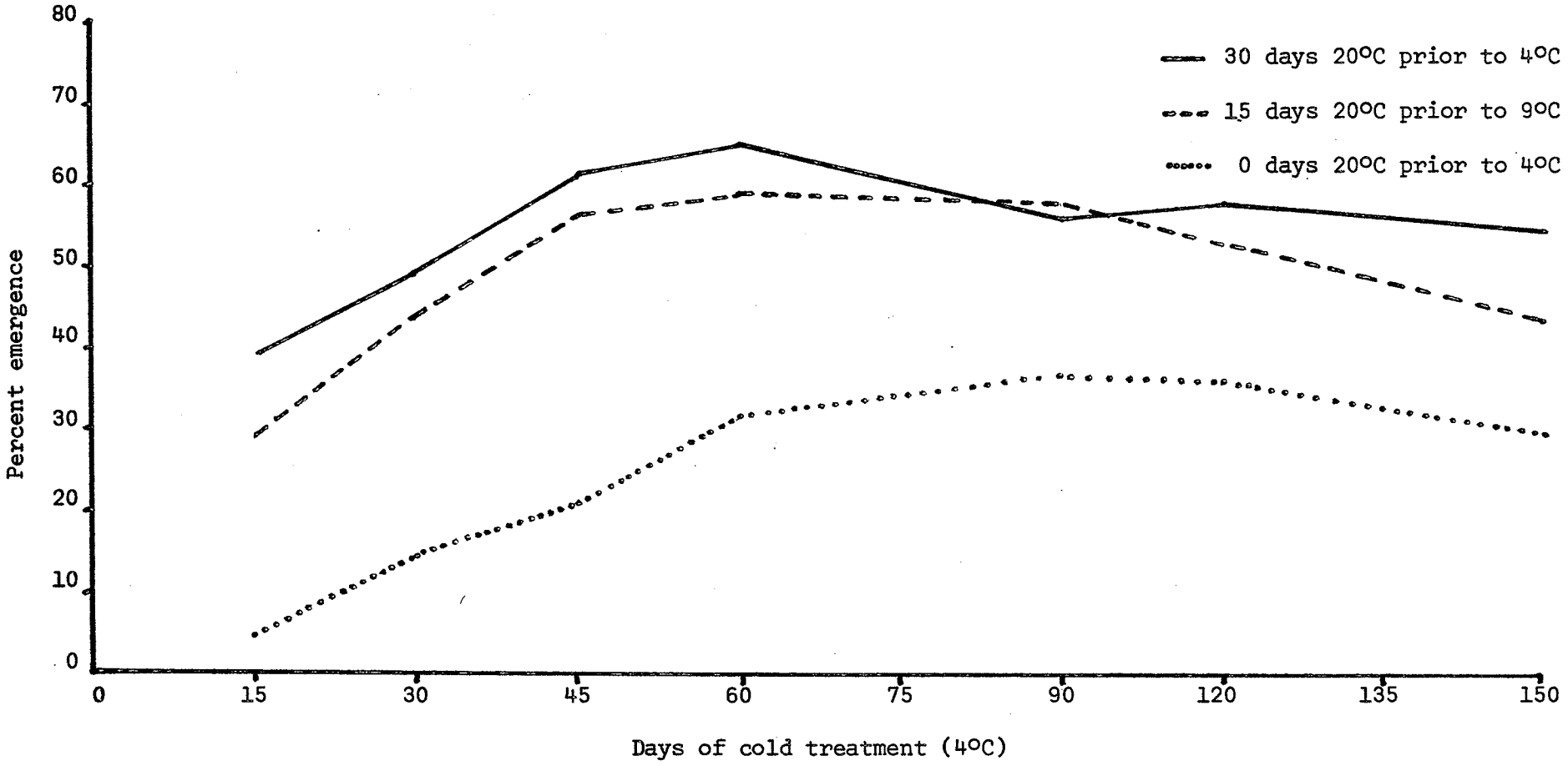


Figure 3. Mean percent emergence of scarified Cornus stolonifera seed at 20°C

TABLE 15. Effect of nylon packaging during after-ripening on emergence of scarified Cornus stolonifera

Rep.	Nylon Package	No Package
1	23	27
2	27	23
3	14	17
4	23	24
5	23	26
6	22	21
7	19	25
8	36	26
9	20	16
10	15	19
11	12	21
12	21	21
13	10	23
14	14	29
15	25	35
Mean	20.27	23.53

"T" test - no significant difference at "T" .01
*25-30 minutes in constantly stirred conc. H_2SO_4
**Moist turface at 4°C for 63 days

TABLE 16. Mean* soil moisture potentials at different elevations throughout the season (Bars)

Station Numbers	Sampling Date								
	June 1	June 11	June 19	June 24	July 2	July 11	July 21	August 14	September 24
1 - 6	-7.3	-1.3	-4.3	-11.6	-22.8	-51.5	-3.3	-4.1	-6.4
7 - 12	-4.9	-0.7	-4.7	- 7.2	-10.8	-26.6	-2.5	-3.2	-4.2
13 - 18	-7.1	-0.4	-4.7	-15.7	-13.1	-36.2	-3.0	-3.8	-4.0
19 - 24	-4.0	-0.5	-5.7	-12.7	-16.0	-29.1	-3.2	-4.4	-3.1
25 - 30	-8.9	-0.5	-5.6	-12.5	-16.2	-53.9	-6.3	-1.8	-2.3
31 - 36	-5.2	-0.4	-4.1	-11.1	-10.1	-27.1	-2.1	-1.0	-1.4
37 - 42	-4.8	-0.6	-6.5	-10.9	-17.7	-18.9	-2.3	-3.2	-1.6
Mean Total	-6.0	-0.6	-5.1	-11.7	-15.2	-34.7	-3.2	-3.1	-3.3

*Mean of six sampling stations at each level

stations experienced droughty conditions at least at one sampling time during the summer. As illustrated in Table 16, moisture was generally unavailable for plant growth during the first two to three weeks in July. Although the method of measurement used, after Fawcett and Collis-George (1967), is subject to errors and the sampling times were not as frequent as desired, the measurements provided a useful estimate of water potential throughout the season. The values obtained are not discontinuous with the rainfall data presented in Appendix 5. Maximum and minimum temperatures are also presented in Appendix 5.

Soil water potential days were used in the regression analysis. These values were obtained by calculating the area under the curve constructed by plotting the water potentials of each location throughout the summer. Thus a high value indicates a dry location while a low one would be wet.

The variability observed in the data was large. Precipitation was assumed to be equal on the plot. Water ran off the plot at unequal rates. With a slope of 31 percent water movement was very rapid. The upper portion of the hill drained and dried much faster than the lower ones. Soil particle size also affected the soil moisture potential. As the soil was coarser on the upper elevations due to erosion, water retention was considerably less.

