Lowbush Blueberry (*Vaccinium myrtilloides* Michaux) Management on Hydro-electric Rights-of-way in Northern Manitoba

by

Jennifer E. Barker

A thesis submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science

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Abstract

This study examines the population ecology of *V. myrtilloides* at two experimental sites (a rock outcrop and a sandy jack pine area) in the Thompson region of northern Manitoba. Experimental management trials were conducted at these sites to stimulate vegetative and reproductive growth in order to create a crop with harvest potential. Germination and propagation requirements were studied in the laboratory. Environmental preferences were examined to determine the necessary conditions for creating a stable shrub community to aid in right-of-way vegetation management.

The experimental management treatments were derived from the methods used in large scale management of *V. angustifolium* in eastern Canada i.e. spring burning, spring and fall clipping, fertilizer addition, and mulching. Changes in stem numbers and cover values were used to determine treatment effects. The management techniques that proved to be most useful in increasing vegetative reproduction (stem number) of *V. myrtilloides* on the rock outcrop were spring burning and fall clipping. The results for the sandy site were inconclusive due to a high variability in stem numbers within and between treatment groups. The sandy site exhibited a significant increase in cover values in response to fertilizer treatments and spring clipping with fertilizer. Other vegetation stimulated by the management treatments were *Carex* spp. (sedges) at the sandy site, which responded positively to fertilization. Seed germination was most successful in pots containing native soil, and resulted in vigorous seedlings. Vegetative reproduction in the form of stem cuttings was unsuccessful.

Future studies should be directed toward determining the appropriate fire cycle, and the optimal burn intensity for Manitoba populations of lowbush blueberry, incorporating community-based research. The ability of *V. myrtilloides* to establish a productive stable shrub community must be monitored over a long time period.

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Chapter 1 - Introduction

Lowbush blueberries (*Vaccinium myrtilloides* and *V. angustifolium*) are a significant component of Manitoba's boreal vegetation. They are an important food source for wildlife, and are used by humans as a supplementary food source. Lowbush blueberries are commonly encountered in open forests and disturbed sites, and are most abundant on acidic soils. Natural stands occur along a number of Manitoba Hydro rights-of-way in northern Manitoba. Although blueberries are not currently an important cash crop in Manitoba, profitable managed stands are found in eastern Canada (the Maritimes, Québec and Ontario) and in the states of Michigan, Maine, Wisconsin and Minnesota.

While studies have investigated the cash crop potential of blueberries in eastern Canada, corresponding studies in the Canadian prairies are lacking. One localized study in northern Manitoba has examined the potential marketing of the product in the form of jams and jellies (Bjornson and Ceplis 1992). The community interest was not strong enough to continue the endeavour. A six-year study conducted by the Saskatchewan Provincial Government in La Ronge, examined various management and cultivation techniques for the lowbush blueberry (Ivanochko 1988-1993). Two acres of forest that had lowbush blueberry in the understory were clear-cut. Several management techniques were applied that are common to the methods of eastern Canada's industry: burning, mowing, fertilization, herbicide, pesticide, shading and irrigation. Their results concluded that management techniques on the prairies must be different from those in the Maritimes. The lowbush blueberries were most productive three seasons after pruning was conducted. The maximum yield was ca. 700 kilograms per acre with an average of ca. 350 kilograms per acre. Winter-kill and spring and August drought were found to lower productivity significantly.

This study examines the population ecology of *V. myrtilloides*, the management of extant stands to stimulate vegetative and reproductive growth in order to create a crop with harvest potential; germination and propagation requirements, growing conditions, and environmental preferences, through a literature review and through laboratory experiments; and the creation of a stable shrub community to aid in right-of-way vegetation management. The findings from this study will be shared with Nelson House First Nation so that they can use the information to their benefit.

In essence, this thesis provides a literature review, summarizing the existing information on lowbush blueberries and management. It also provides preliminary results regarding lowbush blueberry (*V. myrtilloides*) management in northern Manitoba. Recommendations are given for future studies as well as directives for potential lowbush blueberry management.

1.1 Taxonomy, Biology and Ecology of Lowbush Blueberry

1.1.1 Family Ericaceae

The Ericaceae family is composed mainly of shrubs, although the family also includes some herbaceous and climbing plant species (Heywood 1978). This family includes ca. 100 genera and ca. 3 000 species. The Ericaceae family occurs worldwide. Considerable morphological variation occurs among members of the family, but all species have simple leaves lacking stipules, usually in an alternate arrangement. Most ericaceous species occur in relatively nutrient-poor habitats, often in association with mycorrhizal fungi that aid in nutrient uptake. Most family members have evergreen leaves that are adapted to dry, nutrient-poor environments (i.e. reduced, needle-like, folded). The inflorescence varies in arrangement, but the floral structure is consistently regular and bisexual.

Economically important ericaceous genera include the ornamentals *Rhododendron*, *Erica* (heath), *Calluna* (heather) and *Gaultheria* (wintergreen). Many members of the genus

Vaccinium (blueberries, cranberries) are important commercial fruit plants, including the highbush blueberry (*V. corymbosum*), lowbush blueberries (*V. angustifolium* and *V. myrtilloides*), European bilberry (*V. myrtillus*), lingonberry (*V. vitis-idaea*) and cranberry (*V. macrocarpus*).

1.1.2 Genus Vaccinium

The Vaccinioideae is one of five subfamilies in the Ericaceae. It contains five tribes and fifty genera, composed mainly of berry-producing shrubs and vines with inflorescences along the stems of the main branches (Heywood 1978). There are twenty-six species of *Vaccinium* native to North America. The ovary may be either inferior or superior. The genus *Vaccinium*, which is a member of the subfamily Vaccinioideae, has a base chromosome number of n=12. Polyploids have arisen naturally since there are no significant sterility barriers between species. Many species in the genus *Vaccinium* are tetraploids. Higher ploidy levels may account for the adaptability of this genus to a wide range of environmental conditions (Galletta and Himelrick 1990).

There are inconsistencies in the taxonomic nomenclature of *Vaccinium* species in Canada. Looman and Best (1987) recognize *V. caespitosum*, *V. angustifolium*, *V. uliginosum*, and *V. vitis-idaea* as distinct species. However, they consider *V. myrtilloides* a variety of *V. angustifolium*. Scoggan's Flora of Canada (1978) has recognized five *Vaccinium* species that occur in Manitoba: *V. vitis-idaea*, *V. angustifolium* (with five varieties), *V. caespitosum*, *V. uliginosum* (with subspecies and varieties), and *V. myrtilloides*. I have used Vander Kloet (1988) as the authority on *Vaccinium* species, based on his numerical taxonomic analyses. Vander Kloet has identified five sections in the genus (with associated species) that occur in Manitoba: Cyanococcus (*V. angustifolium* and *V. myrtilloides*), Oxycoccus (*V. oxycoccus*), Vitis-idaea (*V. vitis-idaea*), Vaccinium (*V. uliginosum*), and Myrtillus (*V. caespitosum*). Vander Kloet does not recognize subspecies or varieties in any of the species. Therefore, the six *Vaccinium* species (with proper

authorities and common names) found in the province of Manitoba are: *V. myrtilloides* Michx. (velvet-leaf lowbush blueberry), *V. angustifolium* Ait. (sweet lowbush blueberry), *V. vitis-idaea* L. (lingonberry), *V. caespitosum* Michx. (dwarf bilberry), *V. uliginosum* L. (bog whortleberry), and *V. oxycoccus* L. (small cranberry) (Vander Kloet 1988; University of Manitoba Herbarium records). *V. oxycoccus* is sometimes referred to in the literature as *Oxycoccus microcarpus* (e.g. Looman and Best 1987; Scoggan 1978). In Manitoba, the economically important species are *V. myrtilloides*, *V. angustifolium* and *V. vitis-idaea*. The berries of these species are mainly collected for personal consumption.

1.1.3 Vaccinium myrtilloides Michaux

Vaccinium myrtilloides Michaux (velvet-leaf lowbush blueberry) is a member of the Ericaceae family, in the section Cyanococcus. It was also described as *V. canadense* by Richardson in 1823, *V. angustifolium* var. *integrifolium* by Lepage in 1951, and as a variety of *V. angustifolium* (Looman and Best 1987). Two forms have been described, forma *chicoccum* (Deane) Fernald which has white fruit, and the typical forma *myrtilloides* which produces a blue fruit with a white bloom (Tirmenstein 1990). It is also commonly known as velvet-leaf blueberry, sour-top blueberry, airelle du Canada and airelle fausse-myrtille (Vander Kloet and Hall 1981). The Rocky Cree of northern Manitoba refer to the lowbush blueberry as 'ithinimina', which roughly translates as 'berry of the people'.

Species Description

V. myrtilloides is a dicot having a chromosomal complement of 2n=24. *V. myrtilloides* is the most geographically widespread diploid species in the genus *Vaccinium* (Vander Kloet 1988). The mature plant is a deciduous, broad-leaved low shrub with ascending branches averaging 20-50 cm in length. The densely pubescent young stems are dark brown to green in colour. The simple, net-veined, pubescent leaves are 6-16 mm wide and 20-32 mm in length. Leaves are elliptic to ovate-oblong in shape, with an acute apex

and an obtuse base (**Fig. 1.1**). Two types of buds are formed: the larger flower buds are terminal, while the vegetative buds are proximally located on the stem. The woody, underground rhizomes send up numerous shoots from rhizome buds. Initially, this new shoot growth is usually white or pinkish in colour. The shallow roots are fibrous and are 0.1 - 0.5 mm in diameter. The tap root in the lowbush blueberry is a continuation of the primary seedling root. It has been found up to ca. 1 m below ground level. This tap root may play an important role in times of dry weather, when the rhizomes are unable to claim moisture and nutrients from the soil (Hall 1957). The flowers are borne in lateral or terminal racemes, and have five sepals, five petals fused into a bell-shaped corolla, and 10 stamens in two whorls of five. The inferior ovary produces a bluish-purple berry (6-8 mm in diameter) with a white bloom. Each berry contains ca. 90 small seeds, of which ca. 16 are viable (Vander Kloet and Hall 1981; Vander Kloet 1988).

V. myrtilloides hybridizes with several species, including *V. angustifolium* (2n=48). It is closely related to its European counterpart *V. myrtillus* (bilberry). *V. myrtilloides* may be confused with *V. angustifolium*, since these two species often occur together in natural settings and in commercial fields in eastern North America. However, *V. angustifolium* typically has glabrous leaves and stems, and produces more berries than *V. myrtilloides*. In Manitoba, *V. angustifolium* is found mainly in the extreme south-east (Whiteshell region). In other parts of the province, *V. myrtilloides* is the dominant blueberry species. Detailed studies have been conducted mainly on *V. angustifolium*, since it is the more economically important lowbush blueberry species in North America. However, many of these studies can be directly applied to *V. myrtilloides* since the two species are morphologically and ecologically similar. In this thesis, the term 'lowbush blueberry' is used in reference to both *V. myrtilloides* and *V. angustifolium*, unless otherwise indicated.

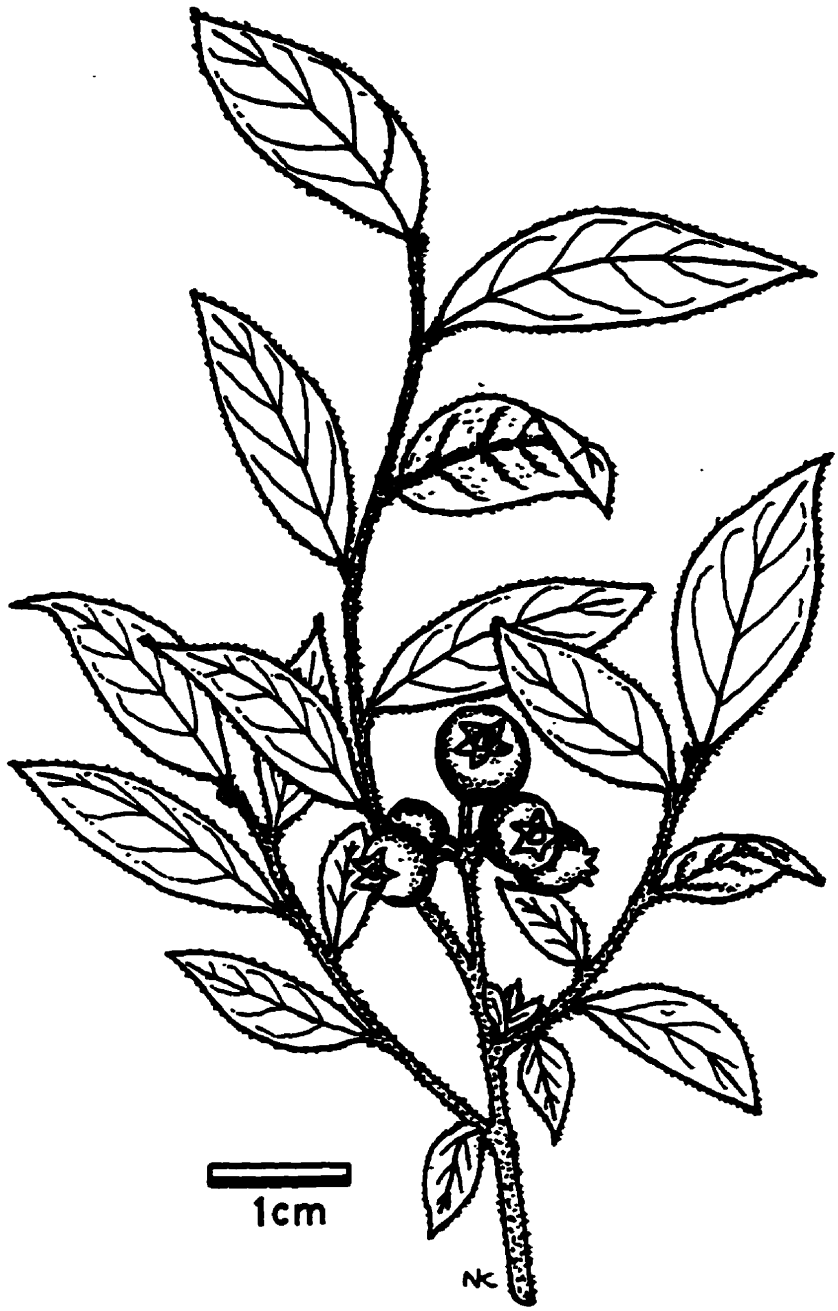


Fig. 1.1 Line drawing of *Vaccinium myrtilloides* Michx. (velvet-leaf lowbush blueberry), showing habit and fruit.

Geographical Range

V. myrtilloides is endemic to North America. It occurs from central Labrador to Vancouver Island, and from about 61°N in the Northwest Territories southeast to the Appalachian Mountains at ca. 39°N. The species does not occur on the island of Newfoundland (**Fig. 1.2**). It grows from sea level to ca. 1 200 m in altitude (Vander Kloet and Hall 1981; Vander Kloet 1988). *V. myrtilloides* has been collected throughout the province of Manitoba, but is most abundant in the boreal forest region. The closely related *V. angustifolium* has been mainly collected from the south-eastern part of Manitoba, although it is also occasionally found in the south-western part of the province (K. Johnson, pers. comm.).

Habitat

In accordance with its wide geographical range, *V. myrtilloides* has adapted to a wide range of environmental conditions. It tolerates a 60 to 200 day growing season, subarctic to temperate habitats, and perhumid to subhumid climate types. Although the species is winter hardy, it may experience dieback if there is not adequate snow cover. Flowers are damaged in late spring frosts. Temperatures below -10°C may be fatal (Vander Kloet and Hall 1981). The vegetative buds are susceptible to freezing injury in the early stages of development (Hall and Hildebrand 1988).

V. myrtilloides shows variable responses to light. The species persists in shaded areas (e.g. beneath a forest canopy), but flowers and fruits more readily in canopy openings (Vander Kloet and Hall 1981; Hall 1955). Fruit set is high in open areas only if there is adequate soil water (Tirmenstein 1990).

V. myrtilloides is found in recently-disturbed habitats in the boreal forest (e.g. burns, clearcuts, abandoned farmland, rights-of-way), and in muskegs, bogs, barrens, headlands, rock outcrops, and mountain meadows (Vander Kloet 1988). It is most

Fig. 1.2 North American distribution of *Vaccinium myrtilloides* Michx. (Vander Kloet 1988; Vander Kloet and Hall 1981).

abundant in young post-disturbance communities, where dense seral stands develop 2 to 3 years after burning (Tirmenstein 1990).

Lowbush blueberries occur on acidic (pH 3.3 to 5.6), mineral to organic soils that are moist but well-drained. The plants will reach high cover values on sandy soils (Tirmenstein 1990). The extensive rhizome system varies in depth, depending on the thickness of the organic horizon (i.e. the rhizomes are shallow if the organic layer is thick). The vast majority of the root system of occurs in the top 15 cm of the soil profile (Eaton and Patriquin 1988). Lowbush blueberry species have low nutrient requirements relative to their herbaceous counterparts (Vander Kloet and Hall 1981). As a result, lowbush blueberries can grow on poor soils and remain productive (Hall 1957).

V. myrtilloides is often an important component of the boreal forest, and is a vigorous pioneer species following disturbance. It shows higher survival potential than *V. angustifolium* in mature forests in the Maritime provinces (Hall et al. 1979). In the forests of eastern Canada, it is commonly associated with *Dennstaedtia punctilobula* (hay-scented fern), *Lycopodium* spp. (club-mosses), *Cornus canadensis* (bunchberry) and *Maianthemum canadense* (wild lily-of-the-valley). In the Maritimes, major competitors in managed stands (usually fields developed from woodlots) include *D. punctilobula*, *Pteridium aquilinum* (bracken fern), *Spirea alba* (meadowsweet), *Prunus pensylvanica* (chokecherry), *C. canadensis*, *Rhododendron canadense* (rhodora) and *Kalmia angustifolia* (sheep laurel) (Vander Kloet and Hall 1981). In the boreal forests of northern Manitoba, common associates include *C. canadensis*, *M. canadense*, *Potentilla tridentata* (three-toothed cinquefoil), *Cladina* spp. (reindeer lichens), *Pleurozium schreberi* (red-stem moss), *Carex* spp. (sedges), *Ledum groenlandicum* (labrador tea), *Arctostaphylos uva-ursi* (bearberry), *Aralia nudicaulis* (wild sarsaparilla), and *Vaccinium vitis-idaea* (lingonberry).

Major vegetation changes must occur before lowbush blueberry clones are damaged or killed. Plants in forested habitats are outshaded once a multi-layered canopy develops, and the species is destroyed by cultivation (Vander Kloet and Hall 1981). Lowbush

blueberry will not persist in areas where slash-burning immediately follows clear-cutting. However, if the slash burn occurs two seasons following the clear-cut, lowbush blueberry stands have a much greater chance of survival (Tirmenstein 1990; Hall 1955). Prior to the advent of oil burners too frequent burning (every other year for several years) exposed the rhizomes and damaged the clone (Kender et al. 1964). Presently, regular oil burning appears to do little damage on commercial fields in Nova Scotia since they are flash burns that are conducted while the ground is wet.

Reproductive Biology

In northern Manitoba, flower buds begin to swell in late May (April or early May in Maritime provinces). In most regions, flowering occurs from late May to mid-July. Blueberry fruit production is biennial in nature. The flower buds develop in one year and become dormant in the fall. Flowering and fruit development occurs during the second year (Tirmenstein 1990). The flowers must normally be insect-pollinated to ensure fruit development, although low rates of self-pollination have been observed in the wild. The main insect pollinators are members of the Andrenidae (mining bees), Halictidae (sweat bees), and Apidae (bumble and honey bees) (Reader 1977). Cross-pollination (outcrossing) has the advantage of maintaining genetic heterogeneity within the population.

After pollination occurs, the corolla turns slightly pink and withers. The ovary enlarges to form an immature green fruit, which turns bluish-purple as the seeds mature. The berries are high in mono- and di-saccharides, vitamin C and carbohydrates, but are low in fats. **Table 1.1** summarizes nutrient values of *V. myrtilloides* berries in Pennsylvania (from Wainio and Forbes (1941), cited in Tirmenstein 1990).