Such variability in soil moisture measurements is not uncommon, particularly when dealing with samples obtained from a depth of 0 to 6 inches. Lesko, Etter and Dillon (1975) found that germination of seeded species on coal mine spoils in Alberta was much more successful on depressional microsites due to the increased availability of moisture. Brown (1973) on the other hand found significant variation in soil moisture on different aspects of slopes but on one particular aspect variation in the 0 to 6 inch zone

was less than that observed in the 6 to 12 inch zone. Rainfall was above average during this study.

Moisture gradients were reported by Arnott (1973) to have strongly influenced survival of direct seeded Pinus sp. and Picea sp. Survival was greatest on mineral soil having an adequate supply of moisture.

(b) Soil Movement

Due to the nature of the terrain, soil movement must be considered as a factor affecting plant growth and survival. Soil particles moved predominantly by water caused either erosion on the upper areas of the hill or burial of the lower portions. Wind-induced soil movement was not observed during the investigation season.

Sheet and rill erosion caused the dislodgement of individual plants. Gully formation had started well before the end of the growing season. Several very heavy thunderstorms were the principal cause.

Transplanting of seedlings was observed. Plants were found growing in between the seeded rows and groups of seedlings were observed to be crowded together. Some seedlings, although not removed, were washed by the water and thus placed under stress due to unearthing of their roots. P. v. melanocarpa was able to withstand severe washing and still survive, while C. stolonifera was not as tolerant of such action. In some instances parts of a row were completely washed out, hence corrections by measuring the remaining row distance were made when recording the number of plants.

Burial of seedlings also took place. Stations 30 to 42 were affected most severely. In some instances seven cm of soil were deposited. The effect of soil deposition could not be corrected since measurements of row length or plant loss could not be made directly. Burial acted slowly in most cases, with gradual deposition of soil throughout the season. Hence

if seedlings expired due to burial they could not be distinguished from those that died due to the rigors of the environment. The measurement of plant height at these stations was also subject to error as seedling height was falsely reduced. In some instances only 2 to 4 leaves were observable. Adventitious rooting was observed in C. stolonifera plants.

(c) Plant Cover Estimates

Competition by weedy species proved to be an influential factor affecting plant growth and survival. Competition reduced the vigour of the seedling by absorption of valuable soil moisture, intercepting sunlight and utilization of soil nutrients.

As the site had been summerfallowed for the year previous to experimentation, the competing vegetation developed during the investigation period. The distribution of competing species was not even (Table 17). Weeds were taller and more numerous on the lower portion of the hill as well as on localized wet spots. Cover percentages were low on sites that were dry and exposed. The distribution of the competing species appeared to follow a moisture regime. A list of the major competing species is presented in Appendix 3.

The presence of competition has resulted in similar situations in other studies. For example, Brown (1973) found that a light herbaceous cover had drastic effects on germination and mortality of Robinia pseudoacacia. Germination and the number of trees living at the end of the study period were eight times greater on graded sites having no herbaceous cover than on similar areas having a light cover of Bromus sp.

Other studies in relation to direct seeding in forestry operations have shown that competition can significantly reduce the survival of seedlings (Sowers 1965, Johnson 1973, Arnott 1973).

TABLE 17. Mean plant cover percentages at different elevations throughout the sampling season

Station Number	Sampling Date			
	June 19	July 11	Sept. 4	Sept. 24
1-6	1.25	3.75	8.8	8.8
7-12	7.9	13.8	23.3	20.0
13-18	2.5	7.9	9.2	9.2
19-24	27.9	35.8	44.2	42.5
25-30	14.2	62.5	70.8	70.8
31-36	19.2	58.3	75.0	75.0
37-42	38.3	75.0	83.3	83.3

(d) Soil Chemistry

1) Nitrate-Nitrogen. There was a loss of nitrogen on the experimental site throughout the duration of the experiment (Table 18). Values were highest in the fall of 1974 and lowest in the fall of 1975.

The lower portions of the hill had greater losses of nitrate-nitrogen than the top. The losses of nitrogen on the top of the hill were constant yet proportionately less than those seen at the bottom. Initially the lower areas of the hill had a greater concentration, yet by the fall of 1975, this was reversed. The considerably higher density of plants could account for the greater nitrate-nitrogen loss. As was previously noted the vegetation present on the top of the hill was very sparse. Plant utilization of nitrogen would therefore be low.

Complete nitrate-nitrogen depletion was not recorded. Nitrogen was available at all stations at all sampling times.

Nitrate-nitrogen availability in relation to direct seeding was reported by Stermitz, Klages and Lotan (1974). They found a significant negative relationship between survival of Pinus radiata and nitrate-nitrogen levels in Montana. As survival increased nitrogen levels decreased. The authors stated that nitrogen is a measure of organic matter in the soil. A high nitrate level corresponds to high organic matter levels. The negative relationship was probably due to poor seed-to-soil contact on sites with high organic accumulation. Such a relationship in this study did not appear to exist.

2) Phosphorous. An elevational gradient is present for the data presented on the analysis of available phosphorous (Table 19). The top of the hill has 10-15 ppm less phosphorous than the bottom. Erosion was the probable cause of this gradient.

TABLE 18. Mean* nitrate-nitrogen levels through time (ppm)

Station Number	Sampling Date		
	Fall 1974	Spring 1975	Fall 1975
1 - 6	3.7	2.9	2.5
7 - 12	-	2.8	2.3
13 - 18	5.3	3.3	1.8
19 - 24	-	4.7	1.6
25 - 30	11.2	4.7	1.5
31 - 36	-	4.2	1.2
37 - 42	14.9	4.2	1.3

*Mean of six sampling stations at each level

TABLE 19. Mean* available phosphorous (ppm) through time

Station Number	Sampling Date		
	Fall 1974	Spring 1975	Fall 1975
1 - 6	11.8	15.6	12.3
7 - 12	-	21.6	16.8
13 - 18	17.4	19.0	15.0
19 - 24	-	22.0	17.6
25 - 30	22.6	23.4	19.0
31 - 36	-	29.4	21.2
37 - 42	34.6	28.8	24.5

*Mean of six sampling stations at each level

There were seasonal changes in this nutrient as well. From Fall 1974 to Spring 1975 there was an increase while from Spring 1975 to Fall 1975 there was a decrease in phosphorous levels. The increase possibly represents a breakdown of organic matter thus increasing the nutrient level. The decline of phosphorous during the growing season may delineate the plant uptake and erosion losses. Phosphorous was available throughout the whole season.

3) Potassium. The mean values of the potassium determinations are presented in Table 20. All values were high. The seasonal and elevational changes are small. Potassium levels as recorded were far above deficiency levels thus should not have a major influence on plant growth.

4) pH Levels. Seasonal changes in the hydrogen ion activity are illustrated in Table 21. There was a gradual decline of values during the sampling period. The upper portions of the hill were definitely more acidic than the lower levels. In all likelihood erosion unearthed more acidic soil as the subsoil in this area is naturally acidic (Ehrlich et al 1958).

Precipitation could contribute to the pH reduction since leaching can remove exchangeable bases from the soil colloids. As the soil is coarse in texture, leaching could be quite significant.

Increases in acidity may also be caused by soil microorganisms and acidic plant exudates (Buckman and Brady 1969). As the vegetation was extremely sparse at the higher elevations exudates cannot be implicated in the acidity activity changes. The Wapus-Clarkesville association is characteristically low in organic matter (Ehrlich et al 1958). The upper levels of the hill also have been severely eroded hence organic matter levels lower. There is little material for soil microorganisms to live

TABLE 20. Mean* available potassium (ppm) through time

Station Number	Sampling Date		
	Fall 1974	Spring 1975	Fall 1975
1 - 6	512.3	598.3	602.3
7 - 12	-	659.1	656.5
13 - 18	599.8	676.0	691.0
19 - 24	-	685.3	659.5
25 - 30	595.0	630.8	632.3
31 - 36	-	665.3	669.3
37 - 42	696.2	695.5	695.1

*Mean of six sampling stations at each level

TABLE 21. Mean* pH through time

Station Number	Sampling Date		
	Fall 1974	Spring 1975	Fall 1975
1 - 6	6.6	6.3	6.2
7 - 12	-	6.5	6.2
13 - 18	6.7	6.4	6.4
19 - 24	-	6.9	6.7
25 - 30	7.4	7.1	7.0
31 - 36	-	7.2	7.0
37 - 42	7.5	7.2	7.1

*Mean of six sampling stations at each level

on, hence these probably did not contribute to the pH changes.

5) Other Elements. Copper, manganese and sulfur were also measured at all locations. This data is presented in Appendix 4. All values were above deficiency levels. Little variation was observed between sampling stations. These nutrients were not expected to play a significant role in survival and growth of the seeded species.

(e) Seedling Height

The height of the seedlings was used as an indicator of performance. Elevational means of mean plant height at each station are presented in Table 22. Interpretation of this data indicates that C. stolonifera outperformed P. v. melanocarpa. The fall sown C. stolonifera grew the tallest during the planting season. This planting was the earliest to emerge, consequently, had a longer growing season. Both the fall and spring sown C. stolonifera grew taller at higher elevations, where competition was less. The spring sown P. v. melanocarpa was the smallest of all plantings. The seedlings grew larger at the middle elevations where more moisture was present; however, competition was also greater.

The use of plant height as a performance indicator was subject to many errors. The differential germination and emergence rates, most pronounced in the fall sown trial caused considerable variation within the recorded values. Seedlings that emerged late in the year were obviously much smaller than those that emerged first. The burial of seedlings at the bottom of the hill resulted in many individuals, when measured, to be much smaller than they actually were.

The number of leaves of each plant sampled was recorded. The variation was high. Environmental factors such as wind, erosion and insects damaged, destroyed and removed leaves from the plants. The increases of

TABLE 22. Mean* seedling height (mm)**

Station Number	Seeding Date and Species		
	Spring Sown *P. v. melanocarpa*	Fall Sown *C. stolonifera*	Spring Sown *C. stolonifera*
1 - 6	25.9	50.0	35.6
7 - 12	33.3	49.4	35.2
13 - 18	30.0	42.1	35.1
19 - 24	39.1	39.5	30.8
25 - 30	21.9	30.4	28.2
31 - 36	16.0	18.5	23.7
37 - 42	14.2	26.3	21.4
Overall Mean	25.8	36.6	30.0

*Means of 10 individuals at each of six sampling stations at each level.

**Measured September 24, 1975

variability were not warranted and the data were not included in analysis.

When competition was low, taller and healthier seedlings were observed. If competition was high, plant performance was adversely affected. On the other hand, if competition was completely absent, seedlings suffered due to exposure. Similar results were reported by Brown (1973). He found that the presence of some vegetation helped to protect young seedlings.

Root development, although not measured was excellent. Roots at least 15 cm long had been developed by all trials. Seedlings were well established by September 1975.

(f) Winter Data

Data obtained during two winters are presented in Tables 23 and 24. Very little snow accumulated on the upper levels of the hill. Wind effectively removed it. The depth of cover increased where vegetation was present and towards the bottom of the hill.

Snow accumulation was greater during 1975-76 than 1974-75; the presence of increased amounts of vegetation contributed to this.

As the experimental site was quite exposed, the snow was packed into hard drifts.

The snow did provide insulation as illustrated by the data in Table 24. Soil temperatures were warmer at snow covered stations. Snow cover assists in protecting the seedlings from winter desiccation (Schopmeyer 1974).

(g) Seasonal Population Fluctuations

Fall and spring sown C. stolonifera and spring sown P. v. melanocarpa emerged on the experimental site. Fall sown P. v. melanocarpa did not emerge.

Fall sown C. stolonifera emerged earliest. Seedlings were first re-

TABLE 23. Mean* snow accumulation** during two winters

Station Number	Nov. 1974	Jan. 1975	Mar. 1975	April 1975	Oct. 1975	Jan. 1976	Feb. 1976
1 - 6	0	0	0	0	0	1.3	0.9
7 - 12	-	-	-	-	0	8.9	12.3
13 - 18	0	0	4.1	0	0	18.2	22.4
19 - 24	-	-	-	-	0	24.1	38.5
25 - 30	0	5.1	26.7	18.3	0	30.5	48.3
31 - 36	-	-	-	-	0	28.8	43.6
37 - 42	0	4.5	6.2	8.0	0	27.7	26.7

*Mean of six sampling stations at each level
**Centimeters

TABLE 24. Snow, soil and air temperatures (°C)

A) Sampling Date - October 29, 1975*

Depth of Reading	Position on Slope					
	Top		Middle		Bottom	
	1	2	3	4	5	6
- 5"	1.6	0.4	1.8	1.1	1.7	1.7
- 3"	1.7	0.1	1.4	0.8	0.7	0.7
- 1"	2.5	0.7	1.8	1.0	2.4	0.5
0	3.0	1.5	2.6	1.7	1.1	0.5
+ 6"	6.4	3.7	4.8	2.8	1.0	1.2
+ 30"	5.2	3.7	4.4	3.1	2.7	2.2
+ 60"	6.2	4.9	4.4	3.0	3.1	2.8

*No snow present

B) Sampling Date - February 13, 1976

Depth of Reading	Position on Slope					
	Top		Middle		Bottom	
	1	2	3	4	5	6
- 5"	- 9.8	-8.7	-5.0	- 4.0	-0.6	- 2.2
- 3"	-10.0	-8.6	-5.1	- 4.4	-1.0	- 2.3
- 1"	- 8.2	-9.4	-6.0	- 4.6	-1.9	- 3.4
0	- 6.8	-9.4	-8.2	- 5.0	-2.0	- 5.0
+ 6"	- 7.4	-9.2	-7.2	- 9.1	-6.2	-10.8
+ 30"	- 8.0	-7.9	-8.8	-10.0	-8.8	- 5.5
+ 60"	- 9.0	-7.4	-9.6	-11.2	-9.8	-11.4
Depth of Snow (cm)	0	10.0	17.5	35.0	40.0	27.5

corded on June 11, 1975 (Table 25, Figure 4). By June 24, 1975 the population maximum had been reached. Very few population fluctuations occurred during the remainder of the season. The total number of seedlings remained relatively constant. It should be noted, however, that new seedlings were noted emerging and dieing until late July since emergence was not uniform.