Seeds may be dispersed in the faeces of avian and mammalian consumers (Vander Kloet and Hall 1981), resulting in a highly clumped distribution pattern of seedlings (Hall et al. 1979). There is some controversy as to whether viability of seeds is decreased after they pass through a digestive tract (Tirmenstein 1990). Seeds germinate in the fall or spring

Table 1.1 Nutritional components (percent) of velvet-leaf lowbush blueberry (*V. myrtilloides*) fruit (from Wainio and Forbes 1941, in Tirmenstein 1990).

	% dry weight	% fresh fruit
Crude protein	4.19	0.63
Ether extract	3.80	0.56
Crude fiber	9.67	1.42
Total ash	1.44	0.21
N-free extract	80.90	11.88
Avail. Protein	2.75	0.50
Lignins	13.85	2.04
Cellulose	7.97	1.17
Tannin	1.28	0.19
Ca	0.4	0.01
Mg	0.07	0.01
P	0.07	0.01
Water	-	85.3

provided that there is adequate soil moisture. The seedling cotyledons are ca. 2 mm in length, and are narrower than the elliptical first seedling leaves. The first seedling leaves are usually more ovate than the mature leaves, making seedling identification difficult. The developing radicle gives rise to laterals, but there are no root hairs.

Plants normally produce rhizomes in the third or fourth year. The annual rings of the rhizomes can be counted to determine clone age (Hall et al. 1979). Clonal expansion is rapid once the plant exceeds a diameter of 20-30 cm (Vander Kloet and Hall 1981). Reproduction in lowbush blueberry is primarily vegetative (i.e. clonal growth), resulting in large patches of the same genotype.

Herbivory

The twigs and foliage of *V. myrtilloides* are consumed mainly by eastern cottontail rabbits and white-tailed deer. Lowbush blueberry foliage is selectively avoided by sheep. The mature fruits are consumed by several bird species (e.g. the American Robin), and by the raccoon, white-tailed deer, red fox, black bear and porcupine (Vander Kloet and Hall 1981). Black bear populations in the north depend quite heavily on the lowbush blueberry fruit in the fall (Tirmenstein 1990).

Plant Biochemistry

Water-soluble anthocyanin pigments are responsible for the red colouring in the leaves and fruits of *Vaccinium* species. These pigments are polyphenolic flavilium salts derived from anthocyanidins (aglycones). Anthocyanins are part of a group of chemical compounds known as flavonoids (Harborne 1982).

Flavonoids are 15-carbon compounds found in plants. Over 2 000 of these compounds have been identified from various plant families and species. Double bonds present in the ring structure of flavonoids allow for absorption of visible light. Hydroxyl groups located in various positions allow for attachment of sugars, which contribute to the

solubility of flavonoids in water. Flavonoids are stored in the vacuole of the plant cell, but are synthesized outside the vacuole. Blue light promotes the formation of flavonoids in plant cells. Flavonoids are thought to protect plants from ultraviolet radiation, and to impart colour to petals and other plant parts (Chichester 1972).

Anthocyanins are coloured pigments that occur in red, purple and blue flowers, and to some extent in stems, leaves, fruits and roots. They are usually found in the epidermal cells. The main factors controlling anthocyanin formation are light, temperature and the nutrient concentration of plant tissue. Anthocyanin accumulation in leaves is triggered by bright, cool days in the fall. Nutrient deficiency (nitrogen, phosphorus, or sulfur) or pathogen attack may result in anthocyanin accumulation in some species (Salisbury and Ross 1992).

The fruits of *Vaccinium myrtillus* contain the anthocyanin Cy 3-xylosylglucoside. Common anthocyanins in the genus *Vaccinium* include Cy 3-glucoside, 3-rhamno-glucoside, and 3-rhamnoglucosylglucoside (Harborne and Mabry 1982).

Mycorrhizal Associations

Endotrophic mycorrhizal associations are frequently encountered in ericaceous shrubs. The soil fungus *Oidiodendron griseum* is the most common associate in the family Ericaceae (Couture et al. 1983). It has been determined that ericoid mycorrhizae aid in nutrient uptake in *V. angustifolium*, and the same can be assumed for *V. myrtilloides* (Dalpé 1989). Indeed, the selective adaptation of lowbush blueberry to nutrient-poor, acidic soils is dependent on this mycorrhizal association (Dalpé 1989; Stevenson 1970). However, the absence of mycorrhizae does not adversely affect germination (Dalpé 1983). Infected roots of lowbush blueberry plants contain fungal hyphae in the intercellular spaces. The hyphae many also enter into the living cortical cells. Well-developed pelotons (coils of hyphae) are found in many cells of the root cortex (Stevenson 1970).

Pests and Pathogens

Insect pest and/or fungal pathogen infestations can result in significant decreases in fruit yield in commercial lowbush blueberry operations. In the Maritime provinces, the main fungal pathogens that attack *V. myrtilloides* are *Botrytis cinerea*, *Exobasidium vaccinii*, *Microsphaera vaccinii* and *Pucciniastrum geoppertianum* (Hall et al. 1979). Insect species that are harmful to *V. angustifolium* are common to *V. myrtilloides*. The adults of the blueberry maggots lay their eggs in the fruit, resulting in a non-marketable product. This insect has not been found in Labrador or Québec. The black army cutworm makes a hole in the flower bud as it begins to swell in the spring, and eats the inner tissue of the flower bud. The pubescence of *V. myrtilloides* is thought to deter the larvae of species of thrips from consuming plant parts. However, when thrips invade the plant, they will lay their eggs in the shoots in May/June. The hatched larvae feed on the shoots until June/August. The invasion of thrips can be determined by the reddish leaves wrapped around the stem (Vander Kloet and Hall 1981). The chainspotted geometer and the redstriped fireworm destroy the foliage and fruit, while the blueberry flea beetle feeds exclusively on the foliage. Other insect pests include the blueberry case beetle, which damages the leaves, fruit and stems, the blueberry tip midge which rolls the terminal leaves, and the stem galler which damages stem tissue (Hall et al. 1979).

Response to Disturbance

Northern boreal forests experience fire intervals of ca. 50 to 100 years (Johnson et al. 1995). *V. myrtilloides* is often abundant following a forest fire, especially if it occurs in the spring or late fall (Tirmenstein 1990). Although the aboveground parts of the plant are killed by the fire, the underground rhizomes generally survive and sprout new growth. Survival of underground parts is dependent on fire severity, rhizome depth and growth stage, and soil moisture level (Vander Kloet and Hall 1981; Shoemaker 1978).

Clonal recovery from fire is most rapid in areas of thick soil cover, where the rhizomes are deeper and more protected. Dramatic increases in biomass occur within the first few years following a fire. Overall plant vigour is increased, and flowering buds are usually more numerous on the new shoots. Berry production is usually at its maximum in the 10 to 20 years following a fire, before the forest canopy closes (Vander Kloet and Hall 1981).

Burning is used as a management technique in order to increase the productivity of commercial lowbush blueberry fields. In the Great Lakes region, a burning interval of 4 to 5 years has been suggested to maintain lowbush blueberry productivity (Tirmenstein 1990). In south-eastern Manitoba, Hoefs and Shay (1981) examined the effects of shading on the shoot growth of *V. angustifolium* following a spring burn. They found that burning initially increased stem number regardless of shade intensity. Shoots emerged 5 weeks after burning, and dieback (cessation of vegetative growth) occurred 4 weeks later. They suggested that aspen (*Populus* spp.) and alder (*Alnus* spp.) could become serious competitors if burning was eliminated as a management tool. They also suggested that burning natural stands would eliminate the inherent patchiness of the communities, leading to greater cover values and perhaps increased productivity.

1.2 Ethnobotany of Lowbush Blueberry

1.2.1 Traditional Use by Indigenous Peoples

The aboriginal peoples of North America discovered the use of plants through visions, dreams, and experiences. They used plants for food, medicine and other purposes related to their survival. Every culture had their own framework of plant use, but there was a common ethic understood by all aboriginal people. There was an interdependence, and particularly a spiritual connection, between human beings and all living creatures. Early European settlers to Canada learned to utilize the same plants for food and as medicinal remedies.

Food

Lowbush blueberries (*V. angustifolium* and *V. myrtilloides*) have long been used by aboriginal peoples throughout much of North America. The berries were eaten fresh, cooked in animal fat to be stored, pounded into pemmican (a mixture of berries, meat and fat pounded into a paste and dried), dried in the sun, and stored in birch bark baskets to be reconstituted upon boiling. Blueberries were also stewed with a sweetener or baked into bread, and upon the availability of trade goods such as sugar were made into jam (Kirk 1975). Dried blueberries were occasionally used as a trade item.

Traditional Herbal Remedies

Traditional medicine is a technique practiced by the aboriginal peoples of North America to promote general wellness, to treat and prevent symptoms of disease, and to alleviate pain. These holistic treatments include the use of herbs, ceremonies and/or prayers, usually undertaken by a medicine person or a shaman. Traditional medicine cannot be described in a specific framework, since the treatment for each person depends on the specific symptoms and on the shaman or healer (Dean Linklater, pers. comm.). The use of plants may be described as herbal remedies, because plants have properties that have been discovered to be useful in the treatment and prevention of physical ailments. The importance of the spiritual significance of plants is recognized, but is not addressed in this discussion.

Zieba (1990), Erichsen-Brown (1979) and Johnson et al. (1995) give accounts of the roots-rhizomes of lowbush blueberries being made into a tea used as a 'women's medicine'. A handful of fresh or dried root is boiled in enough water to make 1 cup of tea. Half is administered and more hot water is added to make another cup. This dose is repeated until the symptoms are gone. Women took this medicine for up to two weeks before giving birth, and following childbirth, to prevent clotting. This tea was also used to prevent miscarriages, to regulate menstruation, and relieve an inflamed uterus. One account

noted that the stems were prepared as a contraceptive. A journal in 1812 reported that blueberry root tea was an effective and safe anti-spasmodic, and that it was an excellent stimulant to the central nervous system (Erichsen-Brown 1979). Johnson et al. (1995) note that the Chipweyan used this tea for headaches. Densmore (1974) learned that the Chipweyan used the dried flowers of the lowbush blueberry as a smudge in the sweat lodge, to cure "craziness".

Accounts in Erichsen-Brown (1979) state that lowbush blueberry leaves were used in a decoction as a blood purifier, diuretic and astringent, and as a gargle for sore throats. The decoction has also been used to treat ulcers, bladder infections, incontinence, diarrhea, bowel disorders, and skin diseases such as eczema. Other accounts have stated that a leaf decoction is also successful in controlling blood sugar levels in diabetic patients (Keene 1995).

1.2.2 European Uses

Food

In 1615, Samuel de Champlain noted that the native North Americans of Lake Huron were picking lowbush blueberries and storing them for the winter. Some other early journalists noted that the aboriginals also used fire pruning in Atlantic regions to stimulate the growth of blueberry patches, a management technique still in use today (Hancock and Draper 1989). In the Maritimes, wild lowbush blueberry stands gained a commercial interest in the 1880's, and were harvested by settlers using hand rakes. The lands that produced good blueberry crops were nutrient-poor and therefore unsuited to farming. These areas were cleared for farmland but subsequently abandoned. With the arrival of the railway, lowbush blueberries in the Maritimes were commercially harvested for export to the United States. Harvesting was a family business that paid five cents per pint. The industry was organized after World War I. In 1928, a law was passed in Nova Scotia to encourage the production of blueberries (New Brunswick, unpubl. doc.).

The availability of freezers in the mid-1930's changed the industry altogether. By the end of the 1930's, about two-thirds of the wild blueberries exported from Canada were frozen. Today, Nova Scotia and Québec are the largest lowbush blueberry producers in Canada, followed by New Brunswick, Newfoundland and Prince Edward Island. The state of Maine produces ca. 55% of the North American crop (New Brunswick, unpubl. doc.). Today, lowbush blueberries are widely cultivated. They are available frozen or fresh, and are found in processed foods such as syrups, jams, baked goods, desserts and dairy products (yogurt and ice cream).

Medicine

A tincture called Myrtille, made from the roots and berries of the European species *Vaccinium myrtillus* (bilberry), has been used as a remedy for various ailments. The dose is 10 to 30 drops, administered orally, every eight hours until the symptoms are gone. The berries of *V. myrtillus* are recognized for their high level of anthocyanins, which have been found to be useful in intestinal action and diarrhea. Dried blueberries are taken internally to treat diarrhea and improve visual acuity (Tyler 1994).

European pharmaceutical companies produce whole fruit bilberry extracts from *V. myrtillus* for medicinal purposes (Mowrey 1988). The active ingredients, anthocyanosides, are sensitive to the presence of water, ascorbic acid, pH, sugar and polyvalent metallic ions. The presence of any of these substances in the extraction and storage process therefore reduces the effectiveness of the anthocyanosides. Bilberry extract is used most widely to improve visual acuity, to treat several visual disorders, and to reduce eye strain. The extract is also used to increase the resistance of blood capillaries and to reduce their permeability. Trials have been conducted on the effectiveness of this medicine in cardio-protective actions, the inhibition of atherosclerosis, and its anti-thrombotic potential. Other clinical investigations suggest that bilberry extracts stimulate peripheral circulation and are an effective anti-inflammatory agent. The medicine has also been used to treat blood vessel

disorders in diabetic patients, and as a sedative for the central nervous system. Tests have revealed that bilberry extract is non-toxic in oral administrations.

Studies are currently underway in Kentville, Nova Scotia to determine whether the anthocyanin compounds found in North American lowbush blueberry species (*V. myrtilloides* and *V. angustifolium*) resemble those of *V. myrtillus*. If they do, there is the potential to open up new markets for wild lowbush blueberries in Canada (J. Argall, pers. comm.).

1.3 The Lowbush Blueberry Industry in Canada

1.3.1 Introduction

Highbush blueberries (*V. corymbosum*) are a significant part of the blueberry industry in Canada, but cultivation is restricted to south-coastal British Columbia. Lowbush blueberry (primarily *V. angustifolium*) fields that are managed in eastern Canada are considered to be 'wild' stands because they are derived from native plants. Management is required to maintain a high cover of lowbush blueberries and thus create a stable shrub community. This practice is sometimes termed "arresting succession", since it involves disturbing an area on a regular basis to mimic natural disturbances known to stimulate the growth and reproduction of desired plant species while restricting the growth of competing vegetation (Niering and Goodwin 1974). In eastern North America, ecological dominance of lowbush blueberries is maintained by regular pruning and the use of selective herbicides. Reduced competition from other plants allows lowbush blueberries to obtain more water and nutrients from the soil, occupy more space, and dominate the stands (Eaton 1994).

Fruit production is influenced by several management factors, including the type of pruning conducted on the field, the pest and pathogen controls administered, irrigation, and fertilizer application. Productivity also depends on numerous environmental factors, such as soil characteristics, low temperatures, severe frosts, droughts, insects and diseases (Eaton 1994). According to Vander Kloet (1988), productivity in managed stands is a

function of pollinator density, self-compatibility, late blooming, uniform ripening, disease resistance, vigorous rhizome growth, easy propagation, and the presence of tall, upright stems.

Fruit yields fluctuate greatly from year to year, depending mainly on climatic conditions as the plants are developing (Eaton 1994). Late frosts are particularly harmful, as flowers are damaged and fruit set is reduced. Heavy rains during flowering reduce the presence of pollinators, which may result in decreased fruit yield. Moist conditions also favour fungal infections. Sunshine is important during the pollination period, and adequate rainfall is required one month following pollination to ensure optimal yields (Hall et al. 1982).

In natural stands, *V. myrtilloides* occurs with (and sometimes dominates) *V. angustifolium* in the forest understory (Vander Kloet 1988). After trees are removed and the field is put into production, the abundance of *V. myrtilloides* decreases. Management practices such as rotational burning and mowing further decrease the abundance of *V. myrtilloides*, since the species is comparatively intolerant of disturbance. It takes two or three growing seasons for *V. myrtilloides* to recover from pruning, whereas *V. angustifolium* recovers after a single season (Vander Kloet 1994). *V. myrtilloides* does not produce as many berries as *V. angustifolium*. However, commercially viable quantities of *V. myrtilloides* occur in managed fields in New Brunswick and Maine. It is estimated that ca. 30% of the two million kg of lowbush blueberries harvested in New Brunswick annually are fruits of *V. myrtilloides* (Tirmenstein 1990; Prescott-Allen and Prescott-Allen 1986). *V. myrtilloides* is also harvested as a late crop in New Hampshire (Shoemaker 1978).

In areas where lowbush blueberries do not occur naturally, fields are composed of *V. angustifolium* plantings. A number of commercial cultivars of this species have been developed using selective breeding techniques. Since *V. myrtilloides* is more cold-hardy

than *V. angustifolium*, it may have breeding potential in the development of cultivars suitable for northern climates (Tirmenstein 1990).

In any agricultural operation, undesirable components of the fields are weeds, insects, and pathogenic fungi. Herbicides, pesticides and fungicides are employed to combat these organisms and thus maximize lowbush blueberry productivity (Blatt and O'Regan 1990). Honey bees are introduced to commercial fields to ensure pollination and fruit set. Irrigation is used in areas of limited soil moisture. Fertilization is commonly practiced to increase the vegetative growth of plants. There are also guidelines for proper harvesting in order to minimize damage to the plants and fruit.

1.3.2 Commercial Production

The entire annual harvest of lowbush blueberries in Canada (Nova Scotia, Newfoundland, Prince Edward Island, New Brunswick and Québec) equals that of the state of Maine. Some commercial yields for Canada are outlined in **Table 1.2**. Most of Canada's harvest is sold to processors in the United States, but the establishment of processing plants in Nova Scotia, New Brunswick and Québec has encouraged the business to remain in Canada.

Lowbush blueberry cultivars propagated from superior clones can be purchased from growers. These 'wild' cultivars are selected for their hardiness and productivity. A number of named 'half-high' cultivars (derived from crosses of lowbush and highbush blueberry species) have been developed by the University of Wisconsin, the University of Minnesota and Michigan State University. These include the cultivars 'Friendship', 'North Country', 'Northblue', 'Northland' and 'St. Cloud' (Hartmann's Grower's Guide 1992). Unfortunately these 'half-high' cultivars are not fully hardy and may succumb to harsh Canadian winters.

In the central United States, 'half-high' cultivars are planted in rows to make harvesting and management easier. The first harvest occurs two years after planting.

Table 1.2 Commercial production of lowbush blueberries in eastern Canada (yield in tonnes). Figures were not available for 1989 to 1994 (Blatt et al. 1989; Lynch 1995).

Year	NS	NF	PEI	NB	PQ
1974	3 428	300	318	1 263	1 837
1975	4 504	1 448	363	1 740	3 402
1976	3 104	499	363	1 706	2 359
1977	3 721	1 660	340	1 499	4 831
1978	5 270	649	386	1 678	2 889
1979	4 864	1 203	227	1 941	3 080
1980	3 787	199	256	1 769	3 219
1981	5 836	237	272	2 313	6 350
1982	6 402	1 023	340	3 493	5 670
1983	8 846	633	363	3 842	3 379
1984	6 853	139	318	1 980	3 118
1985	8 596	145	340	2 359	3 965
1986	7 354	755	227	2 722	460
1987	6 135	2 591	414	3 175	8 980
1988	9 980	1 123	642	4 082	7 710
1994	13 460	500	900	4 700	7 200

Implementation costs of planted fields are high, and it may take from 6 to 11 years to turn a profit (Wildung et al. 1995). By contrast, natural or 'wild' stands have no associated implementation costs, so that economic turnover is much faster. Blatt and O'Regan (1990) compared the economic potential of native versus cultivated stands, based on the traditional crop-burn cycles. They concluded that cultivated stands do cost more to establish, but may result in a greater return over the long term.

1.3.3 Management of Lowbush Blueberry Stands

Site Preparation

Cultivation usually begins on abandoned farmlands or woodlots, since the land has already been cleared of trees and rocks. If the land has not been cleared, the trees must be removed from the area and burned at a separate location, so that the indigenous blueberry plants are not harmed from the intense heat.

In areas of Minnesota where blueberries do not grow naturally, fields must be prepared prior to cultivation. The land must be cleared of trees and brush, and plowed to a depth of 6 to 8 inches. The soil should be coarsely textured (sandy), well-drained, and moderately acidic (pH from 4.2 and 5.2). Herbicides are often used to rid the field of other vegetation prior to the planting of blueberry plants (Wildung and Sargent 1986).