Spring sown C. stolonifera was the latest sowing to emerge. Seedlings were not observed or recorded until June 24, 1975 (Table 25). The population maximum was reached one week later on July 1, 1975. Following this peak a decline in the number of seedlings was observed and continued until July 21, 1975. Thereafter the population remained relatively stable.

Similar types of population fluctuations were reported by Brown (1973). After early May seeding of Pinus rigida germination and emergence was excellent (90%). By mid June the population had declined to 65 percent and declined 5 percent more by September.

Cool wet weather ensued the June 1, 1975 sowing date (Appendix 5). This contributed to the delay in emergence of the seedlings. The loss of individuals recorded from July 1 to July 21, 1975 corresponded to moisture deficiency (Table 16). Due to later emergence, this planting was not fully established when the moisture deficit occurred. This contrasts with early emergence of the fall sown C. stolonifera which enabled better survival through the dry period.

Emergence of spring sown P. v. melanocarpa was first recorded on June 19, 1975 (Table 25). The peak number of individuals was recorded six days later on June 24, 1975. This was followed by a decline of the population which terminated on July 21, 1975. Thereafter, the population remained relatively constant (Figure 4).

As observed in the laboratory emergence trials of P. v. melanocarpa

TABLE 25. Mean* percent survival through time

Species and Reading Time	Sampling Times										
	1975										1976
	June 11	June 19	June 24	July 1	July 11	July 21	July 30	August 14	September 3	September 24	June 24
Fall seeded *C. stolonifera*	21.1	33.6	34.4	33.3	33.2	35.8	36.4	35.7	34.5	33.2	17.0
Spring seeded *C. stolonifera*	-	-	30.0	59.0	48.5	41.3	41.5	42.1	42.4	40.5	20.4
Spring seeded *P. v. melanocarpa*	-	45.0	56.7	52.3	46.7	44.7	47.0	45.7	41.0	39.3	37.3
Fall seeded *P. v. melanocarpa*	-	-	-	-	-	-	-	-	-	-	1.8

*Mean survival at 42 sampling sites

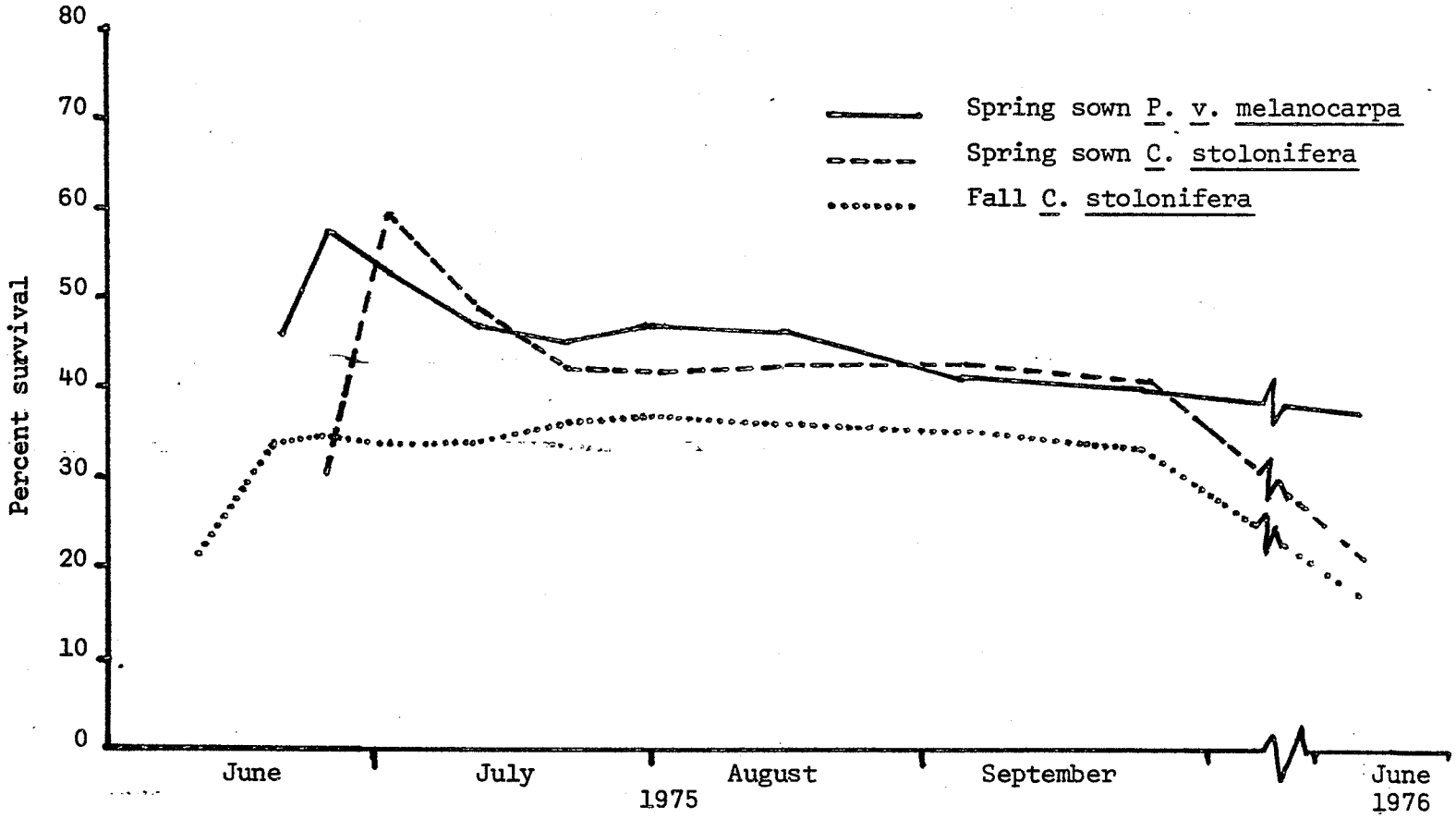


Figure 4. Mean percent survival through time

radicle growth did occur during after-ripening. This also was noted in seeds prior to spring sowing. Thus the decline of the P. v. melanocarpa population before the moisture deficit may have been caused by damage of the young roots during sowing. During the period June 24 to July 2, 1975, warm temperatures were reported (Appendix 5). The soil was drying quickly (Table 16), hence seed or seedlings near the surface would be under considerable stress. Moisture and heat stress have caused considerable mortality in direct seed trials (Brown 1973, Arnott 1973).

It should be noted, however, that P. v. melanocarpa became established and survived better than spring sown C. stolonifera. The latter exhibited larger losses during the drought. This was possibly caused by later emergence.