Pruning and Flail Mowing

Pruning of native lowbush blueberry stands is necessary to mimic natural disturbances and produce a continually high-yielding crop. Pruning replaces the older, highly branched, less productive shoots with new ones produced from the rhizomes and basal stems. Spring or autumn pruning increases vegetative branching for that growing season, and stimulates the formation of reproductive buds. Fruits are not produced until the following growing season. Pruning is also a non-chemical method of weed and pest control. In the Maritimes, burning and flail mowing are the most common pruning practices

used in lowbush blueberry crop management. Once the blueberry field has been established, a two-year cycle is implemented for each half of the productive land: one prune year and one crop year. These cycles alternate so that there is a berry harvest every year (Sibley 1994).

Flail mowing is most useful in level areas, and is less expensive than burning since mowing uses less fuel (Blatt et al. 1989). Since the stems are cut above the ground, the renewal shoots come from above-ground stem buds. Mowing is usually accompanied by fertilizer application to increase vegetative growth of the plants. Fertilizer application results in taller plants that are easier to harvest. The type and quantity of fertilizer application depends on the nutrient availability of the soil on the particular field.

Mowing in the spring reduces the abundance of competing vegetation, particularly species that are less tolerant of disturbance. Mowing in the late fall often stimulates the growth of competing vegetation (particularly grasses) and is therefore not recommended. Mowing several times during the growing season is effective in suppressing taller shrubs and tree saplings. However, this method of weed control is very labour intensive compared to applying selective herbicides (Smith and Hilton 1971).

Burning

Burning stands of lowbush blueberries to stimulate growth is one of the oldest vegetation management techniques. When Europeans arrived in North America in the 1600's, the aboriginal people were already burning native stands of lowbush blueberries (Hancock and Draper 1989). Today, burning can be accomplished using oil or propane gas equipment, or by spreading straw to carry the fire. The most common time to burn is in early spring, following snowmelt but prior to the onset of blueberry plant growth. The vegetation is burned to within half an inch of the ground in order to stimulate new vegetative growth from the rhizomes (Sibley 1985). Burning favours regrowth from underground rhizome buds, yielding shoots that are more vigorous than those originated

from aerial portions. The number of stems, stem length, number of flower buds, number of flower buds per stem, and the proportion of stems with flower buds are greater when burning is conducted in the early spring (Eaton and White 1960).

During a burn, nutrients are released from the burning vegetation and the soil organic matter. Using straw as a fire carrier will also increase the soil nutrient content (Hanson et al. 1982). However, intensive and frequent burning can deplete the soil organic matter. Some workers therefore recommend that mowing should be favoured over burning, and that burning should be used only to combat insect pest infestations (Warman 1987).

The most productive fields in eastern Canada maintain a one inch litter layer and are burned every two to three years. Little organic matter burns if the ground is wet or frozen (Shoemaker 1978). In general, managed burns do not have deleterious effects on rhizome health or soil nutrient status (Black 1963). The nitrogen volatilized during a controlled flash burn comes from the above-ground plant parts, but not from the litter, roots, rhizomes, or soil (Eaton 1986). Without burning, lowbush blueberry cover declines due to the encroachment of competing vegetation (Black 1963).

Burning is known to reduce competition from weedy species and kill detrimental insect and fungal populations (Smith and Hilton 1971; Black 1963). In some cases, soil temperature increases following a burn due to decreased surface albedo, resulting in significant moisture loss (Hanson et al. 1982). This may be detrimental to fruit maturation, since the lack of moisture may cause desiccation of vegetative parts during the growing season.

Irrigation

Soil moisture is needed for proper flower bud development, and to maximize berry mass (Hepler and Yarborough 1991). In areas of adequate moisture and humidity (such as the Maritime region), irrigation is generally not necessary. Irrigation is an added expense that must significantly increase yield to be worth the time, effort and cost. When stands of

lowbush blueberries are established from selected cultivars, it is recommended that they be irrigated in the planting and establishment years. In Québec and Ontario, it is suggested that the growing crop should receive 2.5 cm of water per week from June to mid-August (Marcoux and Vandenburg 1985). The Minnesota Blueberry Establishment Calendar suggests irrigating in the early morning. The soil should never dry out, nor should it be saturated. Water stress results in a reddening of the leaves, weak shoots, early leaf drop and decreased fruit set (Wildung and Sargent 1986). In Nova Scotia, it is suggested that irrigation be used to increase plant height in order to make harvesting easier (Nova Scotia Blueberry Industry Tour 1988). In areas where late spring frosts may occur, irrigation may be necessary to protect the blossoms from freezing. Watering also ensures the movement of nutrients through the soil (Galletta and Himelrick 1990). Irrigating during the pruning season enhances bud formation, resulting in increased yield in the following year (Benoit et al. 1984).

Lowbush blueberry cultivation and harvesting has been considered in Manitoba and Saskatchewan, but a limiting factor common to both studies was inadequate soil moisture (Hoefs and Shay 1981; Ivanochko 1993b).

Mulching

Where an adequate source of water is not available, a sawdust or peat mulch can be used to help retain soil moisture and to suppress the growth of competing vegetation (Kender and Eggert 1966). Mulching will not increase flower bud formation or stem growth in pruned plants, however (Tirmenstein 1990). Surface mulching may increase total rhizome length, resulting in more vigorous growth than in non-mulched plants (Kender and Eggert 1966).

Fertilization

Highly productive lowbush blueberry fields in eastern Canada are managed using a combination of fertilizers, pesticides and herbicides (Blatt and O'Regan 1990). There are several factors that determine whether fertilization of lowbush blueberry fields is necessary. The soil and leaves are analyzed for nutrient content, and these levels are compared to those of successful wild lowbush blueberry fields. An appropriate nutrient enrichment program is derived by comparing these values.

Since lowbush blueberries occur on acidic soils, the most available form of nitrogen is ammonium. Nitrate is also available, but in smaller amounts. Nitrogen contributes mostly to vegetative growth rather than flower bud formation (Eaton and Patriquin 1990). Nitrogen, once assimilated, is translocated in organic form to the fruit during its development (Hall et al. 1970).

Lowbush blueberries do not respond to ammonium fertilizers if ambient nitrogen levels are adequate (Blatt 1983). In fields of moderate fertility, the addition of nitrogen fertilizer is detrimental as it stimulates the growth of competing vegetation (Blatt et al. 1989; Eaton and Patriquin 1988). The rate of fertilizer addition must therefore be low since blueberries are relatively poor competitors (Hepler and Ismail 1985).

The effect of fertilizer application on lowbush blueberry productivity is dependent on soil factors (nutrient status, pH, texture) and prevailing climatic conditions. Most short-term studies have found that fertilizer addition does not increase stand productivity, while long-term studies reveal that herbicide application is more effective than fertilization in increasing blueberry yields. Thus, interspecific competition appears to be a major factor limiting lowbush blueberry production (Eaton 1994). A four-year study in Nova Scotia indicated that the addition of fertilizer to pruned fields did not significantly increase yields (Warman 1987). The Atlantic Horticultural Crops Committee (1985) concluded that fertilization must be accompanied by adequate weed control in order to be worthwhile, and that the addition of nutrients is most effective when blueberry cover exceeds 75%. Soil

fertilization may be important in the early years of field improvement (Eaton 1994). The use of slow-release fertilizer is recommended on sandy, coarse-textured soils (Smagula and Hepler 1978). Fertilizer addition often increases plant height, and may result in winter injury if the upper branches are not covered in snow (Wildung and Sargent 1986; Smagula and Hepler 1978).

Weed, Insect and Fungal Control

Pests can be defined in an agricultural sense as natural or introduced species of flora or fauna that hinder maximum productivity of the blueberry crop. Weeds, in the traditional sense, reduce productivity by taking up space and nutrients that would otherwise be available to the crop. Management of insect and fungal pests is necessary in some areas, to prevent the reduction of blueberry productivity. Pest management is especially necessary where there is a high cover of plants with the same genetic complement (i.e. clonal growth). If the originator of the clone initially did not carry genetic resistance to the pest, the entire clone would not be resistant.

Weeds

The species of weeds that are present in a particular field depend largely on site history. Fields derived from woodlots often contain species normally associated with a forest understory, such as *Cornus canadensis* and *Maianthemum canadense*. Fields derived from farmland often have high numbers of graminoid weeds (Advisory Committee on Berry Crops 1991). In an agricultural sense, these species interfere with the blueberry harvest and are competitors for space and nutrients. These two factors may potentially decrease the yield of a blueberry stand (Eaton 1994).

The most common practice for weed control in the Maritimes is to apply an appropriate herbicide after pruning in the spring, before the blueberry leaves emerge. In the following summer and fall, spot applications of herbicide can eliminate the more persistent

bushes and perennials. Treating competitive vegetation has proven to increase the yield of commercial stands, by making nutrients in the soil available to the blueberry plants (McIsaac 1995).

These are some examples of the common herbicides and their application rates using the broadcast method.

- Velpar (hexazinone), at 1.5 - 2.0 kg active ingredient (6 to 8 L) per hectare, is useful in controlling some woody species, graminoids, and some broad-leaved weeds.
- Atrazine, at 4.0 kg active ingredient per hectare, is recommended for fields with few woody species, but many grasses and sedges.
- Sinbar 80 (terbacil), at 1.2 - 2.0 kg active ingredient (1.5 to 2.5 kg product) per hectare, is effective against grasses and fern.
- Roundup is only used in spot applications or when preparing blueberry fields for planting. (Advisory Committee on Berry Crops 1991)

Velpar gained popularity in the 1980's as the most effective selective herbicide. However, herbicides are a short term solution for eliminating competitive vegetation (Eaton 1994). Herbicide-tolerant populations of weed species (e.g. *Cornus canadensis*) are already evolving. Extensive use of herbicides may also increase soil erosion (since the root mat is partially destroyed), thereby exposing blueberry rhizomes and roots to desiccation. A proposed solution is to reduce herbicide applications, or to apply mulches to build up the soil organic matter. In addition, the planting of blueberry plants in bare spots discourages further weed invasion. Biological controls (e.g. insect introduction) can also be used to attack invasive plants.

Insects

At various times during the prune and crop years, sprays may be used to control insect pests. Aircraft or ground spraying equipment is used to broadcast these insecticides (Sibley 1988).

The blueberry maggot is the most destructive insect to crops in the Maritime region. These maggots infest the fruit, making it unacceptable for marketing. The maggots have no natural predators, but weed suppression and rotational burning help to reduce their populations. Infested berries should be picked and destroyed so that further infestation is avoided. Traps that are placed in the fields can monitor populations of adults, so that a spraying schedule can be determined. Some of the common insecticides used for eliminating the blueberry maggot are Cygon, Sys-tem or Rogor 480 EC (0.5 L per hectare), Guthion 240 EC (1.4 L per hectare), Guthion or APM 50 WP (0.6 kg per hectare), and Imidian 50 WP (2.0 kg per hectare) (Atlantic Agriculture Report).

There are other major insect pests described by Blatt et al. (1989):

- Blueberry leaftiers frequent wild, abandoned or poorly managed stands. Larvae infest and destroy the flower buds, thereby reducing yield and productivity. Populations can be reduced by rotational burning and insecticides.
- Blueberry spanworms damage leaf and flower buds, blossoms, and shoots, thereby reducing yield significantly. They are more prevalent on fields managed by mowing.
- The eggs of the blueberry thrips are laid in the leaf tissue, and the nymphs are present within curled leaves. The infected sprouts produce little fruit, so treatments are applied during the prune season to prevent losses.
- Blueberry flea beetles feed on the foliage, resulting in crop losses. There is less of a problem if the field is pruned by burning, but insecticide may be necessary to prevent crop losses.
- Blueberry leaf beetles feed on the leaf material between the veins. Severe infestations are found in poorly managed fields and may eventually kill the plants.
- Blueberry case beetles girdle the stems of plants, and repeated girdling may result in crop losses. Burning and insecticide treatments are effective.

- Black army cutworms can quickly destroy entire fields if a large outbreak occurs. These cutworms, which infest the terminal buds in the spring, and can defoliate hectares of plants in a short time period.

Fungi

Fungal infections can significantly reduce the productivity of blueberry plants. Burning reduces the level of infection by destroying the infected plant parts, thereby deterring the spread of the fungus. Mowing does not destroy the infected material and may promote the spread of the pathogen (Blatt et al. 1989). The two main types of blight are *Monilinia* (mummy berry) and *Botrytis* blight. They may occur separately or together on the same field.

Monilinia blight attacks the leaves, blossoms and fruit. The fungal spores are released while the plant is flowering. The fungus develops in the flowers and fruits, eventually destroying the berry and turning it into a fungal mass. Since *Monilinia* thrives in moist conditions, it is a problem in years of heavy rainfall or in areas with poor drainage (Blatt et al. 1989). In order to manage these infestations, spraying with Funginex 190EC at 1.7 L per hectare is recommended. One application should be administered when flower buds are opening and the leaves show a few millimeters of growth. The second application should be applied 7 to 10 days later. This fungicide should be applied at least 60 days prior to harvest.

Botrytis blight attacks the leaves, blossoms and fruit. Infected leaves turn light brown in colour and become covered with a gray coloured mold. The mold produces spores that attack the blossom and subsequently the fruit. Other fruit that comes in contact with an infected blossom or fruit will become infected as well. *Botrytis* is also favoured by wet conditions during the bloom period. This blight can be controlled by a variety of fungicides (Delbridge and Hildebrand 1995), including:

- ferbam 76 WDG (2.25 kg per hectare). It must be applied at least 40 days prior to harvest.
- Easout 70WP (1.1 kg per hectare). It must be applied at least 60 days prior to harvest. Some fungal strains have already built up a tolerance to this fungicide, so it may not be effective in a particular area.
- captan 50WP (3.25 kg per hectare). It must be applied at least 2 days prior to harvest.
- captan 80WP (2.25 kg per hectare). It must be applied at least 2 days prior to harvest.

Fungicides are often applied prior to a predicted wet period. Further applications are necessary at 7 to 10 day intervals if the weather conditions are favorable to blight development.

Pollination

As stated previously, lowbush blueberry flowers must be cross-pollinated for maximum fruit production. In non-cultivated stands, the number of native pollinators may be sufficient to visit all the blossoms. Since lowbush blueberries have been intensively managed, they produce many more flowering buds than natural stands. In some fields, it appears that the number of native pollinators is no longer adequate to visit all the blossoms. Honey bees, alfalfa leaf cutter bees, or bumble bees are used extensively in commercial fields in Nova Scotia and Maine to ensure cross-pollination (Eaton 1994). One hive to each acre of land (two per hectare) is introduced during the blooming period. The "blueberry honey" produced from these hives is sold as a secondary product from blueberry fields.

1.3.4 Harvesting and Marketing

In eastern Canada, the lowbush blueberry harvest begins in mid-August as over 90% of the berries are ripe by this time. Harvesting lasts from one to five weeks,

depending on environmental conditions (Blatt et al. 1989). Berries remain on the plant until late fall, so little is wasted. Several factors contribute to the quality of the harvested product: a good hand-picking technique, adequate supervision, and proper handling after harvest (Sibley 1985). Today, fields that are relatively weed free and have level terrain are harvested effectively with mechanical harvesters (Blatt et al. 1989).

Since the harvesting season is short, the growers must have a well-organized harvesting plan. Weed control is essential to increase picking speed and to maximize yield. Prior to harvest, fields are cleared of all debris that may get in the way of an efficient harvest. A field is divided into rows, and each picker is assigned a row. Blueberry 'rakes' are usually used to collect the fruit. These rakes are dustpan shaped, with long tines which comb through the bush and lift the berries into the bottom. The berries are emptied into a bucket, and each picker "weighs in" after a full bucket is collected. The picker is paid by mass rather than volume to encourage clean picking, i.e. no leaves or stems (Sibley 1985). An experienced picker can collect 500 to 1 000 pounds (ca. 225 to 450 kg) per day, and is paid 10 to 12 cents per pound (ca. 25 cents per kg) (Sibley 1988). A mechanical (tractor driven) harvester can collect ca. 6 hectares in a 10 hour day. Mechanical harvesting costs half as much as hiring hand rakers (Sibley 1994, 1988). Average yields in eastern Canada are ca. 1 800 kg per hectare (Hancock and Draper 1989).

The berries are passed through a winnower, which blows the lighter material (soil, leaves, twigs) away from the fruit. The berries must be dry and large to pass through the winnower. The berries are packed lightly, handled carefully and immediately shipped to the processor, sometimes twice per day (Sibley 1985). The processor usually quick freezes the berries before selling them on the market (Galletta and Himelrick 1990). "Pick-your-own" programs are sometimes used, especially in cultivated stands where rows make picking assignments easier. From the processor, the quick-frozen berries are shipped to manufacturers where they are incorporated into pie fillings or pies, jams, syrups, cereals, granola bars, yogurt etc. Only about 5% of the fresh fruit is shipped straight to major

grocery chains, fruit stands, or fundraising organizations (Sibley 1988). To fill the fresh market demands, picking must be done carefully to produce a dry, clean fruit. This requires more time and effort, adding significantly to the cost. In 1988, growers received from $2.00 to $2.50 per pound for fresh berries, and 50 to 60 cents per pound for berries that were quick-frozen (Nova Scotia 1988). The price paid varies according to product quality and market demand.

The benefit to marketing wild lowbush blueberries is that the term 'wild' imparts an image of pristine wilderness that is attractive to many consumers. Although the lowbush blueberry is a native species, it is rarely harvested from truly pristine wilderness. However, the crop is generally managed with far fewer chemical additives than other commercial fruit. The largest foreign markets for the Canadian harvest are northern Europe, the United States, and Asia (Wild Blueberries Promotional Pamphlet New Brunswick, no date).

1.3.5 Prospects for the Canadian Prairie Provinces

Although *V. myrtilloides* occurs across the prairie provinces, few studies have been conducted to determine its economic potential. Hoefs and Shay (1981) examined the effects of shading on the shoot growth of *V. angustifolium* in south-eastern Manitoba, in order to determine optimum light conditions for potential commercial production. The dry climate of Manitoba was determined to be the factor limiting lowbush blueberry growth. Shading at intermediate intensities (75%) increased water economy, resulting in faster growth, larger leaves and longer shoots. The taller shoots produced more branches, many of which produced fruit. They concluded that intermediate shading is essential for optimal lowbush blueberry growth in Manitoba. Smith (1962, in Hoefs and Shay 1981) determined that populations of *V. myrtilloides* and *V. vitis-idaea* in Alberta preferred lower light levels as well.

A feasibility study and experiments were conducted by Ivanochko (1986-1993) near La Ronge, Saskatchewan, to determine the best management techniques for *V.*

myrtilloides. A variety of management methods was examined, including those used in eastern Canada. It was concluded that lowbush blueberry productivity in Saskatchewan was not high enough to offset management costs. The plants were found to be susceptible to late spring frosts, spring and late summer drought, winterkill, and competition from associated vegetation. The final recommendations were to: (a) consider irrigation or shading; (b) introduce *V. angustifolium*; or (c) harvest a late crop of *V. vitis-idaea*. To date, agricultural production of *V. myrtilloides* has not been pursued on the prairies.

Bjornson and Ceplis (1991) conducted a developmental market study on the various wild berries picked by the native peoples of northern Manitoba. Lowbush blueberry (*V. myrtilloides*) and lingonberry (*V. vitis-idaea*) were among the berries collected. It was determined that transporting the fresh product to market would be difficult due to the remoteness of the communities. In addition, it proved difficult to keep individuals committed to organizing, harvesting, processing and marketing the final product, in part because most lacked the proper business training to carry out the marketing. Nevertheless, the authors concluded that the market potential for wild berries in Manitoba may be great. However, individuals with enthusiasm and training will be required to build the necessary routes for successful product marketing.

The present study (Thompson - Nelson House) is similar to that undertaken by Ivanochko (1986-1993), albeit over a much shorter time period. The information collected from my study will be used toward determining the growth requirements for *V. myrtilloides*, providing the potential for commercial production of blueberries on the Hydro-line rights-of-way, stimulating the local economy, and making efficient use of the cleared land provided by the rights-of-way. To date, blueberry picking is done for personal consumption only, and no management practices are in place.

1.4 Rights-of-Way Vegetation Management in Northern Manitoba

It is necessary to remove trees from hydro-electric rights-of-way (ROW) so that they do not interfere with power lines, and so that the trees do not present a hazard to the lines during forest fires. Presently, rights-of-way in northern Manitoba are managed by physically removing trees using V-blading and/or bulldozers in the winter months when the ground is frozen. Rights-of-way in the southern regions of the province were treated with herbicides until the early 1990's. In northern Manitoba, herbicide application was deemed unnecessary and undesirable (W. Shanks, pers. comm.).

Previous vegetation studies conducted along rights-of-way in central Manitoba have recommended that stable shrub communities be established to reduce or eliminate the need for costly vegetation maintenance. MacLellan (1982) examined the floristic variation along rights-of-way in Manitoba. The study was initiated to determine whether the presence of the ROW aided windborne seed dispersal. Since *Vaccinium* species are consistently members of the ROW vegetation and of adjacent forested areas, it was recommended that ROW vegetation management includes the promotion of these low-growing shrubs.

Diamond (1993) studied the effects of herbicidal treatments on the mycorrhizal associations of ROW vegetation. Herbicidal treatments of *Tordon 101* did not affect the mycorrhizal associations. However, the ROW conditions (e.g. increased exposure to light and moisture loss) were responsible for differences in fungal associates. Herbicidal treatments of *Tordon 10K* were responsible for the stimulation of fungal associates at some sites, thereby aiding in vigorous tree re-establishment on ROW. Tree species that were designated as hazardous to the safety of the Hydro-lines were jack pine, black spruce, poplar and white birch. *V. vitis-idaea*, and *V. myrtilloides* were low shrubs that formed dense cover on ROW in dry jack pine sites. Diamond suggested that these types of shrubs should be established as stable shrub communities, for more effective vegetation management.

Walker (1994) studied vegetation dynamics on rights-of-way. Forest cover was determined from LANDSAT imagery and ground truthing. Management treatments were recommended for different forest cover based on the recruitment rates of tree species. Management recommendations suggested a treatment frequency of 15-20 years in dry coniferous sites.

Previous studies have revealed that the creation of stable shrub communities is an efficient and cost-effective method of managing rights-of-way. Niering and Egler (1955) identified the benefits of using stable shrub vegetation for managing ROWs and utility corridors. Shrub dominated vegetation is more effective in resisting tree invasion than are grasslands. Maintenance costs are low and biodiversity is conserved. Pound and Egler (1953) observed that cleared and abandoned areas in south-eastern New York state were subsequently recolonized by a low plant community. This stable shrub community, dominated by *Vaccinium* species, resisted tree invasion for 15 years. Niering and Goodwin (1974) found that lowbush blueberries are often selected for vegetation management and stable shrub cover due to their ability to resist tree invasion (47 years in Connecticut). The authors also suggested that a mosaic of shrub communities should be established to maintain high biotic diversity.

The establishment of stable shrub communities would eliminate the need for mechanical tree-removal, and would encourage the growth of long-lived low shrubs along rights-of-way. Stable shrub communities are initially established by creating a disturbance (e.g. fire, pruning or herbicide application) that stimulates the growth of one or more preferred shrub species while suppressing potential competitor species. The preferred species will dominate the area for a period of time (the so-called 'stable phase'), but this arresting of species succession will not continue indefinitely (Niering and Goodwin 1974). Niering and Goodwin also note that the popular term 'arresting succession' implies that the community will reach a 'climax'. In fact, the shrub community is not a successional end point, but represents instead a stage of stability within the dynamics of the system.

Chapter 2 - Study Area

2.1 Introduction

The study region is located in north-central Manitoba, north-west of the city of Thompson. The area is northern coniferous boreal forest located on the granitic Canadian Shield (Zoladeski et al. 1995). The northern coniferous forest or taiga occupies a band of up to 1 000 km in width from the Yukon to Labrador (Larsen 1980). It covers ca. 8% of the earth's land mass, has a circumpolar distribution, and is restricted to the northern hemisphere (Whittaker 1975). Precipitation in general is low, and occurs mostly during the summer months. The mean annual temperature is near or below zero degrees Celsius. Glacial deposits from the last ice age have shaped and formed the landscape. The topography consists of rocky uplands of the Canadian Shield, and lowlands that are filled with vegetation or waterways. In the boreal forest, variables such as precipitation and air temperature influence soil temperature and moisture, which in turn affect nutrient cycling and vegetation dynamics. Nutrient cycling is slow in the boreal forest (Prescott et al. 1989), but most boreal plant species are physiologically adapted to nutrient-limited environments. Plant species have also developed life-history strategies to cope with a short growing season and to the recurrent, catastrophic forest fires that are characteristic of this ecosystem.

2.1.1 Vegetation

Forest stand composition and structure are a function of site age, post-glacial vegetation history, surficial geology, edaphic factors, climate, and disturbance regime. Jack pine dominates xeric sites where competition from black spruce is absent and forest fires are frequent. More mesic sites support a wide variety of forest stand types, including black spruce, trembling aspen, and mixed coniferous-deciduous forest. Poorly drained sites burn less frequently and support stands of black spruce and sometimes larch (Ritchie 1956).

The following forest type descriptions are derived from the Forest Ecosystem Classification (FEC) for Manitoba (Zoladeski et al. 1995). Even-aged stands of jack pine (with some black spruce, trembling aspen and/or white birch) are found on well-drained, nutrient deficient rock outcrops and sandy sites throughout central Manitoba. The understory is comprised mostly of ericaceous shrubs (e.g. *Ledum groenlandicum*, *Vaccinium myrtilloides*, *Arctostaphylos uva-ursi*), herbs (e.g. *Cornus canadensis*, *Maianthemum canadense*, *Aralia nudicaulis*), and feather mosses (e.g. *Pleurozium schreberi*). These stands are characteristic of regenerating forests where black spruce will eventually dominate.

Some upland sites are dominated by a mixed forest of black spruce and jack pine, with a poorly developed shrub and herb understory. The forest floor is dominated by a well developed lichen and moss community. These forests originate from regenerating jack pine stands, and will eventually be succeeded by black spruce if there are no further disturbances.

Poorly drained lowlands of the Canadian Shield are often dominated by mature forests of black spruce. The herb layer is more diverse in areas of better drainage, whereas waterlogged areas have a well developed *Sphagnum* moss community. The shrub layer in some of these stands can be completely dominated by *Ledum groenlandicum* (labrador tea). Vegetational development in general is slow due to the low nutrient availability and a high water table.

Mesic sites usually contain a mixed stand of black spruce, jack pine, trembling aspen, and white birch. *Petasites palmatus*, *Equisetum arvense*, and *Elymus innovatus* can be found in the herb layer, while ericaceous shrubs, along with *Rosa acicularis* and *Rubus pubescens*, are found in the shrub layer. The abundance of jack pine decreases in the absence of fire. These sites are especially common in the northern parts of the province.

2.2 Quaternary Ecology

The landscape of central Manitoba was primarily influenced by the presence of a moving glacial ice sheet. Glacial Lake Agassiz, which formed as the glacier retreated, covered most of central Manitoba by 11 500 years BP. Upon climatic warming, the glacier retreated fully from Manitoba by ca. 8 000 years BP, and glacial Lake Agassiz drained shortly thereafter. The ice sheet left till deposits of sand and gravel on the boreal shield, forming the eskers and kames on the landscape. Most of Manitoba was initially recolonized by white spruce and jack pine forests (Teller 1984; Ritchie and Yarranton 1978). By 6 000 years BP, as a result of continued warming, the tree line was located ca. 250 km north of its present position. The forest-tundra border began to shift south 3 500 years ago, and by 3 000 years BP was approximately 60 km south of its present location. Over the past 3 000 years, the tree line has remained within 100 km of its current position (Teller 1984). In the past 6 000 years, species composition in the central boreal forest has varied somewhat in response to climate change, post-glacial species migrations, fire frequency and severity, and interspecific competition (Ritchie and Yarranton 1978).

2.3 Surficial Geology

The Precambrian granitic bedrock that makes up the Canadian Shield was formed over 3 billion years ago. The Canadian Shield, stretching across central and south-eastern Manitoba, is comprised of undulating uplands and lowlands created by rock outcroppings. Most of the area has low relief. Glacial and other surficial activities, such as alluvial and fluvial deposition of gravel and sand, have modified the landscape. Erosion, soil profile development, bog and dune formation, frost action, and beaver induced waterway damming have also contributed to landscape modification. Lowland depressions are filled with lakes, fens and bogs. The granitic parent material of the Canadian Shield results in well-drained, acidic, nutrient-deficient, poorly-developed soils (Teller 1984; Ritchie 1956).

2.4 Landscape and Landform

Surficial topography determines the amount of incoming solar radiation (slope, aspect), as well as drainage patterns at the landscape level. Surficial topography and parent materials interact to determine the vegetation, soil, moisture regime, and disturbance potential in the boreal forest. A variable and patchy landscape promotes habitat diversity and complexity (Kenkel and Watson 1996). In particular, upland sites on rock outcrops have little soil development and are dominated by a jack pine and black spruce forest type. They are very well drained and are highly susceptible to forest fires. Dry sites on sandy deposits also have little soil development and are dominated mostly by jack pine. These areas are frequently disturbed by forest fires as well. Poorly drained, boggy sites are dominated by mature black spruce forests. The soil consists mainly of layers of *Sphagnum* moss. These stands are less susceptible to forest fires due to the high moisture levels.

2.5 Edaphic Factors

Several soil factors determine the vegetation dynamics of the boreal forest in central Manitoba. However, areas of virtually identical substrate and topography can have entirely different vegetation types associated with them. According to Ritchie (1956), this variation in vegetation composition is largely attributable to different forest fire histories. Edaphic factors that determine vegetation composition and structure in central Manitoba include:

1. Soil Drainage and Texture: Well drained, sandy areas and xeric rock outcrops are usually dominated by jack pine and ericaceous shrubs. Silt-clay soils having greater retention potential often support deciduous forests of trembling aspen and/or balsam poplar. Poorly drained areas of muskeg are usually dominated by black spruce, labrador tea, and *Sphagnum* moss. Peat bogs are similar but lack a tree stratum (Ritchie 1956).

2. Nutrient Status: Areas of low fertility are generally dominated by jack pine and/or black spruce, while trembling aspen and white birch are more common in areas of moderate fertility. Fertile areas are comprised mainly of larch or balsam poplar. The high acidity of many boreal forest soils results in decreased nutrient availability (Barber 1995).

3. Organic Matter: Black spruce, larch and ericaceous shrubs are commonly encountered in areas having high amounts of poorly-decomposed organic peat (*Sphagnum* spp.).

The dominant soil types in the boreal forest of central Manitoba are grey luvisols, eutric brunisols, and organic cryosols. Grey luvisols result from clay parent materials of lacustrine origin. They occur on well to moderately-well drained surfaces and are strongly calcareous. Eutric brunisols form from loams, very fine sandy loams, or gravelly sands of fluvioglacial origin. They also occur on well to moderately-well drained surfaces and can be strongly to weakly calcareous. Organic cryosols are characteristic of mesic woody bog-forests. They are poorly drained areas of bog veneer (Canada Soil Inventory 1989).

In central Manitoba, lowbush blueberry cover is highest in areas classified as discontinuous organic mats over bedrock, extremely shallow soil over bedrock, and shallow to moderately deep, well-drained sandy soils (Zoladeski et al. 1995). These substrates are typical of granitic Canadian Shield rock outcrops and fluvioglacial deposits (Canada Soil Inventory 1989).

2.6 Description of Experimental Study Sites

The two study sites were located north-west of Thompson (**Fig. 2.1**) and are described in detail below.

SITE 1 (rocky). This site, located between poles 219 and 220 on the Thompson-Notigi Hydro right-of-way (55° 50'N, 99° 01'W), is accessible by a trail off the main highway (**Fig. 2.2a**). It is located on a Canadian Shield rock outcrop. The forests

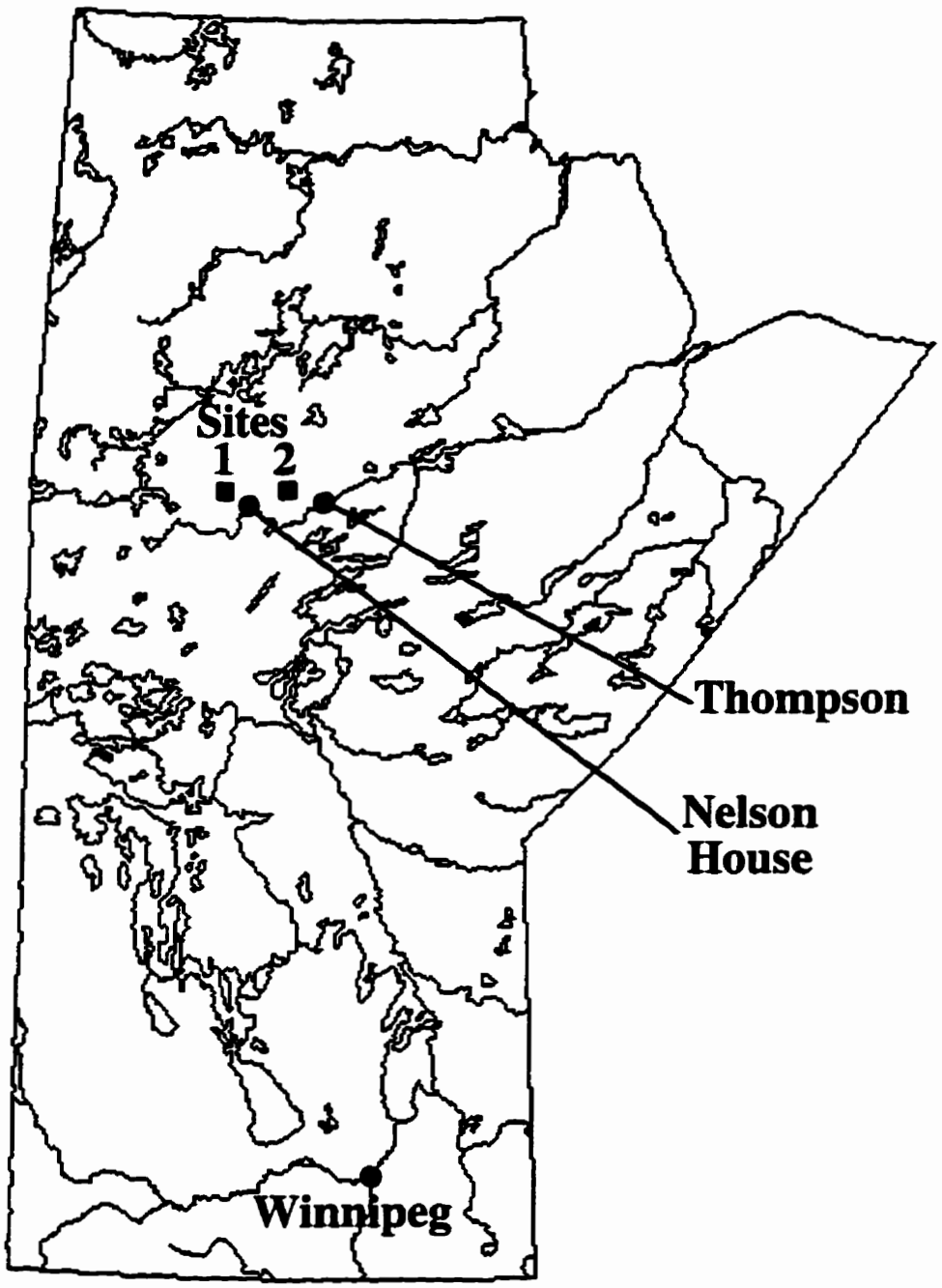


Fig. 2.1 Location of the study area for lowbush blueberry management trials for 1995-1996, including site locations in relation to Thompson and Nelson House.

Fig. 2.2a. A north-west facing aerial photo of site 1. Note Manitoba Provincial Trunk Highway 391 and a recent burn in the distance.

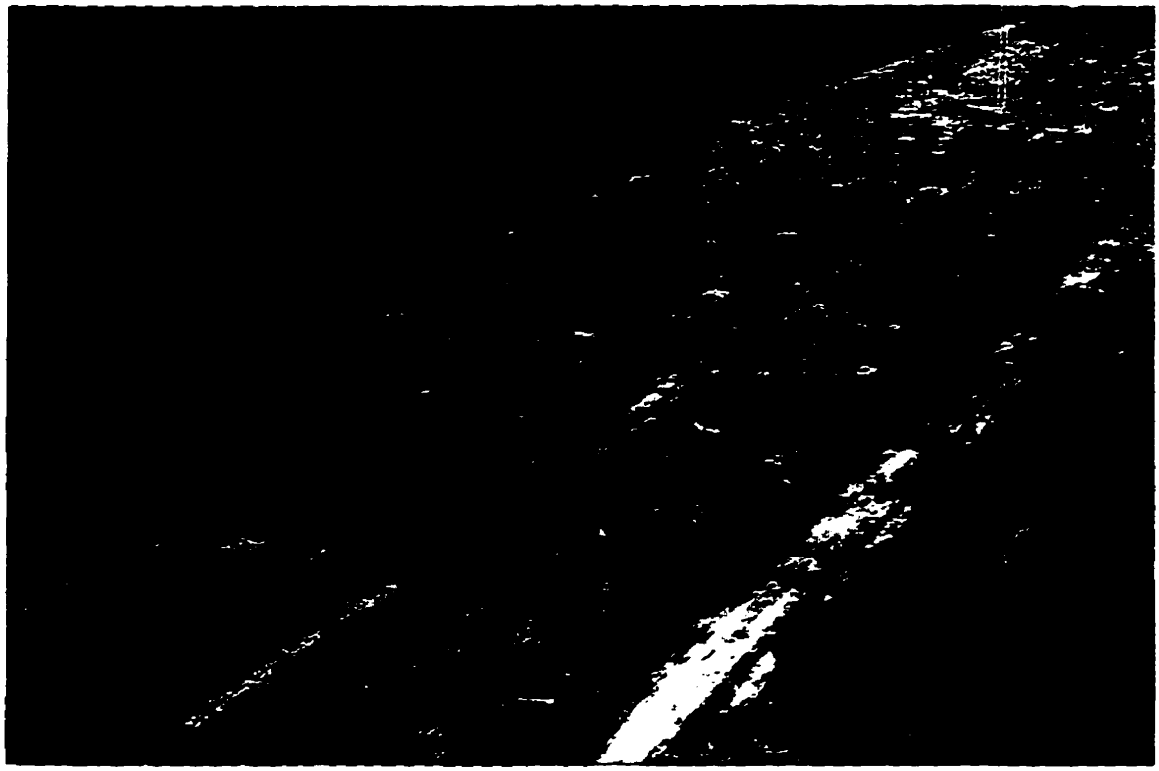


Fig. 2.2b. An aerial photo of site 2, facing west-south-west. The hydro-line runs from east to west. The mulched treatment plots are detectable at this scale.

adjacent to this site are dominated by relatively dense stands of mature jack pine and black spruce (mean of ca. 15 cm diameter). Jack pine dominates the dry uplands, while black spruce is more abundant in low-lying areas. The understory is comprised mainly of reindeer lichen (*Cladina* spp.), young white birch (*Betula papyrifera*), sedges (*Carex* spp.), wild sarsaparilla (*Aralia nudicaulis*), lingonberry (*Vaccinium vitis-idaea*), and lowbush blueberry (*V. myrtilloides*). The study plots were situated on an east-facing rocky slope where the soil organic layer was usually less than 5 cm deep. This site type is classified as 'jack pine-black spruce/lichen' by Zoladeski et al. (1995). Drainage ranges from excessive (on rocky slopes) to poor (depressions in the bedrock). The area as a whole is well-drained due to its sloping nature.

SITE 2 (sandy): This site is located at 55° 50'N, 98° 16'W, between poles 91 and 92 on the Thompson-Notigi Hydro-line right-of-way (**Fig. 2.2b**). This area is situated on a glacio-fluvial sandy ridge (lateral moraine), and experienced a forest fire in the mid-1960's (Veldhuis 1995). This site is topographically flat and well-drained, and is dominated by regenerating jack pine ca. 10-15 cm in diameter. The forest understory is comprised of red-stem moss (*Pleurozium schreberi*), reindeer lichens (*Cladina* spp.), labrador tea (*Ledum groenlandicum*), lingonberry (*Vaccinium vitis-idaea*), bearberry (*Arctostaphylos uva-ursi*), and lowbush blueberry (*V. myrtilloides*). This vegetation resembles the 'jack pine/feather moss' site type described by Zoladeski et al. (1995). The soil, which is classified as a eutric brunisol, is shallow to moderately deep and sandy. The organic layer is 6 to 15 cm thick. The site is well to excessively drained.