Fall sown P. v. melanocarpa did not emerge. Approximately six seedlings were observed during the entire sampling season. The after-ripening requirements for the seed were not met. As observed in the laboratory study, P. v. melanocarpa emergence was higher if the seeds received a 20°C treatment prior to 4°C. Due to the late sowing date (October 15, 16, 1974), it is probable that the seed did not receive this desirable warm period. This contributed to the poor results of this trial. Lesko, Etter & Dillon (1975) recommended against direct seeding of woody plants. The seeds failed to emerge, however no concrete reasons for this failure were provided; improper seeding dates were suspect.

Survival of all trials declined during August and early September (Figure 4). In this time period over ten inches of precipitation fell, predominantly during four heavy thundershowers (Appendix 4). Erosion or soil deposition were very noticeable at many locations. It is probable that this factor contributed to the decline of populations.

During the winter of 1975-1976, spring and fall sown C. stolonifera suffered significant losses of plants. Almost 50 percent of both plantings were lost (Table 25). In both cases losses were greatest at locations which did not have snow cover during the winter (Table 23) and those that were under heavy competition the previous year (Table 17). The snow provided beneficial protection while competition reduced the vigour of the seedlings.

Over winter only 10 percent of spring sown P. v. melanocarpa seedlings were lost (Table 25). Emergence of new seedlings was also observed. P. v. melanocarpa was better able to withstand the rigours of the environment.

Fall sown P. v. melanocarpa emerged sporatically at many locations during the second year as observed during June, 1976. A total of ninety-two individuals or 1.8 percent were observed (Table 25), a small proportion of those planted yet considering the events of the previous two winters and one summer, a significant amount. The after-ripening and germination requirements were at least partially met.

Winter mortality in direct seeded trials has been poorly studied. Few researchers have reported on second year survival. Brown (1973) found winter survival to be variable but primarily associated with the exposure and aspect of the site. Survival was best on northeast slopes having a slight amount of cover present.

IV. Statistical Analysis

(a) Correlation Analysis

A matrix of correlation values are presented in Table 26. All independent variables and dependent variables were correlated against each other in an attempt to find linear relationships among them. In total,

TABLE 26. Correlation matrix of independent and dependent variables

	Moisture Potential	% Cover	pH	Nitrate-Nitrogen	Phosphorous	Potassium	Elevation	Snow Accumulation	Fall Seeded C. stolonifera - Survival	- Height	- Emergence Maximum	- Spring Survival	Spring Seeded C. stolonifera - Survival	- Height	- Emergence Maximum	- Spring Survival	Spring Seeded P. v. melanocarpa - Survival	- Height	- Emergence Maximum	- Spring Survival
Moisture Potential		+.36*	+.26	-.07	+.45**	+.30*	-.30*	+.09	+.27	-.26	+.35*	-.05	-.18	-.25	+.13	+.02	-.36*	-.09	-.17	-.05
% Cover			+.84**	-.26	+.70**	+.18	-.80**	+.52**	-.23	+.60**	+.42**	.07	-.26	-.40**	+.16	-.08	-.38*	.27	.03	-.21
pH				-.26	+.72**	+.19	-.77**	+.62**	+.26	-.47**	+.41**	+.01	-.18	-.41**	+.18	+.06	-.36*	-.22	-.08	-.03
Nitrate-Nitrogen					-.12	-.28	+.62**	-.52**	+.12	+.43**	-.03	+.30*	+.50**	+.23	-.11	+.32*	-.03	+.32*	-.37*	+.04
Phosphorous						+.26	-.57**	+.31*	+.25	-.31*	+.32*	+.08	-.16	-.60**	+.06	-.01	+.25	-.15	-.03	+.04
Potassium							-.37*	+.21	+.03	-.21	+.14	0	-.31*	-.23	+.26	-.21	-.02	-.19	+.22	+.02
Elevation								-.75**	-.11	+.70**	-.34*	+.23	+.41**	+.49**	-.22	-.14	+.42**	+.43**	-.07	+.24
Snow Accumulation									+.36*	-.50**	+.44**	+.06	+.22	-.48**	+.24	0	-.23	+.17	+.62**	+.03
Fall Seeded C. stolonifera - Survival										-.01	+.89**	+.70**								
- Height											-.22	+.20								
- Emergence Maximum												+.52**								
- Spring Survival																				
Spring Seeded C. stolonifera - Survival														+.35*	+.41**	+.73**				
- Height															-.03	+.29				
- Emergence Maximum																+.35*				
- Spring Survival																				
Spring Seeded P. v. melanocarpa - Survival																		+.43**	+.59**	+.68**
- Height																			+.02	+.54**
- Emergence Maximum																				+.41**
- Spring Survival																				

. = 5% level significance

.. = 1% level significance

138 correlations were tried. Of these a total of 40 were significant at the 1% level and an additional 12 were significant at the 5% level.

Interpretation of these results is difficult as there are many factors interrelated. The slope presents an elevational complex gradient even though the vertical rise was just over fifty feet. The parameters measured as well as the response of the plants to this environment reflected these developments.

All of the eight independent variables measured during the experiment were significantly correlated to the elevation of the site. Thus much of the variation observed was predictable in a linear fashion in relation to the elevation of the sampling station. With increases in elevation there were corresponding increases in nitrate-nitrogen levels and decreases in percent cover, pH, phosphorous, potassium, snow accumulation and water potential (increasing dryness).

The relationships between pH, percent cover, available phosphorous and elevation were particularly strong. With an increase in elevation there were significant increases in pH, available phosphorous and percent cover. It would appear that cover percentages may be responding to a gradient relating to pH and phosphorous which in itself was imposed on the elevation of the slope.

Elevation played a significant role in investigating the response of the seeding trials. A significant negative relationship was found between elevation and the emergence maximum of fall sown C. stolonifera. Positive correlations between elevation of the station and the height of fall sown C. stolonifera, survival and height of spring sown C. stolonifera and the survival and height of spring sown P. v. melanocarpa. It is interesting to note that the seedling responded in this manner. They grew and sur-

vived better on the higher elevations of the slope where conditions as discussed earlier were harsher.

The amount of moisture available for plant growth affected the seeding trials. The emergence maximum for fall sown C. stolonifera was negatively correlated indicating that germination was increased on moist sites. The survival of spring sown P. v. melanocarpa was related as well but positively. Survival was greater on drier sites. P. v. melanocarpa is better adapted to xeric locations (Smith 1974). It is hypothesized that if moisture was available for plant growth it did not affect the survival pattern. However, if moisture was unavailable, as illustrated during the July drought the effect is highly significant. Moisture did not affect the majority of the plantings until it was a limiting factor. If not limiting, the effects of the other factors overroad the moisture response curve. A more detailed study would be required to determine the response of the species to different moisture regimes.

It should be noted that the emergence maximums of each trial were significantly correlated with the survival of the plants in the fall. Thus the losses that occurred due to erosion and burial were not sporadic in their influence. Fall survival was predictable knowing the emergence maximums.