2.7 Climate

The continental climate of central Manitoba is noted for its short warm summers and long, cold winters. The southern border of the boreal forest corresponds with the mean January position of the Arctic front (Bryson 1966). The mean annual temperature at

Thompson (55° 48'N, 97° 52'W) is -3.3°C, ranging from -25.1°C in January to 15.6°C in July (**Fig. 2.3**). The mean daily temperature is below freezing for six months of the year, from November to April. There are ca. 126 frost-free days between May and September. The continental boreal forest usually experiences < 75 cm of total annual precipitation. The Thompson area receives an average of 53.6 cm, approximately two-thirds of which falls as rain during the summer months (Zoladeski et al. 1995). Forest fires are more frequent in the spring and summer months if the weather is hot and dry.

2.8 Disturbance

2.8.1 Fire

Catastrophic natural crown fires are the most important disturbance feature of the boreal forest ecosystem in central Manitoba. Between 1918 and 1989, an average of 394 fires per year have resulted in an average of 128 600 ha burned per year. The 1 147 fires that occurred during the spring and summer of 1989 burned 3.28 million ha, consuming 9% of the forested area in the province. In late April and early May, forest fires are usually caused by humans, while the fires that occur in July are primarily ignited by lightning strikes. Since precipitation generally increases in June, the frequency of forest fires decreases (Hirsch 1991).

Boreal forest fire frequency in central Canada averages from 50 to 100 years, but considerable variation occurs at the landscape level. Wetlands such as bogs, swamps and marshes burn less frequently, whereas well-drained upland sites are frequently burned (Johnson et al. 1995). In the boreal forest, a climax community may never be reached due to the frequency of forest fires (Archambault and Bergeron 1992). Burning creates a mosaic disturbance pattern at the landscape level, resulting in even-aged forest stands at different successional stages (Ritchie 1956). Forest fires result in soil litter loss and increased soil temperature and moisture loss. Burning may also result in a pulse of

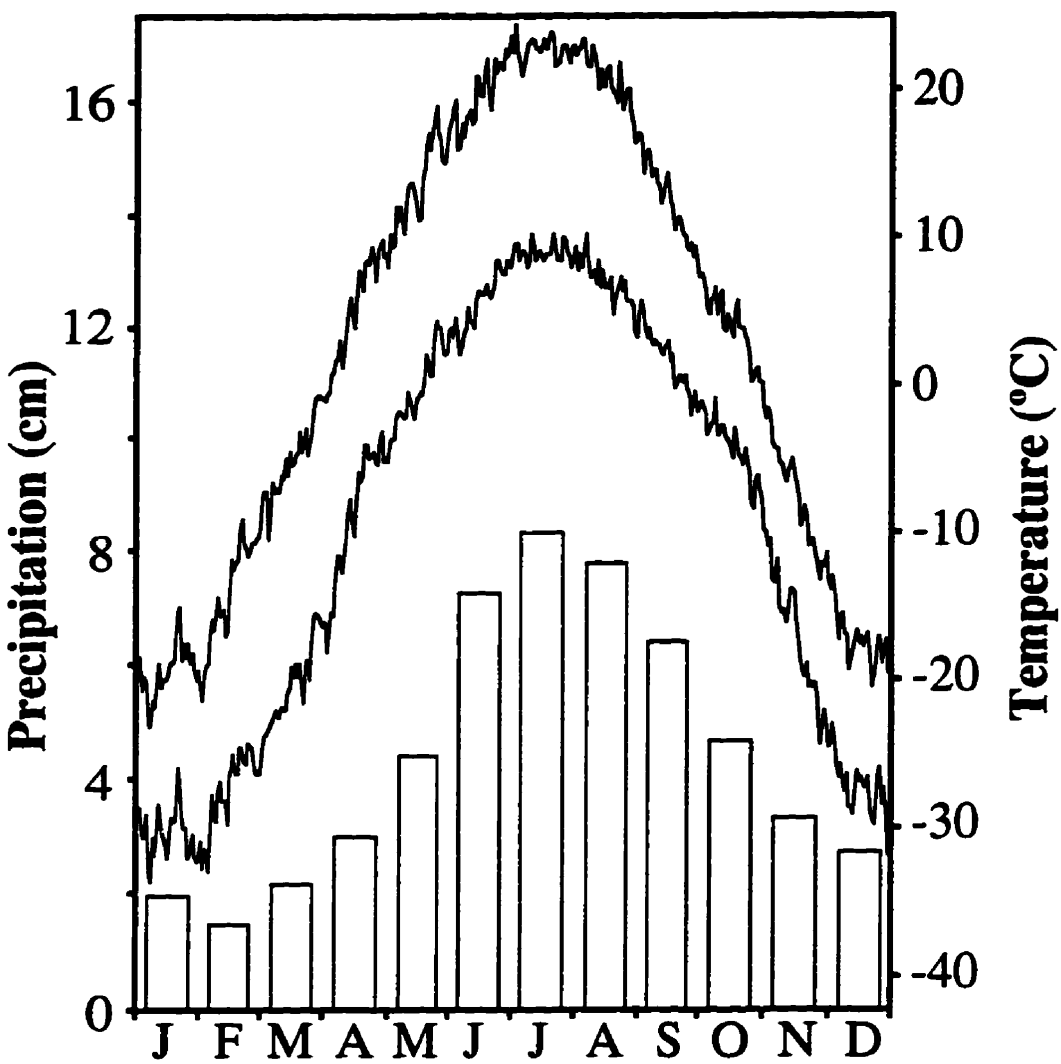


Fig. 2.3 Long-term (1967-1996) mean daily maximum/minimum temperatures (lines) and mean monthly precipitation (bars) for Thompson, Manitoba (from Environment Canada - Climate Services).

nutrients, although nitrogen is volatilized if temperatures exceed 400°C (Johnson 1992; Vierick 1983).

Boreal forest species show specific life-history adaptations to frequent and recurrent forest fires, including serotinous or semi-serotinous cones (e.g. jack pine, black spruce), clonal growth from underground roots-rhizomes (e.g. trembling aspen, white birch), and prolific seed production (e.g. balsam fir, white spruce). Many understory shrubs and herbs regenerate from underground parts following a fire (Johnson et al. 1995).

2.8.2 Herbivory

Large ungulates such as moose and woodland caribou are responsible for much of the grazing that occurs in the boreal forest of north-central Manitoba (Kenkel and Watson 1996). Rabbits and various insect and bird species browse on numerous understory plant species. Beavers are responsible for the felling of deciduous tree species (mainly trembling aspen), both for food and in the construction of dams. Bears, several birds and other mammals consume the fleshy fruits of many ericaceous shrubs, as well as raspberry, pin cherry, gooseberry and saskatoon.

2.8.3 Human Activity

Human activities are responsible for a number of disturbances in the boreal forest. In the Thompson area of central Manitoba, timber is harvested from accessible areas, natural forest fires are suppressed to protect northern communities and forestry operations, and mineral ore is extracted and processed. The by-products of mineral ore smelting may contribute to both aerial and groundwater pollution. In northern Manitoba, the diversion and impoundment of natural waterways for hydro-electric development have resulted in localized changes to the landscape.

Chapter 3 - Materials and Methods

3.1 Community Cooperation

Community based research methods have been used successfully in initiating scientific studies in rural and native communities (Ward 1996). The approach of modern society to research can often be invasive and authoritarian. The goal of community based research is to create a positive, non-exploitative, collaborative research environment that will benefit all participants. The researcher should act as a resource person or project facilitator who includes the values of the stakeholders in the process (Stringer 1996).

There are several examples of successful community based research. The Indian government has been promoting community forest management because traditional systems of forest management in India have proved to be more appropriate and resilient than non-traditional methods (Colchester 1992). The community based approach in forestry has been successful in developing relations between foresters and the local people. The success of the project depends on a functional and well-established decision-making system at a local level. Usually, potentially conflicting interests are reconciled by the provision of employment opportunities for the community members. 'Institution building' is being practiced by the government to improve communications so that the needs of the community can be met in an effective and sensitive way.

Locally, Dave Riddle (Historic Resources Branch, Archaeology) has been collecting archaeological artifacts from the beaches of flooded lakes in northern Manitoba since the implementation of the Churchill River Diversion project. Every summer, community members from Nelson House are hired to collect artifacts and be part of the crew. In turn, the selected members learn about their heritage and contribute to the historical collections. Most artifacts are stored at the Museum of Man and Nature (Winnipeg), but any artifacts recovered from burials are returned to the community along

with the human remains. This type of community-based research has been taking place for over 20 years.

Other examples can be discovered at the University of Manitoba. Richard Zeiba (1990) completed a Natural Resources practicum on the use of native herbs by healers of the northern Cree. Obtaining knowledge of traditional medicines required the establishment of a trusting relationship with native healers. This was accomplished by living with the community, developing good communication, and using community based research methods. Another community-based project was established with the residents of Carman, Manitoba, to revegetate an area of tilled farmland into a native mixed grass prairie. A graduate student, Dan Baluta, conducted experiments to determine the best seed mixture to maximize diversity and hired local students to maintain the plots. Finally, sustainable harvesting of alternative forest products is being examined by graduate student Shaunna Morgan in south-eastern Manitoba and western Ontario. With the cooperation of the local native communities, permanent experimental plots are being established to determine the long term effects of harvesting lowbush blueberries (*Vaccinium angustifolium*) and sweet flag (*Acorus americana*), in order to determine a sustainable harvesting intensity.

I adopted community based research methods in this study to gain support for the experiment, to expose community members to scientific methods that may benefit them in the future, and to learn more about the relationship between the people and their land. I used a combination of community based methods and experimental methods, and there were several advantages to taking this approach. The needs of the project were met through fostering contacts, generating interest, and creating awareness that the community would benefit from the project, both directly and indirectly. The community was also made aware that the project was being funded by Manitoba Hydro. I encountered some skepticism because the water impoundment projects of the 1970's have soured relations between Nelson House and Manitoba Hydro. I explained that Hydro often funds research projects, and emphasized that there were only good intentions. The only setback I encountered was

due to the "laid back" lifestyle of the community. The students were extremely helpful in the field and were able to carry out the tasks associated with the data collection, but they were sometimes unreliable. A relaxed approach is necessary to maintain good relations with the students, but it is also important to instill a sense of responsibility for the needs of the project.

It is important to be aware of culturally relevant gestures, such as tobacco offerings. The Rocky Cree culture consider tobacco offerings to be a gesture of respect. For example, tobacco is offered for a prayer, when plant medicines are collected or administered, or as a gesture of deep appreciation. These types of culturally relevant gestures can be beneficial in showing your respect for the community.

For my study, I sent a letter of introduction to various northern communities (Norway House, Split Lake, Nelson House, Cross Lake) by facsimile, and followed them up with telephone calls. I discovered that Cree is a verbal culture, and writing is a secondary form of communication. In certain communities, any activities that will directly affect its members must be approved by the chief and council. I made the leaders aware that I was planning a site survey of lowbush blueberry growth along the Manitoba Hydro-line rights-of-way in their area. Community leaders were given the opportunity to discourage or welcome a survey in their area. When I made personal contact with individuals from the community, I asked if they would be willing to share their knowledge about the blueberries growing in their area.

The Nelson House First Nation Band Council responded positively to my proposed study, and a contact person from the council was assigned to me. The council was aware that the community would directly benefit from the results of the study, and by the employment of summer students. Alice Moore (a community elder from Nelson House) had a camp near the Hydro line, where she used to pick blueberries with her family. She thought that studying the blueberries was a good idea, and welcomed me to use that site for my experiment. I offered her a gift of tobacco in return for her hospitality.

Eileen Moody, a high school student from the community, was hired for a period of four weeks in 1995 to help in plot establishment and baseline data collection. Two field assistants, Kathleen Francois and Sheldon Prince, were hired for an eight-week period in the summer of 1996. Wayne Francois (Natural Resource Officer, Nelson House) and local resident Malcolm Peterson volunteered their time to help with the spring burn trails.

I stayed with a family in Nelson House during the two field seasons and rented their vehicle for field work. I found that becoming part of the community was essential for generating interest in my project, and gaining cooperation and assistance from community members. Leonard Linklater of the Nelson House Development Corporation has even expressed interest in pursuing the marketing potential of non-timber forest products, including wild lowbush blueberries.

3.2 Surveys of Lowbush Blueberry Habitat

3.2.1 Aerial Hydro-Line Survey

On August 20, 1996, the Manitoba Hydro Line Maintenance Office in Thompson arranged for an aerial line survey by helicopter. My field assistant and I surveyed the right-of-way from site 2 to Laurie River, looking for optimum wild lowbush blueberry habitats (i.e. sandy areas dominated by jack pine, rocky outcrops, and recently burned areas) that were reasonably accessible.

3.2.2 Post-Fire Regeneration of Lowbush Blueberries

On September 17, 1996, the Manitoba Department of Natural Resources arranged a trip to the Tin Can Lake area, which is situated ca. 80 km north of Thompson. The lake is accessible only by float planes and snowmobiles. This site is located on a sand esker and experienced a natural forest fire in 1984. It is dominated by regenerating jack pine and an understory of lowbush blueberry. Some of the esker lakes in this area are being stocked with trout for recreational purposes. Since the area is well known for its abundance of wild

blueberries, I was invited there by Dave Riddle (part-owner of the trout farm) who is interested in managing these wild blueberry stands. To estimate the productivity of this area, I obtained percent cover estimates and stem counts of lowbush blueberry from ten randomly placed 1x1 m plots. Unfortunately, it was too late in the growing season to obtain estimates of fruit production.

3.3 Lowbush Blueberry Management Experiment

3.3.1 Site Selection

I selected my two study sites based on rights-of-way accessibility (most lines in northern Manitoba are only accessible by helicopter, snowmobile, or all-terrain vehicle), an adequate lowbush blueberry cover (at least 20%), and proximity to the Nelson House First Nation. I also attempted to find sites that were representative of the different lowbush blueberry habitat types in the area (rocky outcrops, well-drained sandy sites) (See Chapter 2).

3.3.2 Schedule

- June 1995: Initial site survey, including locating study sites, establishing and enumerating the experimental plots, and experimental design and assignments.
- July 1995: Baseline data collection, including productivity and cover values of lowbush blueberry and associated vegetation.
- August 1995: Fall data collection, including berry harvesting, soil sample collection for seed bank germination trials, stem cuttings for vegetative propagation trials, and administering fall clip treatments to plots.
- May 1996: Application of spring management treatments to plots, including burning, mulching, clipping, and fertilizer application.
- July 1996: Summer data collection, including soil samples for nutrient analysis, and stem cuttings for vegetative propagation trials.

- August 1996: Fall data collection, including final plot enumeration (productivity data and cover values) and berry harvesting (unpruned plots only).

3.3.3 Experimental Design

Based on a literature review of the management of wild lowbush blueberry stands in eastern Canada, I selected eight treatments (seven management methods plus a control; see Section 3.3.4). At each of the two study sites, an experiment was set up using a replicated randomized block design. Each experimental block was 13 x 13 m in size, and was located in an area of relatively uniform lowbush blueberry cover. There were 16 blocks at site 1 (rocky), and 20 at site 2 (sandy). Nine 2 x 2 m plots, at least 1 m apart, were located in each block. These nine plots were located in areas of moderate lowbush blueberry cover. The seven management methods were randomly assigned to the plots, with the remaining two plots serving as controls. Data were collected from two randomly selected 1 x 1 m subplots within each plot. A typical experimental block is illustrated in **Fig. 3.1**. The layout of the experimental blocks at each site is shown in **Figs. 3.2** and **3.3**.

3.3.4 Management Treatments

Note: the abbreviations following the treatment description (in brackets) are used in Chapter 4 (Results).

1. **Fertilization** (FERTI) may result in increased vegetative growth, allowing a lowbush blueberry clone to expand and outcompete the other vegetation. However, fertilization may stimulate the growth of competing species as well. The rate of nutrient addition must be low since blueberries are poor competitors. A 17-17-17 (N-P-K) slow-release fertilizer was suggested by Leonard Eaton of Nova Scotia, at a rate of 120 g per 2 x 2 m treatment plot. Border Chemicals of Winnipeg donated the product. I applied the fertilizer to all plots on May 29, 1996.

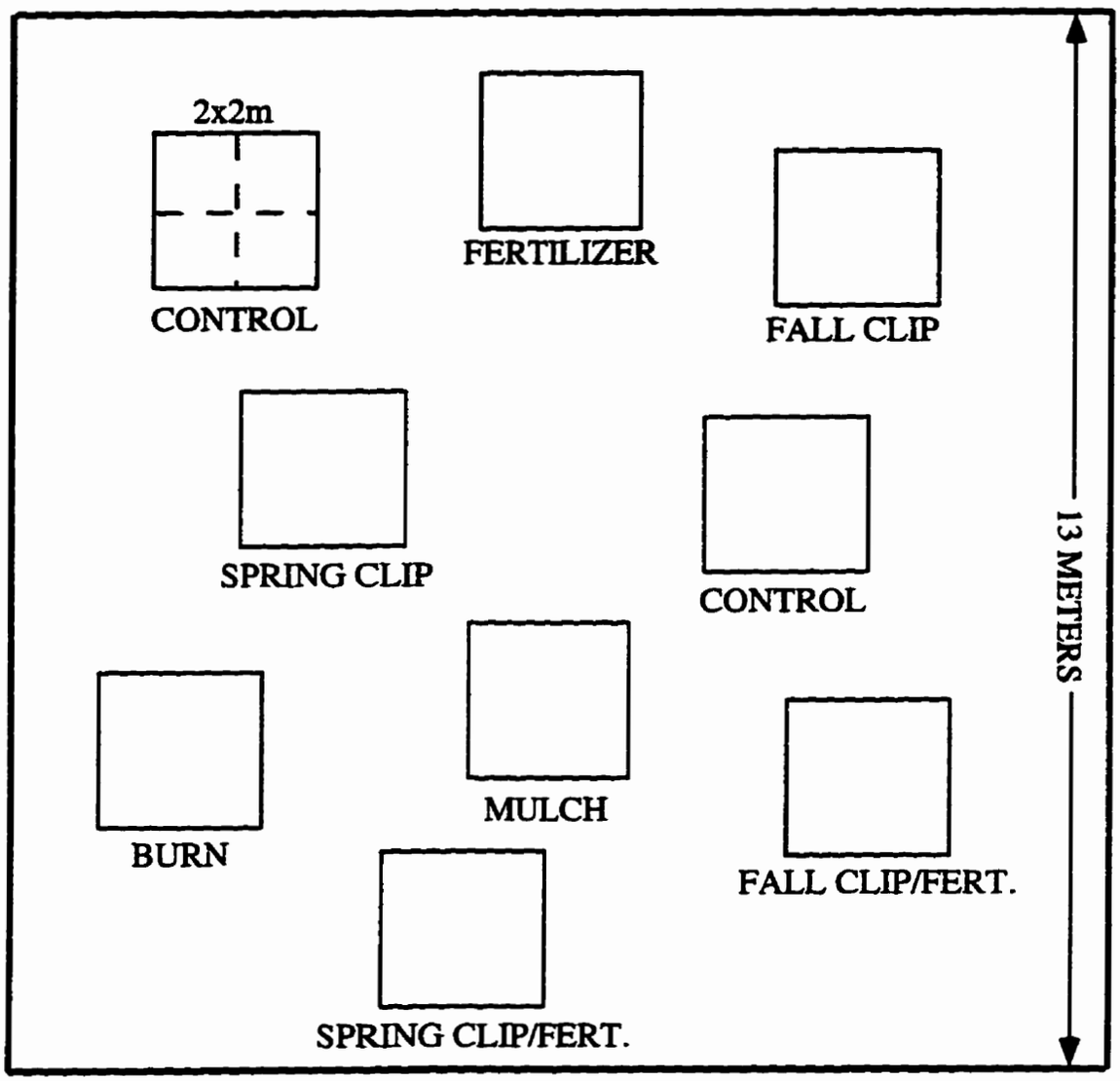


Fig. 3.1 An example of the randomized block design used in the lowbush blueberry management treatment experiments. All treatments were randomly assigned to the $4m^2$ plots and the two $1m^2$ sample plots were randomly selected within each treatment plot.

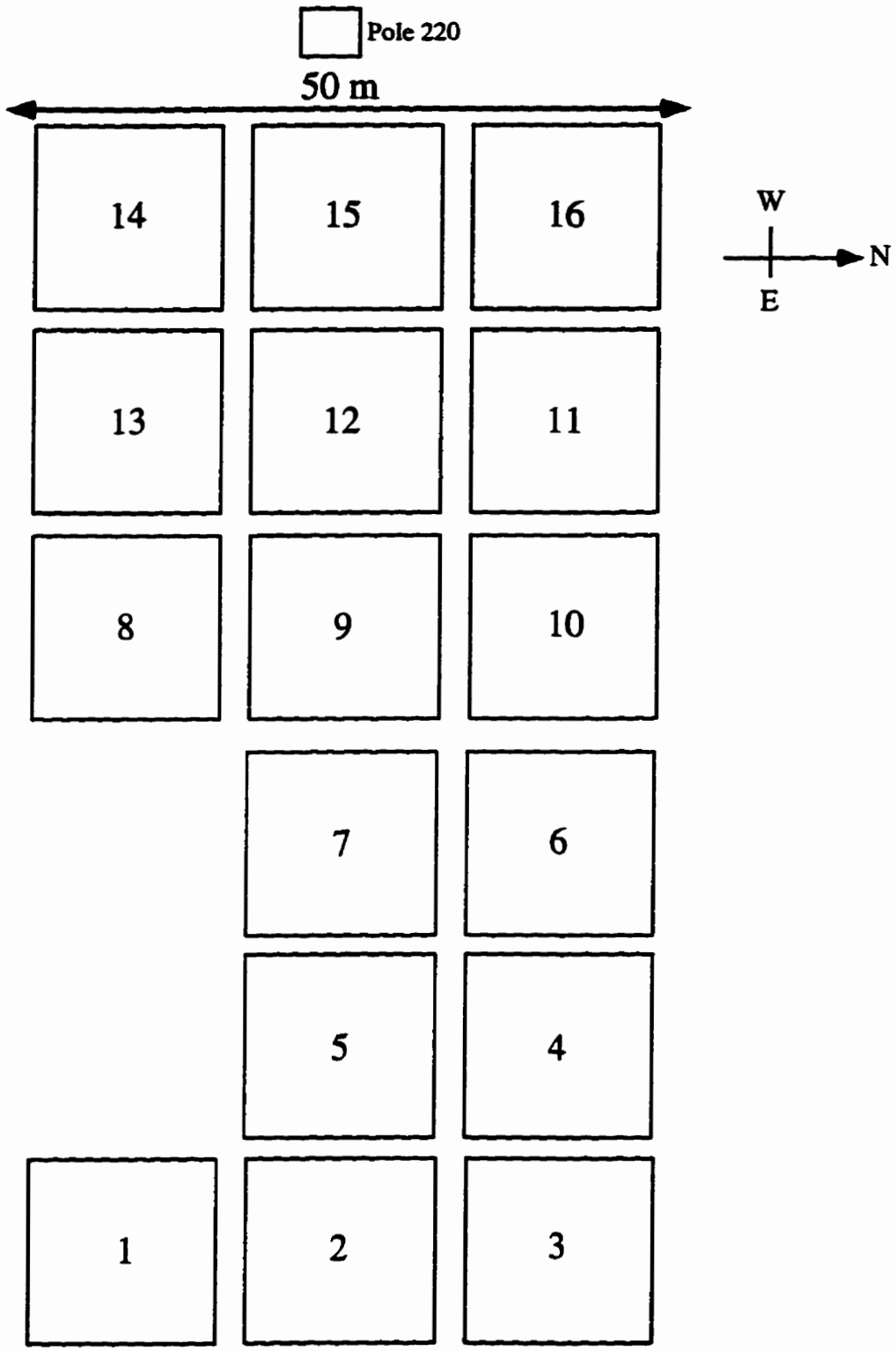


Fig. 3.2 The layout of the experimental blocks for the lowbush blueberry management treatments at site 1 (rocky). Block 1 begins at the bottom of an east facing slope, and block 16 is located at the top of the slope.

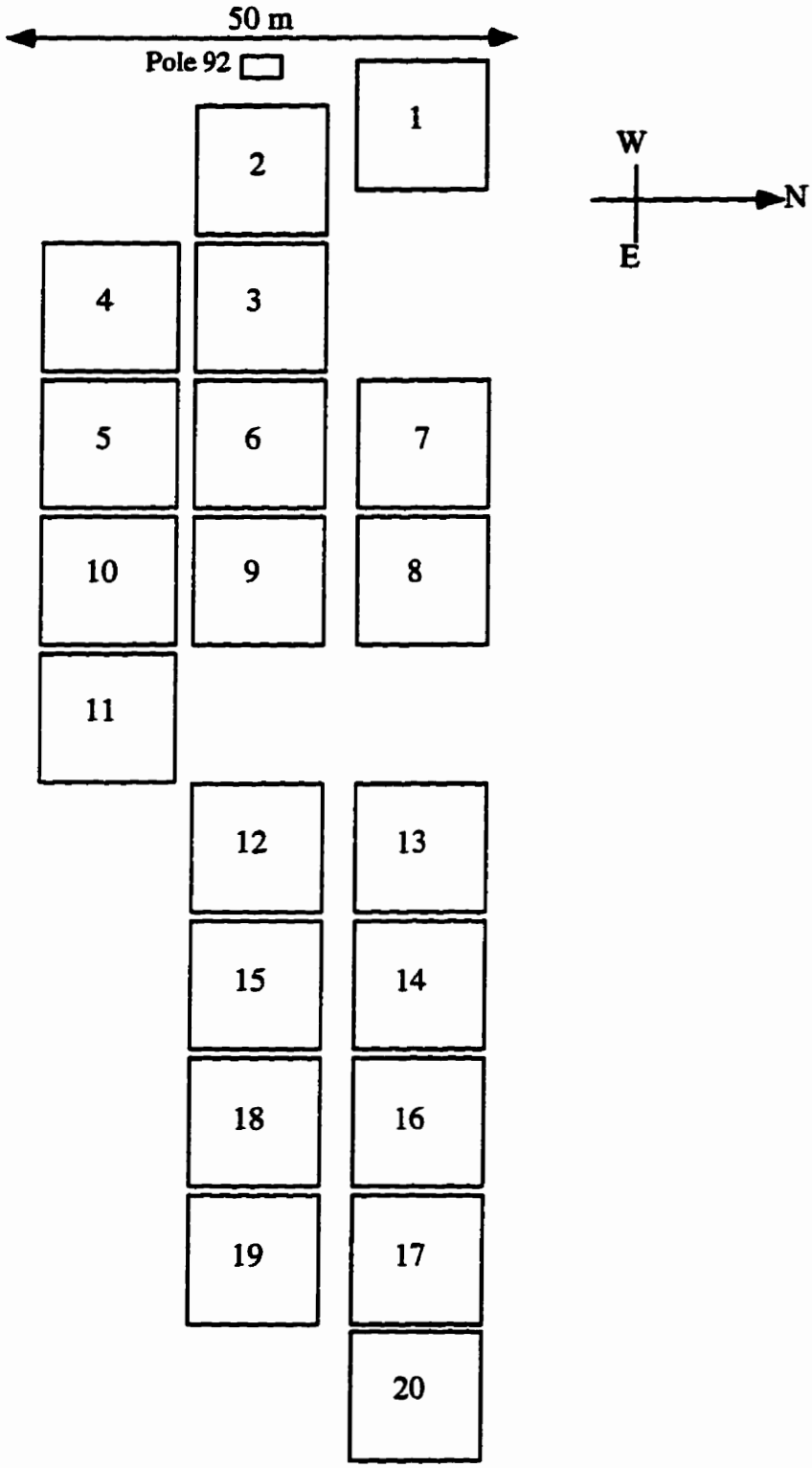


Fig. 3.3 The layout of the experimental blocks for the lowbush blueberry management treatments at site 2 (sandy). The access trail is located on the north side near pole 92.

2. **Clipping vegetation in the fall** (FALCL) may stimulate branching of lowbush blueberry plants in the following spring, allowing them to outcompete other vegetation. However, this management technique may also stimulate the growth of competing graminoid species. The vegetation was clipped to a height of 2 cm using hedge trimmers. Clipping took place between August 15 - 19, 1995, after the berries were harvested.
3. **Clipping vegetation in the spring** (SP.CL) stimulates branching in that season, and may allow lowbush blueberries to outcompete species that are less tolerant of pruning. On May 29, 1996 the vegetation was clipped to a height of 2 cm using hedge trimmers.
4. **Applying sawdust mulch** (MULCH) to the plots may result in increased soil moisture retention. This in turn increases fruit biomass and helps prevent fruit desiccation in the event of a late summer drought. Conifer sawdust mulch was collected from Norwest Manufacturing of Thompson, and was placed into large plastic bags. Each bag held ca. 100 litres of sawdust, which converts to a thickness of ca. 2.5 cm on each 2 x 2 m plot. The plastic bags were picked up by the line maintenance crew in a Flex-Track and dropped off at each of the sites. The mulch was applied on May 30-31, 1996.

   An irrigation treatment was initially planned, by using make-shift cisterns or pumping water from a nearby lake or stream. This proved impractical, however, and the mulching treatment was used instead.
5. **Burning** (BURN), a common management practice in eastern Canada, mimics the natural disturbance of forest fires. Burning in the spring (when there is still snow in the adjacent forest) stimulates regrowth from underground rhizomes by killing the aboveground portion, which in turn increases fruit productivity in the following years. No fruit is produced in the year of the burn. Burning was conducted using a 2 inch diameter hand-held Tiger torch with a pressure regulated 20 lb. product propane tank.

The intensity of the burn depends on several factors, including the mass of the tank, the tank temperature at the time of burning, the distance of the torch head from the ground, and the regulator pressure reading. These factors were held constant to ensure that burn intensities across plots were nearly identical. Uncontrollable factors such as soil and air temperature and moisture affect the burn temperature as well. Burning should only be conducted in the morning or early evening when winds are calm.

Plots at Site 1 (rocky) were burned on May 23, and those of site 2 (sandy) on May 27, 1996. Dead wood was first cleared from the plots so that it would not ignite. Tank pressure was maintained at 5 psi. The torch was held ca. 15 cm from the ground. Once the plants had ignited and burned to the ground, the fire was stamped out or doused with a back can. The wind was gusting at times during the site 1 burn, which hampered fire extinguishing. Despite this, no plot burned for more than one minute. Waxes of different melting temperatures were used to estimate burn temperature at ground level. The estimates ranged from 107° to 163°C.

6. **Fall clipping and fertilizer addition** (FAFER) the following spring may mimic the effects of burning. I clipped the plots following the berry harvest in August, 1995 and applied fertilizer on May 28-30, 1996.
7. **Clipping and adding fertilizer in early spring** (SP.FE) may also mimic the effects of burning. The fall and spring clips were conducted to determine whether the timing of the clipping treatment affects the results. Clipping and fertilizer addition were undertaken in late May of 1996.
8. **Control** (CONTR) plots were left untreated. Control plots are useful in determining seasonal and year-to-year effects in the absence of a treatment perturbation. In this study, the control plots were used to help determine the effectiveness of the management treatments.

3.3.5 Data Collection

After the experimental plots were established in 1995, baseline data from each plot were collected to determine lowbush blueberry productivity and vegetation cover prior to the application of the management treatments. The same information was collected again in the fall of 1996, after the management treatments had been applied.

Lowbush blueberry productivity was determined in each 1 x 1 m subplot by estimating percentage plant cover, counting the number of stems, determining the number of flower buds, and measuring the fresh biomass of berries. The number of flowering buds was counted as the berries were being harvested in mid-August. Percent cover estimates of associated plant species were also determined in each subplot in both 1995 and 1996. Voucher plant specimens were also collected.

3.3.6 Data Analyses

In each experimental subplot (1 x 1 m), productivity values were recorded both before (1995) and after (1996) the application of the management treatments. Plot-replicate values for each block were determined by averaging the two subplot values (four subplots in the case of the control). First-order differences were then computed for each plot-replicate ($Mean_{1996}$ - $Mean_{1995}$), to determine the specific response to a given treatment. For example, a first-order difference less than zero indicates that the treatment had a negative effect on productivity. First-order differences for each plot (over all treatments) were then ranked, and a Kruskal-Wallis non-parametric analysis of variance (ANOVA) was used to determine whether there were significant differences between the management treatments. The test statistic is referred to a chi-squared distribution with $n - 1 = 7$ degrees of freedom. A ranked (non-parametric) statistical test was used since the first-order differences could be negative or positive values, and because the data were not normally distributed. Separate analyses were undertaken on the stem counts and percent cover estimates of lowbush blueberry. Berry production and flowering buds could not be used to

assess productivity, since pruned treatments (burning, clipping) do not produce a berry crop in the year of the treatment.

The data were also summarized graphically using boxplots. In a boxplot, the outlined central box delineates the 50% range of the data (25th to 75th percentiles). A horizontal line within this central box denotes the median value. The 'whiskers' above and below the box represent the extent of the main body of the data. Extreme outliers are separately plotted as circles, while very-extreme outliers are plotted using an asterisk. The boxplots were used to visually compare the treatment results to those of the control plots. The relative frequencies of positive, negative and zero first-order differences were also computed and tabulated to aid in the comparison of management treatments.

Percent cover values for associated species in the plots were also determined in 1995 and 1996. This information was used to compute overall mean species cover values in order to characterize the two sites. In addition, first-order differences were computed for species occurring frequently in the plots. These differences were used to determine the effect of the management treatments on potential competitors. The sedges (*Carex* spp.) and three-toothed cinquefoil (*Potentilla tridentata*) were tested. A non-parametric ANOVA was used to test whether the management treatments positively or negatively affected the cover of these potential competitors.

3.4 Soil Analysis

Two soil cores were collected from each site at the end of July 1996 for nutrient analysis. These samples were at least 500 ml in volume and were collected from the top 15 cm of the soil profile in non-treated plots. Nutrient nalysis was undertaken by Norwest Labs, Winnipeg. Each core was analyzed for total nitrate, available phosphate, potassium, sulphate, calcium, sodium and magnesium. Soil pH, salinity and organic matter content were also determined. The results obtained were compared to the soil recommendations

given by the Atlantic Horticultural Crops Committee (1985) for lowbush blueberries, to determine whether the sites were nutrient-limited.

3.5 Population Biology of Lowbush Blueberry

3.5.1 Soil Seed Bank

Two surface soil samples were collected from each experimental block (32 samples from site 1, 40 samples from site 2). These samples were collected by carefully scooping ca. 250 ml of surface material into a sealed plastic bag. Each soil sample was spread over a 2:1:1 mixture of perlite, peat and greenhouse soil placed in 15 cm diameter plastic pots. The pots were then placed in the Botany Department (University of Manitoba) greenhouse and watered regularly. Emerging seedlings were marked and identified to species. One set of soil samples was germinated immediately, while the second set was first stored for three months in a cold room to simulate overwintering conditions.

3.5.2 Phenology

Over the two field seasons (1995 and 1996), I recorded the timing of important phenological events (e.g. leaf-out, flowering) in native lowbush blueberry stands at the two sites. In 1996, separate phenological profiles were recorded for the pruned (burning, clipping) treatments.

3.5.3 Leaf Area Index

The 'leaf area index' (LAI) is used to estimate the total surface area of leaves for a given surface area of ground (Begon et al. 1996). In general, greater LAI values indicate higher potential primary productivity. However, very high LAI values indicate self-shading and reduced potential productivity. Leaf pattern and leaf angle also affect the actual productivity per unit of surface area. I collected all the leaves of lowbush blueberry from a 100 cm^2 area (three areas per site), and estimated the leaf surface area by fitting them on a

sheet of metric graph paper and calculating the surface area occupied. Even though the leaves were fit closely together, there were still spaces between the leaves. I therefore estimated a percent cover of the total area they occupied on the graph paper to obtain the final surface area value.

3.5.4 Reproductive Allocation

Mean fresh biomass values (expressed as kg/ha) were determined for berries harvested from the experimental plots in August of 1995 and 1996. A larger sample was available in 1995 since the pruned treatment plots (burning, clipping) did not produce berries in 1996. Berry productivity was compared to those of commercial fields in eastern Canada.

3.5.5 Above to Below-ground Biomass Ratio

I harvested the above and below-ground biomass of lowbush blueberries from three 100 cm^2 areas at each site on July 20, 1996. The plant material was carefully sorted into above and below-ground parts, dried, and massed. The above to below-ground biomass ratio was then calculated. A biomass ratio < 1 indicates that the majority of the plant's energy is stored below ground (in lowbush blueberries, mainly the rhizomes).

3.6 Lowbush Blueberry Propagation Experiments

Although managing extant ('wild') stands of lowbush blueberries is simpler and more cost-effective than planting new fields, future endeavours may include greenhouse propagation experiments to create more cold-hardy strains of lowbush blueberry, to establish plantings in other areas, or to increase the genetic diversity of natural stands. For these reasons, preliminary propagation experiments were undertaken as part of this project.

3.6.1 Seed Collection and Germination Experiments

Seeds were extracted from fresh berries collected from the experimental plots. Separation of the pulp from the viable seed was accomplished by blending a mixture of fresh berries and water (Morrow et al. 1954). After several washings, the viable seed sank to the bottom of the blender. The seeds were then removed from the blender and dried overnight. The dried seeds were separated into fractions using 600, 590 and 500 μm screens. Only the 600 μm fraction was used, since it has been previously demonstrated that the larger seeds germinate at a higher rate (Aalders et al. 1980).

In September 1995, I placed 25 seeds in each of five sterilized glass petri dishes lined with moistened filter paper. The petri dishes were sealed and placed in a controlled environment growth chamber at 18°C, and with 16 hours of light and 8 hours of dark. After six weeks, percent germination was recorded, and the germinated seedlings were transplanted into clay pots and grown in the greenhouse for three months.

I also attempted seed germination in 10 clay pots containing a 1:1 peat to vermiculite mix (Aalders et al. 1980). Native soil collected from site 2 was added to five of the pots. Each pot contained 125 seeds. The pots were placed in the greenhouse for six weeks and then in a darkened cold room for two months (mid-November 1995 to mid-January 1996) to 'winter-harden' the germinated plants and stimulate bud formation. The hardened plants were grown in the greenhouse for three months.

In 1996, I planted lowbush blueberry seeds into greenhouse flats containing a 1:1 peat to vermiculite mix. The soil was fertilized with 22.5 g of 10-40-10 N-P-K fertilizer (6% nitrate N, 4% ammonia N), 22.5 g of 0-40-0 phosphate (P_2O_5), and 5 g of iron chelate (Aalders and Hall 1979). Six hundred seeds were mixed with fine sand and carefully distributed over the soil. The flats were watered daily and covered with a transparent lid to prevent excessive evapotranspiration. After eight weeks, I placed the flats in a darkened cold room for two months (mid-November 1996 to mid-January 1997). The trays were

then placed in the greenhouse for three months, and the emerging seedlings were marked and counted.

3.6.2 Vegetative Propagation (Stem Cuttings)

Stem cuttings were taken from lowbush blueberry clones in August 1995 and July 1996, just prior to late summer dieback. In 1995, I took a small number of cuttings (three pots, 10 cuttings per pot) to determine the most appropriate of three commercially available rooting media (1 - soft wood, 2 - semi-soft wood, 3 - hard wood). Using a sterilized scalpel, shoots were cut from a branch or stem and the lower one-third of the leaves removed. The rooting end was then dipped in the rooting medium and the cuttings were planted into peat. Each pot was covered with a plastic bag to prevent excessive evapotranspiration. After six weeks, the rooting ends of all stem cuttings were examined. It was found that rooting medium no. 3 resulted in the greatest amount of root development. The remaining stem cuttings (six pots with 20 stems per pot) were therefore planted using rooting medium no. 3 and monitored in the greenhouse for 3 months.