The 1976 spring survival of the seeding trials was not correlated with any of the independent variables of the previous season with the exception of fall sown C. stolonifera and nitrate-nitrogen (Table 26). The major relationships involved the emergence maximum, fall survival and performance of the individual species and seeding dates. Thus, after the seedlings were established for one growing season, the effects of the independent variables were reduced when considering the 1976 spring survival.

Correlation analysis yielded many significant relations; however, due to the complex nature of the gradients involved it falls short in building an understanding of the overall study. Multiple linear regression analysis was employed to further study the complex relationships.

(b) Multiple Linear Regression

Results of multiple regression analysis yielded statistically significant models in all but one case. All attempts to generate a significant model for fall survival of fall sown C. stolonifera were unsuccessful.

In general, the coefficients of determination were low which indicates that the predictive abilities of the model are low. Hence, although the models formulated explain a statistically significant amount of the variation recorded, use of the lines in forecasting plant responses are restricted. The models generated are only applicable to the site and time period under study.

1) Fall Survival. Results of multiple regression yielded the following model for the fall survival of spring sown P. v. melanocarpa:

y = -9.6688 + 0.066 water potential days + 0.0408 percent cover - 1.1889 pH - 4.4746 [nitrate-nitrogen] + .3210 [phosphorous] - 0.0053 [potassium] + 0.3645 elevation (significant at the 5 percent level). The coefficient of determination was found to be 35.13 percent. The standard partial regression coefficients are presented in Table 27. Elevation of the slope proved to be the most influential factor.

Analysis of data for fall survival of spring sown C. stolonifera provided the following model:

y = 17.3227 + 0.0037 water potential days - 0.1202 percent cover + 6.7036 pH + 9.8908 [nitrate-nitrogen] + 0.0217 [phosphorous] - 0.0635 [potassium] (significant at 5 percent level).

TABLE 27. Standard partial regression coefficients of fall survival of spring sown P. v. melanocarpa

Variable	Coefficient
Elevation	0.8471
Water potential days	0.2843
Phosphorous	0.2335
Percent cover	0.1889
pH	0.0722
Nitrate-nitrogen	0.04661
Potassium	0.0316

The coefficient of determination was 31.01 percent. The standard partial regression coefficients are presented in Table 28. Concentrations of nitrate-nitrogen were the single most important variable.

It is interesting to note that both nitrate-nitrogen concentrations and elevation were significantly correlated (Table 26).

2) Seedling Height. Multiple regression analysis yielded the following model for the height of spring sown P. v. melanocarpa:

y = -8.8248 + 0.066 percent cover + 0.1494 [nitrate-nitrogen] + 0.4164 elevation (significant at 5 percent level). The coefficient of determination was 19.91 percent. The standard partial regression coefficients are presented in Table 29. The elevation of the slope was most influential variable in this model.

Similar analysis of the height of spring sown C. stolonifera provided the following model:

y = 15.5726 + 0.0039 water potential days - 0.0455 percent cover - 2.1681 pH - 1.6394 [nitrate-nitrogen] + 0.3500 elevation (significant at 5 percent level). The coefficient of determination was 25.87 percent.

The standard partial regression coefficients are presented in Table 30. Elevation again proved to be the most important single variable.

The model generated for the height of fall sown C. stolonifera was:

y = 83.9738 + 0.0046 water potential days - 0.1506 percent cover + 8.2377 pH - 0.3241 [nitrate-nitrogen] + 0.5620 [phosphorous] + 0.0165 potassium + 0.6390 elevation (significant at the 1 percent level). The coefficient of determination was 54.37 percent. The standard partial regression coefficients are presented in Table 31. Elevation was the single most important variable.

TABLE 28. Standard partial regression coefficients of fall survival of spring sown C. stolonifera

Variable	Coefficient
Nitrate-nitrogen	0.4366
Percent cover	0.2358
pH	0.1725
Potassium	0.1603
Water potential days	0.0093
Phosphorous	0.0067

TABLE 29. Standard partial regression coefficients of the height of spring sown P. v. melanocarpa

Variable	Coefficient
Elevation	0.5725
Percent cover	0.1824
[Nitrate-nitrogen]	0.0092

TABLE 30. Standard partial regression coefficients of the height of spring sown C. stolonifera

Variable	Coefficient
Elevation	0.3500
Percent cover	0.1484
Nitrate-nitrogen	0.1203
Water potential days	0.1183
pH	0.0927

TABLE 31. Standard partial regression coefficients of the height of fall sown C. stolonifera

Variable	Coefficient
Elevation	0.7266
Percent cover	0.3411
pH	0.2412
[Phosphorous]	0.2000
Water potential days	0.0970
Potassium	0.0481
[Nitrate-nitrogen]	0.0166

3) Spring Survival. Models for the spring survival of the three seeding trials were generated. These were:

a) Spring Sown P. v. melanocarpa

y = 114.0798 - .0065 water potential days + 0.0476 snow accumulation (cm) - 0.0876 percent cover + 0.8432 fall survival + 0.1844 seedling height + .0005 germination maximum + 13.4568 pH - 0.2586 [nitrate-nitrogen] - 0.2241 [phosphorous] + 0.0383 [potassium] + 0.1201 elevation (significant at 1 percent level). Coefficient of determination = 71.57 percent.

b) Spring Sown C. stolonifera

y = -129.6987 - 0.0062 water potential days + 0.1035 snow accumulation (cm) + 0.0887 percent cover + 0.5907 fall survival + 0.2632 seedling height + 0.0310 germination maximum + 11.2460 pH + 1.7742 [nitrate-nitrogen] - 0.2674 [phosphorous] + 0.0787 potassium - 0.02244 elevation (significant at 1 percent level). Coefficient of determination = 68.31 percent.

c) Fall Sown C. stolonifera

y = 121.7059 - 0.0030 water potential days + 0.0925 snow accumulation (cm) - 0.0338 percent cover + 0.6233 fall survival - 0.1107 seedling height - 0.1301 germination maximum + 7.7053 pH + 0.1006 [nitrate-nitrogen] + 0.1406 [phosphorous] + 0.0475 [potassium] + 0.5748 elevation (significant at 1 percent level). Coefficient of determination = 62.27 percent.

The standard partial regression coefficients for each trial are presented in Tables 32 through 34.

In all cases the fall survival of the seedlings was the most important variable in determining the spring survival.