In July 1996, the collected stem cuttings were planted according to the methods outlined in Hall et al. (1978). No rooting medium was used, and the cuttings were placed in greenhouse flats instead of pots. The soil used was a 1:1 mixture of moist sand and peat. The flats, containing 11 rows of 10 cuttings each, were watered every day for four months.

Chapter 4 - Results

4.1 Surveys of Lowbush Blueberry Habitat

4.1.1 Aerial Line Survey

The objective of the line survey was to locate accessible areas of high lowbush blueberry cover within the study region. Major vegetation cover and physiography were used to determine the location of lowbush blueberry stands. Specifically, the presence of jack pine and rock outcrops were used as indicators of potential blueberry habitat. Jack pine stands, which occur in dry, sandy habitats favoured by lowbush blueberry, were easily distinguishable from those dominated by black spruce and/or deciduous tree species. Black spruce generally occurs in poorly-drained, peat-dominated habitat. Mixed coniferous-deciduous forests, which often occur on fine-textured clay-loam substrates, are dominated by black spruce and trembling aspen in the canopy and by graminoids, forbs and tall shrubs in the understory. Lowbush blueberry may occur in such sites, but at low cover.

The right-of-way between site 2 and the Nelson House junction passes through a region dominated by black spruce bogs at various stages of succession. Such areas are not suitable lowbush blueberry habitat. Other than site 1, there is no road access to areas of high blueberry cover along the right-of-way between the Nelson House junction and Notigi Dam. The right-of-way north-west of Notigi Dam passes over numerous granitic rock outcrops that are suitable lowbush blueberry habitat. A recently burned area ca. 6 km past Notigi (at pole 102) is accessible by road. Approximately half the length of the right-of-way between Notigi to Laurie River was burned in 1995. Much of this area has considerable potential for lowbush blueberry harvesting and management.

Accessibility to productive lowbush blueberry stands in northern Manitoba is the single largest factor limiting their management and harvest potential. Helicopter access into remote sites is possible, but the cost is prohibitive (ca. $600 per hour of air time).

4.1.2 Post-Fire Regeneration of Lowbush Blueberries

The camp that I visited is located on Tin Can Lake (ca. 80 km north of Thompson), in an area that was burned 12 years ago. The site is a sand esker dominated by regenerating jack pine. In September 1996, the jack pine saplings were ca. 2 m tall and were just beginning to shade out the understory, which is currently dominated by lowbush blueberry (**Fig. 4.1**). Percent cover and productivity values of lowbush blueberry at this site are much greater than in study sites 1 and 2. Mean lowbush blueberry cover is 57 ± 24% (n=10), and there is an average of 42 ± 19 stems/m^2. The mean percent cover and stem numbers for site 1 are 19 ± 15% and 35 ± 25 stems/m^2 (n=288) respectively. Site 2 has a mean cover value of 16 ± 11% (n=360) and mean stem numbers of 41 ± 22 stems/m^2. These results indicate that lowbush blueberry stands in northern Manitoba remain highly productive for at least 12 years following a fire. I could not estimate fruit productivity at this site since most of the berries had already been collected by the time of my visit. However, based on the most productive plots in study site 1, I estimate a minimum annual fruit productivity at Tin Can Lake of ca. 1 300 kg/ha (possibly much higher). The owners of the camp had observed high annual blueberry productivity in the three years since the area was developed.

David Riddle and Leroy Francois manage a trout farm located on the Tin Can Lake site. The lakes in this area have been artificially stocked with trout species. Dave and Leroy have indicated an interest in the sustainable management and harvesting of the lowbush blueberry stands in the area. This camp is being developed as a multi-recreational tourist facility (i.e. fishing, canoeing, dog-sledding, wildlife-watching).

4.2 Lowbush Blueberry Management Experiment

4.2.1 Description of Associated Vegetation

The plant species recorded in the study plots, together with relative frequency and mean cover values (± 1 s.d.) at each site, are presented in **Table 4.1**. Additional species

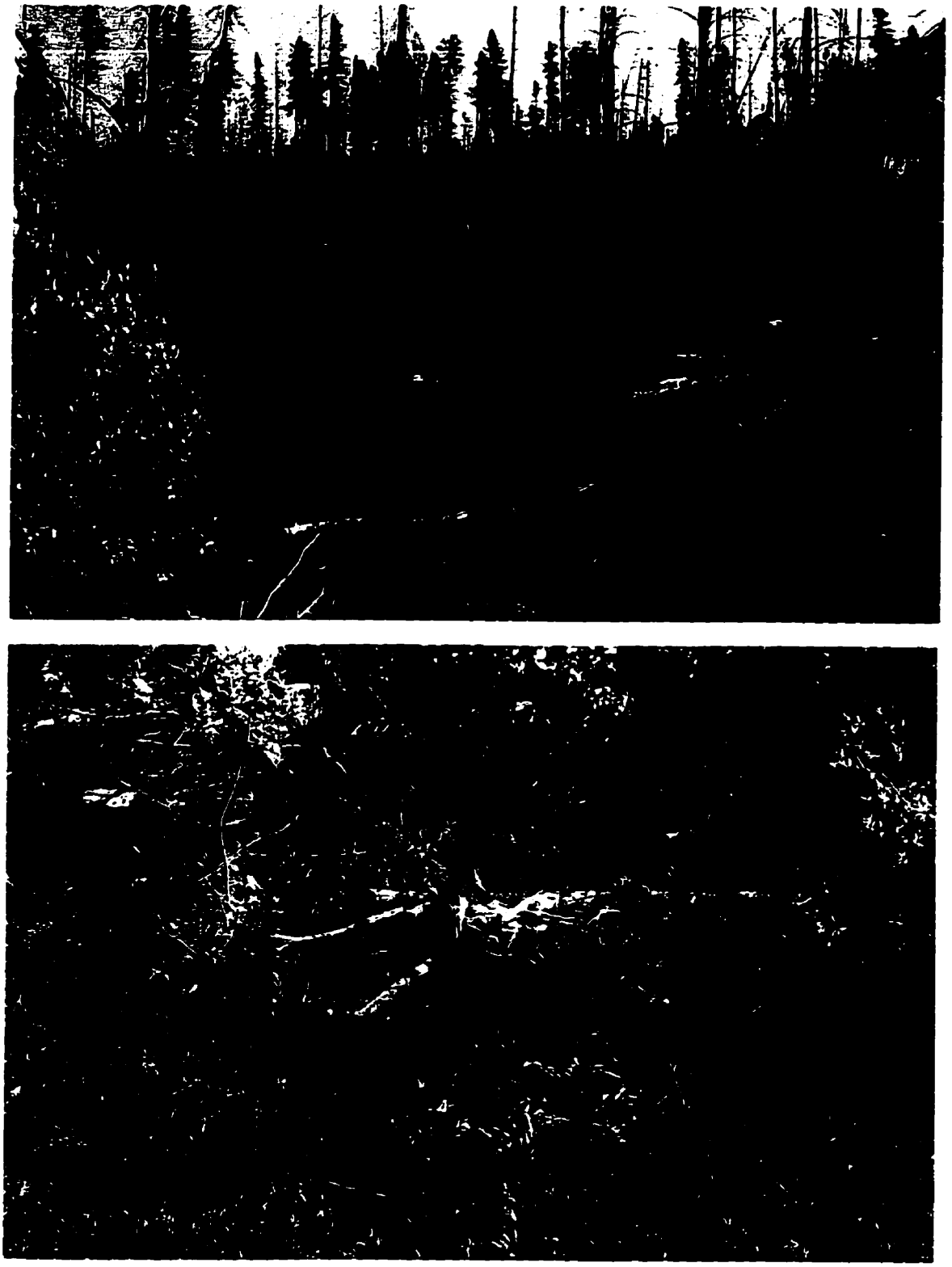


Fig. 4.1 Photos of a jack pine regeneration site at Tin Can Lake, Manitoba, in September 1996. This area experienced a forest fire in 1984 and the understory has a high cover of lowbush blueberry plants (the shrubs with red leaves).

Table 4.1 The mean percent cover values (± 1 s.d.) of the associated vegetation, and the relative frequencies, calculated from control plots of 1995 and 1996 data.

		Site 1 Cover			Site 2 Cover		
Species	**Common Name**	**Mean**	**S.D.**	**R.F.**	**Mean**	**S.D.**	**R.F.**
Vaccinium myrtilloides	lowbush blueberry	17.30	16.72	0.80	17.07	11.33	0.98
Cladina spp.	reindeer lichens	31.98	27.88	0.77	22.11	18.43	0.68
Vaccinium vitis-idaea	lingonberry	0.88	3.65	0.08	7.56	9.43	0.68
Carex spp.	sedges	1.38	4.14	0.17	6.54	11.36	0.53
Cornus canadensis	bunchberry	0.06	0.50	0.02	5.88	8.42	0.54
Pleurozium schreberi	red-stem moss	12.25	9.91	0.12	15.78	12.51	0.4
Dicranum polysetum	wavy dicranum	11.64	6.87	0.12	12.68	9.21	0.37
Agrostis scabra	rough hair grass	0.10	1.10	0.35	0.83	4.33	0.1
Potentilla tridentata	three-toothed cinquefoil	6.76	11.60	0.40	0.01	0.21	0.01
Maianthemum canadense	wild lily-of-the-valley	0.89	4.28	0.06	1.61	3.76	0.25
Epilobium angustifolium	fireweed	0.46	2.39	0.08	0.94	3.14	0.18
Populus tremuloides	trembling aspen	3.06	8.34	0.20	0.12	1.27	0.02
Aralia nudicaulis	wild sarsaparilla	1.57	4.64	0.19	–	–	–
Pinus banksiana	jack pine	0.37	5.41	0.01	0.72	4.64	0.13
Rubus idaeus	wild raspberry	0.73	3.03	0.10	–	–	–
Betula papyrifera	white birch	1.36	8.73	0.04	0.66	5.53	0.04
Salix discolor	diamond willow	1.14	7.90	0.05	0.21	3.10	0.02
Ledum groenlandicum	labrador tea	0.86	6.35	0.03	0.47	3.26	0.03
Crepis tectorum	hawk's beard	0.23	1.25	0.05	–	–	–
Calamagrostis inexpansa	northern reed grass	4.95	12.50	0.02	–	–	–
Prunus pensylvanica	pin cherry	0.12	1.44	0.01	–	–	–
Picea mariana	black spruce	0.08	1.23	0.01	0.03	0.56	<0.01
Ribes triste	red currant	0.03	0.36	0.01	–	–	–
Corydalis sempervirens	pink corydalis	0.03	0.31	0.01	–	–	–
Fragaria virginiana	wild strawberry	0.01	0.17	0.01	–	–	–
Rosa acicularis	wild rose	–	–	–	0.10	1.16	0.01
Amelanchier alnifolia	saskatoon	0.01	0.24	<0.01	–	–	–
Sonchus arvensis	sow thistle	–	–	–	0.01	0.21	<0.01
Equisetum sylvaticum	woodland horsetail	–	–	–	0.00	0.07	<0.01

found along the rights-of-way but not recorded in the plots include *Saxifraga tricuspidata, Pyrola asarifolia, Polygonum cilinode, Ribes hirtellum, Lycopodium obscurum, Vaccinium caespitosum, Oryzopsis asperifolia, Agrostis scabra, Achillea millefolium, Antennaria aprica,* and *Geum aleppicum* var. *strictum*. A number of bryophyte and lichen species were also encountered. However, in this study only the most common and abundant species (*Pleurozium schreberi, Dicranum polysetum, Cladina* spp., *Cladonia* spp.) were recorded.

A brief summary of the associated vegetation at each study site is presented below:

Site 1 (rocky)

The dominant species at this site were lichens (*Cladina rangiferina, Cladina stellaris, Cladina mitis, Cladonia* spp.), lowbush blueberry (*Vaccinium myrtilloides*), three-toothed cinquefoil (*Potentilla tridentata*), and purple reed grass (*Calamagrostis purpurascens*). Common associates include red-stem moss (*Pleurozium schreberi*), wavy dicranum (*Dicranum polysetum*), sedge (*Carex siccata*), wild lily-of-the-valley (*Maianthemum canadense*), lingonberry (*Vaccinium vitis-idaea*), and wild sarsaparilla (*Aralia nudicaulis*). Saplings of trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), jack pine (*Pinus banksiana*), and black spruce (*Picea mariana*) occurred along the right-of-way.

Site 2 (sandy)

The dominant species at this site were lichens (*C. rangiferina, C. stellaris, Cladonia* spp.), lowbush blueberry (*V. myrtilloides*), red-stem moss (*Pleurozium schreberi*), lingonberry (*V. vitis-idaea*) and bunchberry (*Cornus canadensis*). Common associates include fireweed (*Epilobium angustifolium*), sedges (*Carex siccata, C. houtoniana, C. brunnescens*), and wild lily-of-the-valley (*M. canadense*). Saplings of trembling aspen (*Populus tremuloides*), pussy willow (*Salix discolor*), white birch (*Betula papyrifera*), jack pine (*Pinus banksiana*), and black spruce (*Picea mariana*) are occasionally encountered along the right-of-way.

4.2.2 Management Treatments

The results from the control plots show the background variation in cover and stem numbers in response to variables other than the treatments. A treatment response can be detected when there is an increase or decrease in stem numbers or cover values relative to the control. Stem counts essentially measure the new growth from rhizomes or stem buds, while cover is a relative measure of stem vigour. An effective treatment is determined by an increase in either parameter, but the most effective treatment is that which increases both stem numbers and cover values. Such a result would indicate that the treatment stimulates new growth from rhizomes or stem buds, and increases the vigour of these new shoots.

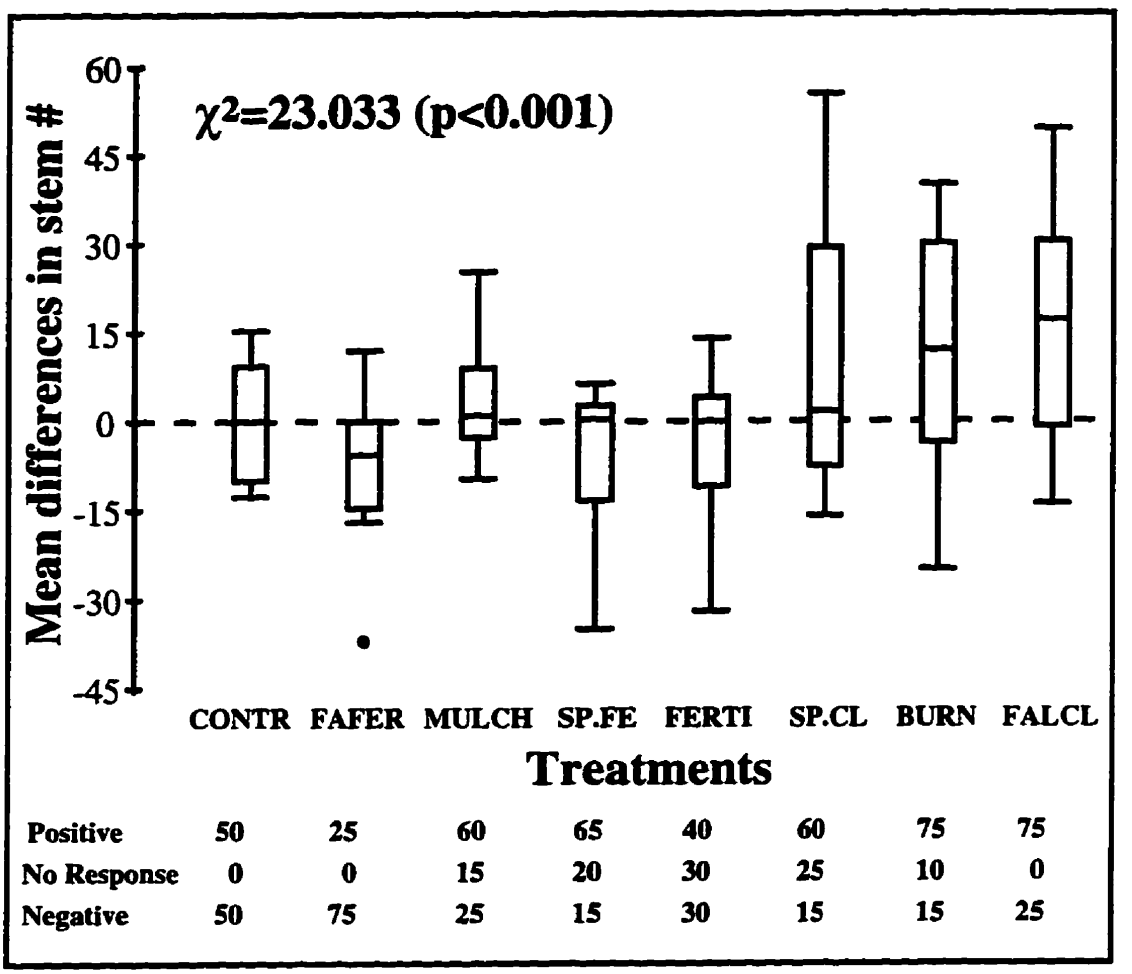
Site 1 (rocky)

(a) Stem Counts (Lowbush Blueberry): The Kruskal-Wallis non-parametric ANOVA indicated that there were significant differences in stem numbers between the management treatments (χ^2=23.0, p<0.001). The results indicate that stem numbers for the burn treatments and the fall clipped treatments were higher than those of the control plots. The relative frequencies of positive, negative and no response to treatment ($Mean_{1995}$ - $Mean_{1996}$) indicate that burning and fall clipping increased stem counts relative to the control (**Fig. 4.2**).

These results indicate that spring burning and fall clipping stimulate vegetative regrowth from the underground rhizome buds. In clipped stands, prolific new growth arises from the remaining above-ground stem buds since apical dominance is lost (Vander Kloet and Hall 1981). By contrast, new growth in burned stands arises from underground rhizome buds.

The non-pruning (mulching and fertilization) treatments did not stimulate new shoot growth, indicating that new above-ground vegetative growth is not stimulated by these treatments in the short term.

The relative frequencies of positive and negative responses showed that the spring clip with fertilizer resulted in more positive responses than the spring clip treatment alone.



Positive	50	25	60	65	40	60	75	75
No Response	0	0	15	20	30	25	10	0
Negative	50	75	25	15	30	15	15	25

Fig. 4.2 Boxplots showing the mean differences in stem numbers for *V. myrtilloides* in response to treatment at site 1. The boxplot distributions were used to determine the different treatment groups. Relative frequencies of positive, negative, and no response to treatment were calculated as well. The burning and fall clipping treatments show an increase in stem numbers.

(b) Cover Values (Lowbush Blueberry): There were significant differences in percent lowbush blueberry cover between the management treatments as indicated by the Kruskal-Wallis non-parametric ANOVA (χ^2=14.6, p=0.04). Cover decreased in response to spring clipping, with and without fertilizer (**Fig. 4.3**). The minor increase in median values for the fall clip with fertilizer and burn treatments support the positive response of stem numbers.

According to the relative frequencies, the control plots showed the greatest increases in cover values. These increases must have been minor, however, since the boxplot shows a relatively small distribution, compared to burned plots, for example.