(c) General Discussion

Interpretation of the regression models has been difficult due to the complex ecological interactions which occurred on the

TABLE 32. Standard partial regression coefficients of the spring survival of spring sown P. v. melanocarpa

Variable	Coefficient
Fall survival	0.6945
pH	0.6729
Percent cover	0.3340
Seedling height (cm)	0.2567
Water potential days	0.2308
Elevation	0.2299
[Potassium]	0.1879
[Phosphorous]	0.1343
Snow accumulation (cm)	0.0939
[Nitrate-nitrogen]	0.0222
Germination maximum	0.004

TABLE 33. Standard partial regression coefficients of the spring survival of spring sown C. stolonifera

Variable	Coefficient
Fall survival	0.7351
pH	0.3601
Potassium	0.2472
Percent cover	0.2166
Seedling height	0.1970
Water potential days	0.1409
Snow accumulation	0.1377
[Phosphorous]	0.1026
[Nitrate-nitrogen]	0.0975
Germination maximum	0.0397
Elevation	0.0299

TABLE 34. Standard partial regression coefficients of the spring survival of fall sown C. stolonifera

Variable	Coefficient
Fall survival	0.8360
Elevation	0.5682
pH	0.1990
Germination maximum	0.1913
[Potassium]	0.1203
Seedling height (cm)	0.0964
Snow accumulation (cm)	0.0942
Percent cover	0.0666
Water potential days	0.0550
[Phosphorous]	0.0435
[Nitrate-nitrogen]	0.0045

site. The standard partial regression coefficients provided valuable keys in the evaluation of the importance of each of the independent variables measured. In the regression lines generated for the fall survival and seedling height the station elevation was the single most important variable. In these cases the effect of elevation was positive. There was an increase in both plant survival as observed in P. v. melanocarpa and the seedling height of all trials. Plants grew taller on the upper portions of the hill where conditions would seem to be harsher. Correlation analysis (Table 26) as previously discussed illustrated that there were significant changes of independent variables from the top of the hill to the bottom. Growing conditions were poorer at the top of the hill. Other environmental parameters which were not measured were also observed to be harsher. Soil texture, soil temperature, exposure are good examples.

The percent cover on the top of the hill was low. Weedy species performed better on lower elevations. It was hypothesized that the weeds grew better in response to better growing conditions. To test this hypothesis multiple linear regression with the cover percentages as the dependent variable was utilized. A significant model was generated. $y = 12.8904 - 0.0043$ water potential days $+ 23.3916$ pH $+ 8.2772$ [nitrate-nitrogen] $+ 0.8972$ [phosphorous] $- 0.0990$ [potassium] $- 1.2136$ elevation (significant at the 1 percent level). The coefficient of determination was 83.16 percent ($r = .912$). The standard partial regression coefficients are presented in Table 35.

Once again elevation was the single most influential variable; however, in this model the impact was negative. With an increase in elevation there was a decrease in weedy plant growth. Conditions on the upper

TABLE 35. Standard partial regression coefficients of the percent cover of the experimental site

Variable	Coefficient
Elevation	0.6092
pH	0.3068
[Nitrate-nitrogen]	0.1862
[Phosphorous]	0.1410
[Potassium]	0.1274
Water potential days	0.0400

levels of the hill were not conducive to plant establishment.

These results then contradict those obtained in previous regression analysis.

It is the author's hypothesis that due to competition the growth and survival of the young woody plants was reduced. Thus C. stolonifera and P. v. melanocarpa performed better on the top of the hill compared to the bottom where competition was the strongest. The plants survived and grew better in the absence of competition. Thus the competition effects overrode those of the other parameters measured.

Spring survival regression models yielded valuable information as well. Fall survival in all cases was the most important parameter affecting spring survival. The elevation effect was reduced but still noticeable. Survival was low on the top of the hill where snow cover was absent. In the final outcome the seeding trials were best represented by a small area near the middle of the hill where there was sufficient cover to protect them and growing conditions were more hospitable. The middle zone provides a compromise of two major influences on the plant populations. These were competition and snow cover.

SUMMARY

Emergence of Prunus virginiana melanocarpa at 20°C was highest following 30 days at 20°C followed by 150 days at 4°C. Radicle emergence during treatment was 6.3 percent.

Emergence of Cornus stolonifera at 20°C was greatest following acid scarification for 25-30 minutes followed by 30 days at 20°C and 75 days at 4°C.

Interpretation of the results of the preliminary studies for the after-ripening requirements of Amelanchier alnifolia indicate that 4°C stratification for 150 days to be most beneficial.

Similar experiments for Elaeagnus commutata indicate that 30 to 45 days 4°C stratification increase the rate of emergence. Seedlings emerged, however, without any pretreatment.

All experiments failed to stimulate emergence of Prunus pensylvanica. Only 12 seedlings emerged during the study. Further experimentation is required to recommend an after-ripening treatment.

Sowing after-ripening seed of Prunus virginiana melanocarpa and Cornus stolonifera on a hillside near Neepawa, Manitoba proved successful. Fall sowings of these species yielded only seedlings of Cornus stolonifera. Conditions were not conclusive for after-ripening Prunus virginiana melanocarpa due to the late sowing. Fall sown Cornus stolonifera emerged earliest in the spring and suffered the fewest losses of seedlings during the first growing season. Spring sowings of after-ripened seed emerged later and suffered the most losses due to a moisture deficit. Significant multiple linear regression models were computed for

fall survival, seedling height and spring survival for spring sown Prunus virginiana melanocarpa and spring sown Cornus stolonifera. Models for seedling height and spring survival of fall sown Cornus stolonifera were obtained but a significant model for fall survival could not be generated. In general, the coefficients of determination were low which restricts the predictive abilities of the models. The results of these analyses have been difficult to interpret. A highly significant model was computed for the plant cover or competition on the experimental site.

It is the author's hypothesis that competition reduced survival and growth. The overall survival of all trials was influenced by the degree of competition and amount of snow cover during the ensuing winter. Competition reduced plant growth and survival. Lack of snow cover resulted in winter desiccation causing mortality. A small area in the mid-portion of the experimental area maintained a significant seedling population.

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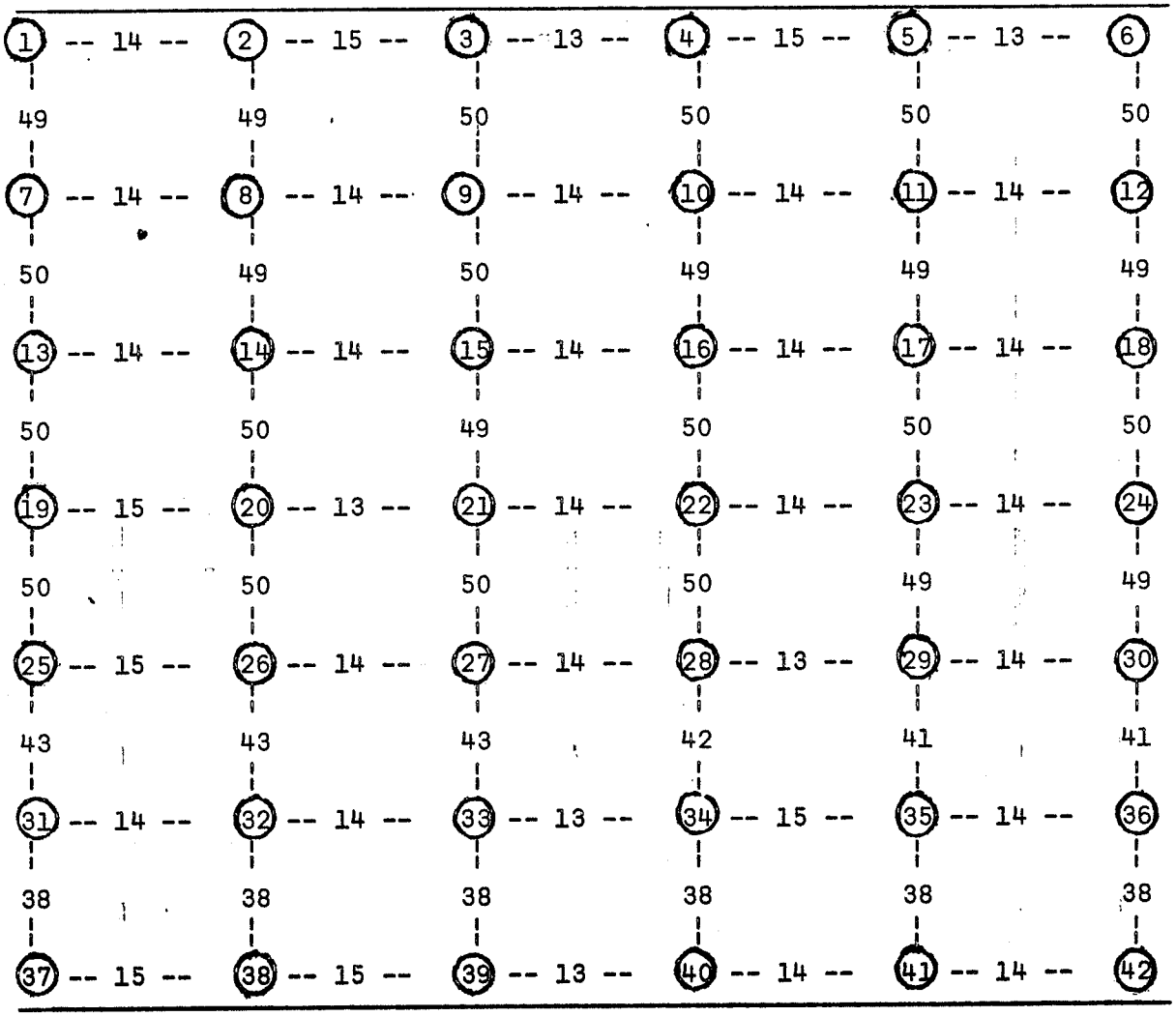
LIST OF APPENDICES

Appendix 1. Study time scale

	1974			1975		1976	
	Fall	Winter	Spring	Summer	Fall	Winter	Spring
Laboratory Work		Preliminary after-ripening studies				Detailed after-ripening studies	
Field Work	Seed collection	Snow accumulation	Spring sowing	Seedling survival	Seed collection	Snow accumulation	Spring survival
	Fall sowing		Soil chemistry	Soil moisture	Seedling performance	Air, soil and snow temperatures	
	Soil chemistry			Plant cover	Soil chemistry		

Appendix 2. Field plot design - distance between stations (feet)



Appendix 3. Major weedy species growing on the experimental site

Common Name	Scientific Name
Timothy	Phleum pratense
Quackgrass	Agropyron repens
Western wheat grass	Agropyron smithii
Canada thistle	Cirsium arvense
Ragweed	Ambrosia artemisiifolia
Clover	Trifolium hybridum
Alfalfa	Medicago sativa
Stinkweed	Thlaspi arvense
Beggarticks	Bidens frondosa
Raspberry	Rubus strigosus
Wild mustard	Sinapis arvensis
Tame oats	Avena sativa
Wild oats	Avena fatua
Shepherd's purse	Capsella bursa-pastoris
Field bindweed	Convolvulus arvensis
Dandelion	Taraxicum officinale
Prickly lettuce	Lactuca scariola
Wormwood	Artemisia frigida
Wild rose	Rosa sp.
Horsetail	Equisetum arvense
Strawberry	Fragaria glauca
Chickweed	Cerastium sp.
Barnyard grass	Echinochloa crusgalli
Hawk's beard	Crepis sp.
Goat's beard	Tragopogon dubius
Cow Cockle	Saponaria vaccaria

Appendix 4. Measurements* of copper, manganese and sulfur in soil samples obtained during the fall of 1975

Sampling Station	Copper (PPM)	Manganese (PPM)	Sulfur (PPM)
1 - 6	0.86	52.7	0.40
7 - 12	-	-	0.75
13 - 18	0.74	40.1	0.40
19 - 24	-	-	1.40
25 - 30	0.26	36.3	1.76
31 - 36	-	-	1.76
37 - 42	0.49	36.5	1.68

*Analysed in duplicate by the Provincial Soil Testing Laboratory.

Appendix 5. Weather data* - maximum and minimum temperatures (°F) and recorded precipitation (inches)

	Month														
	May			June			July			August			September		
Date	Max.	Min.	PPT	Max.	Min.	PPT	Max.	Min.	PPT	Max.	Min.	PPT	Max.	Min.	PPT
1	45	34		69	47		83	54		69	58	.10	55	41	
2	49	35		73	43		81	57		70	54		46	41	.56
3	52	36		59	44		86	56	.30	69	54		67	40	
4	52	34		52	45	.50	87	58		66	50		62	44	.13
5	58	35		55	39	.10	91	64		70	49		58	46	.14
6	65	39		63	39		89	62		80	48		60	46	.03
7	66	43		75	42		82	55		68	60		54	40	
8	67	43		67	54		72	51		75	55	2.00	63	34	
9	70	43		56	50	.30	72	47		69	53		66	46	.03
10	72	51		58	50	.80	76	54		74	52		54	42	
11	60	38		70	50	.20	72	54		72	54		49	35	
12	74	39		78	52		88	65		66	51	1.60	54	31	
13	70	47		68	52		94	66		74	48		72	41	
14	55	37		62	49		94	66		61	48		79	42	
15	75	37		65	45		93	67		70	44		59	46	
16	79	49		66	49		84	71	.20	60	41		74	36	
17	69	48		69	50		72	67	.80	60	41		70	50	.58
18	74	46		76	47		77	60		55	40		56	53	2.57
19	68	48		74	54	.40	72	57		57	46		46	46	.03
20	53	39		86	55		78	54	1.10	61	40		51	42	
21	47	35	.50	75	53		77	55		60	47		60	36	
22	51	34		64	51		66	58	.20	62	54		71	43	
23	51	44		79	51		72	52		77	57		71	39	
24	71	43		83	56		77	52		67	54		68	38	
25	59	46		90	60		84	58		63	52	2.75	73	43	
26	61	41	.70	86	62		79	57		57	43		70	42	
27	63	43		88	51		88	56		62	42		58	45	
28	69	38	.20	81	62		94	63		68	49		52	42	
29	56	41		82	54		86	66		64	52		59	49	.06
30	58	38		84	62		96	65		72	50		48	38	
31	63	40					68	62	2.40	72	47				
Total Precipitation			1.40"			2.30"			4.70"			6.45"			4.13"

*Courtesy Dr. C.F. Shaykewich