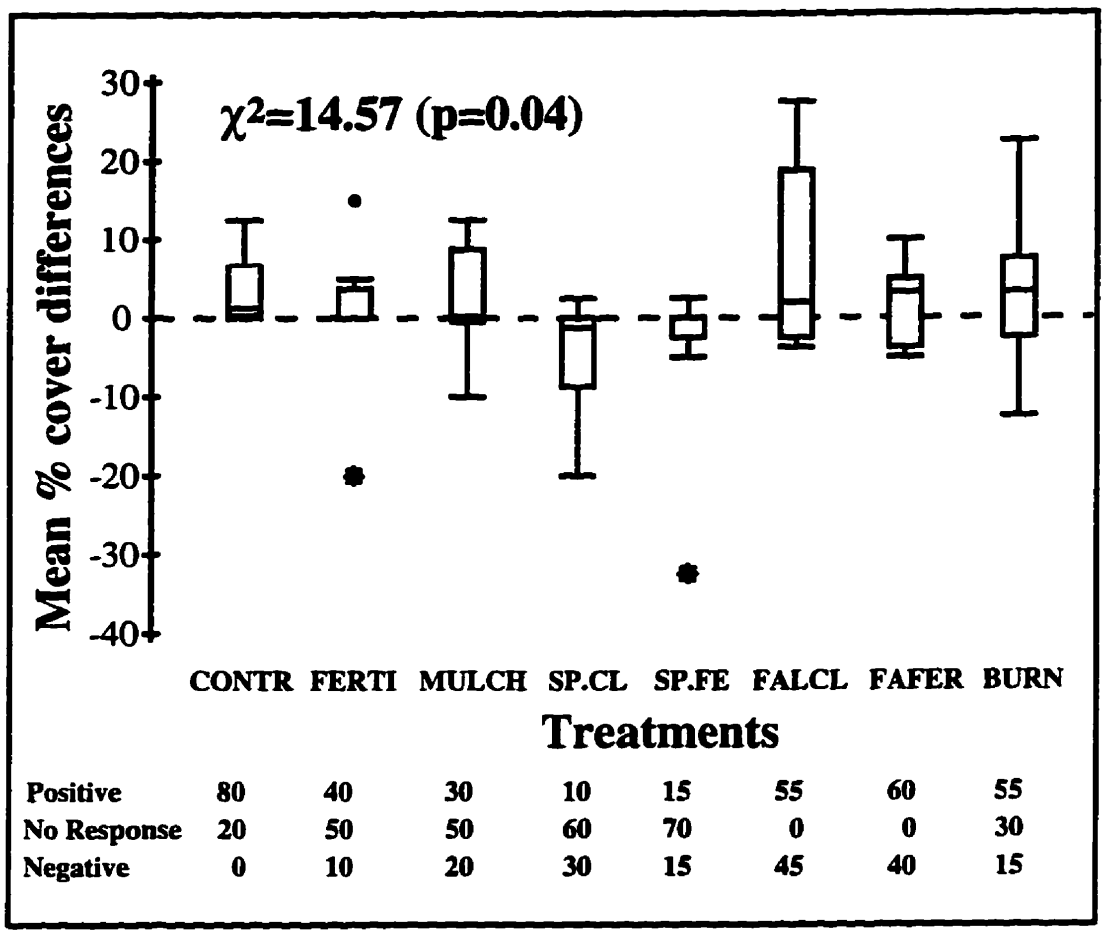
The cover values for the non-pruned plots (fertilization and mulching) showed no response to treatment.

Both spring clipping treatments resulted in a decrease in cover values. However, the results from the stem counts indicate that there was some new shoot growth. Since these results were not followed with increases in cover values, it can be concluded that the new shoots were not as vigorous as those produced from burned or fall clipped treatments.

(c) Cover Values (Associated Species): The only species to show a consistent response to the management treatments was three-toothed cinquefoil (*Potentilla tridentata*), which was adversely affected by the clipping, burning and mulching treatments (χ^2=14.7, p=0.04). None of the associated species increased in cover in response to the management treatments.

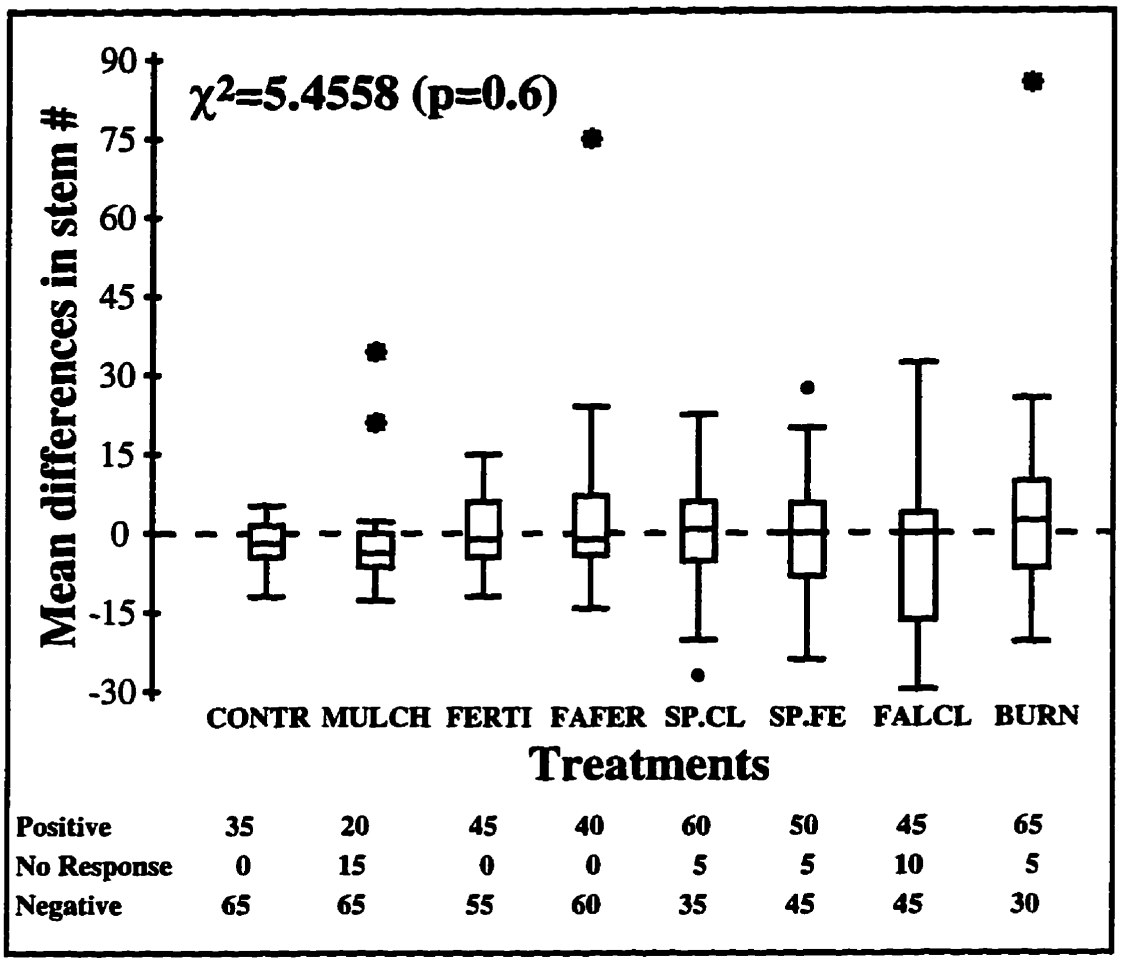
Site 2 (sandy)

(a) Stem Counts (Blueberry): The ANOVA indicated no significant differences in lowbush blueberry stem numbers between the management treatments (χ^2=5.5, p=0.6) (**Fig. 4.4**). All treatments except for mulching resulted in a higher frequency of positive responses relative to the control.



Positive	80	40	30	10	15	55	60	55
No Response	20	50	50	60	70	0	0	30
Negative	0	10	20	30	15	45	40	15

Fig. 4.3 Boxplots showing mean cover values for *V. myrtilloides* in response to treatment for site 1. The boxplot distributions were used to determine the different treatment groups. Relative frequencies of positive, negative, and no response to treatment were calculated.



Positive	35	20	45	40	60	50	45	65
No Response	0	15	0	0	5	5	10	5
Negative	65	65	55	60	35	45	45	30

Fig. 4.4 Boxplots showing mean differences in stem numbers for *V. myrtilloides* at site 2 in response to treatment. The relative frequencies of positive, negative, and no response were calculated to detect the treatment effects.

Even though the results of the statistical test did not detect any responses to treatment, I observed that a few of the treatment plots exhibited marked increases in growth in response to pruning. The relative frequencies show more positive responses in burned and spring clipped plots, however, indicating that these management treatments should be investigated further.

(b) Cover Values (Blueberry): The statistical test indicated that there were significant differences in percent lowbush blueberry cover among the management treatments (χ^2=19.1, p=0.008). Cover in the fall clipped plots decreased, whereas fertilized and spring clipped and fertilized plots demonstrated increased cover values (**Fig. 4.5**).

Significant increases in stem numbers were not detected by the ANOVA, even though there were increases in cover values in response to spring clipping and fertilizing. There were more positive responses to these treatments compared to the control.

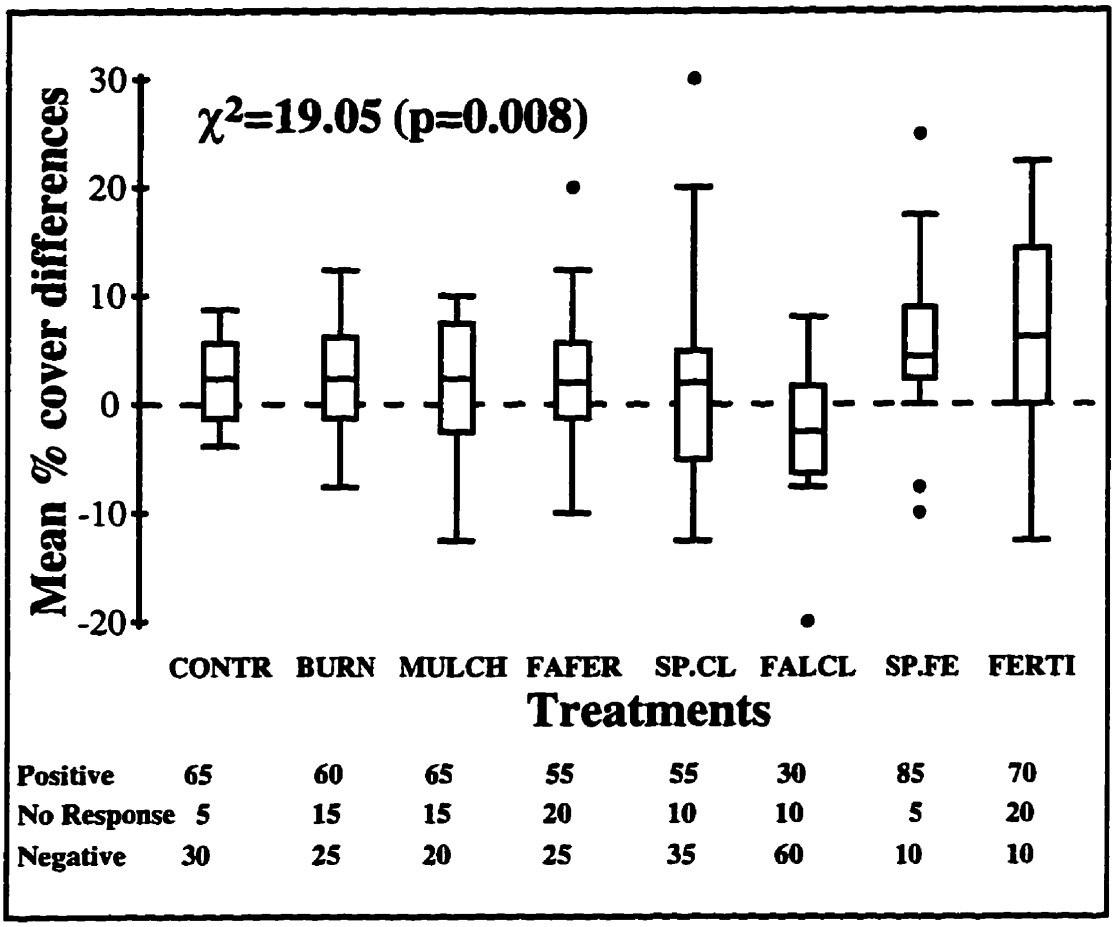
This site has not been disturbed by fire for over 30 years, and the clones showed clear signs of aging (many old, unproductive stems and few young stems).

(c) Cover Values (Associated Vegetation): The sedges (*Carex* spp.) responded positively to all management treatments except for fall clipping and mulching (χ^2=23.7, p<0.001). No other associated species showed a significant response to the management treatments.

4.3 Soil Analysis

Results of the soil analyses, together with recommended levels to optimize blueberry productivity (from Atlantic Horticultural Crops Committee, 1985), are summarized in **Table 4.2**. Recommendations are not given for soil nitrogen since leaf tissue samples were used to determine nitrogen requirements in Atlantic Canada.

Nutrient levels in the soils of the two sites were quite similar at the end of July. Both sites are characterized by acidic, sandy soils of low nutrient status. Nitrogen and



Positive	65	60	65	55	55	30	85	70
No Response	5	15	15	20	10	10	5	20
Negative	30	25	20	25	35	60	10	10

Fig. 4.5 Boxplots showing mean percent cover differences for *V. myrtilloides* in response to treatment for site 2. The relative frequencies of positive, negative, and no response to treatment were calculated to detect differences from the control. The statistical tests show that spring clipping with fertilizer and fertilizer treatments increased cover values.

Table 4.2 Soil variable recommendations for optimum lowbush blueberry growth, and actual soil nutrient levels for two subsamples at sites 1 and 2, based on the top 15 cm. Soil analyses by Norwest Labs of Winnipeg, recommendations by Atlantic Horticultural Crops Committee (1985).

Soil Variable	Recommended	Site 1		Site 2	
	Level	Core 1	Core 2	Core 1	Core 2
Nitrate (kg/ha)		<4.48*	<4.48	<4.48	<4.48
Phosphate (kg/ha)	**50 - 200**	2.24	7.84	6.72	8.96
Potassium (kg/ha)	**50 - 200**	141.12	101.92	125.44	188.16
Sulphate (kg/ha)		22.4	6.72	24.64	33.6
Calcium (kg/ha)	**200 - 800**	661.5	247.5	513	1062
Sodium (kg/ha)		6.75	<2.25	9	6.75
Magnesium (kg/ha)	**40 - 200**	123.75	51.75	58.5	135
pH	**4.5 - 5.5**	5	5.1	4.6	4.7
Salinity		0.9	0.4	0.6	0.1
Organic Matter (%)	**8.0 - 12.0**	3.8	7.4	4.3	7.3

* '<' indicates the values were less than the detectable limit of the analytical equipment.

phosphorus were the major limiting nutrients at both sites. Phosphate levels were far below the recommended levels for Atlantic Canada.

4.4 Population Biology of Lowbush Blueberry

4.4.1 Soil Seed Bank

The species most commonly encountered in the seed bank were pink corydalis (*Corydalis sempervirens*), sedges (*Carex* spp.), and lowbush blueberry (**Table 4.3**). Lowbush blueberry seedlings grown from the seedbank experiments were quite vigorous. After a cold treatment (mid-November 1996 to mid-January 1997), well-developed leaf buds formed on the seedlings and one seedling produced two flowers.

4.4.2 Phenology

The phenology of lowbush blueberry at the two study sites is summarized in **Fig. 4.6**, based on observations of natural stands in the summers of 1995 and 1996. Typically, the leaf buds break by the end of May. Flowering begins in the second week of June and typically continues into mid-July. Fruit development begins shortly after pollination, and by early August the fruit are ripe. The leaves and fruit will remain on the plant until the end of September or early October. The leaves turn red when the overnight temperature falls below freezing, usually by the beginning of September.

Pruned plants (spring burning or clipping) exhibited a somewhat different phenology. After six weeks, these plants exhibited vigorous new growth, with branches often exceeding 15 cm in length.

4.4.3 Leaf Area Index

The leaf area index (LAI), a dimensionless measure, is the ratio of the area of leaf to the area of ground beneath. The mean LAI of 0.83 at the rocky site (site 1), indicated that lowbush blueberry plants do not completely cover the ground surface area. By contrast, the

Table 4.3 Top four ranked species occurring in the seed bank based on frequency of individuals.

Site 1	Site 2
Corydalis sempervirens	*Carex* spp.
Carex spp.	*Vaccinium myrtilloides*
Vaccinium myrtilloides	*Vaccinium vitis-idaea*
Vaccinium vitis-idaea	*Maianthemum canadense*

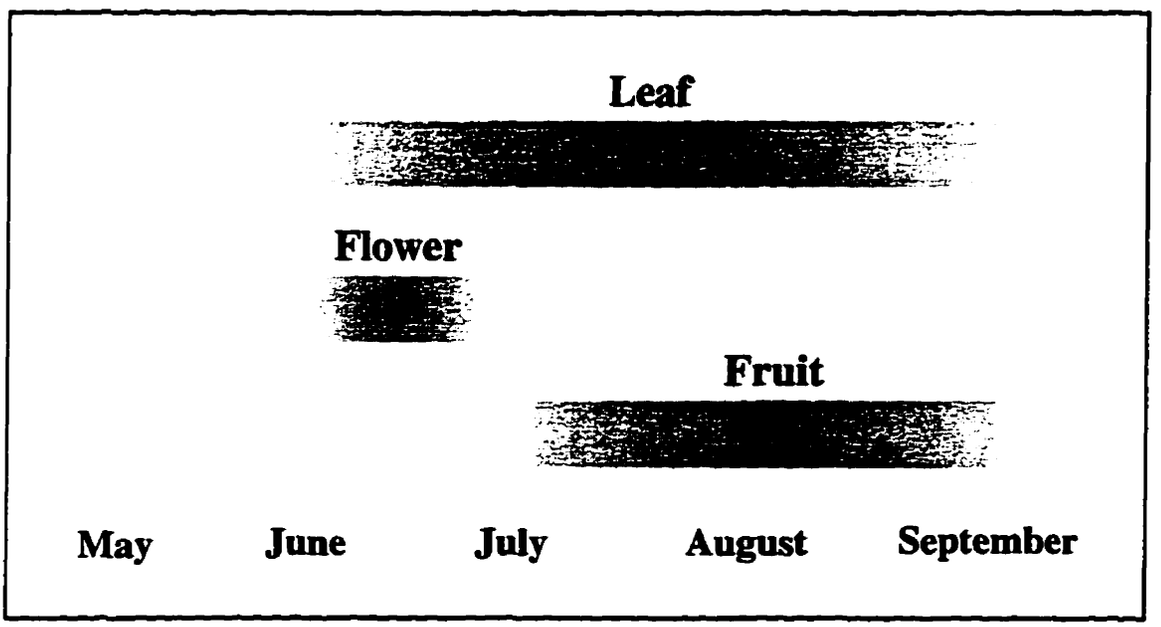


Fig. 4.6 An estimate of the phenology of the lowbush blueberry, *V. myrtilloides* Michx., in northern Manitoba, Thompson region, based on 1995 and 1996 growing seasons.

mean LAI for the sandy site (site 2) was 1.21; a value greater than 1 indicates leaf overlap and self-shading.

4.4.4 Reproduction Allocation

Mean and maximum values of lowbush blueberry fruit production for 1995 and 1996 (per site in kg/ha) are summarized in **Table 4.4**. Means for 1995 are based on the baseline data, while values for 1996 are based on the unmanipulated control plots only. Maximum values are given to indicate a potential yield in managed stands. The rocky site (site 1) produced more fruit overall, and the largest maximum values. The extremely wide variation indicates the inherent patchiness of the blueberry stands.

4.4.5 Biomass Allocation

Above to below-ground biomass ratios varied considerably, but did not differ significantly between sites (**Table 4.5**). In all but one case the ratio was > 1, indicating that most of the biomass of lowbush blueberry is located above ground. Most of the variation in the data reflected large differences in below-ground biomass.

4.5 Lowbush Blueberry Propagation Experiments

4.5.1 Seed Germination

Several problems with fungal infections were encountered when seeds were germinated in the sealed petri dishes, and the seeds that did germinate were not vigorous. In 1995, seed germination was more successful (ca. 30%) in pots that contained native soil. In 1996, seedling germination rates in flats were ca. 30%. Few seedlings survived beyond the cotyledon stage, however.

Table 4.4 Mean blueberry production (±1 s.d.) per site for 1995 (all baseline data) and 1996 (control plots only) in kg/ha. Maximum recorded values per site are given below the means.

	Site 1	Site 2
1995	54.5 ± 97.0	27.0 ± 38.0
	n = 288	n = 360
Max.	794	271
1996	65.1 ± 114.0	25.0 ± 31.6
	n = 64	n = 80
Max.	1 338	140

Table 4.5 Biomass harvested from 100 cm squared samples. Samples were dried, massed, and divided into above-ground (stems and leaves), below-ground (roots and rhizomes), and reproductive buds (with berries in various stages of development).

	Above (g)	Below (g)	Reproductive (g)	Above+Reprod (g)	(A+R)/B
Site 1	3.95	0.83	0.3	4.25	**5.12**
	3.18	2.49	0.45	3.63	**1.46**
	3.23	2.97	0.11	3.34	**1.12**
	2.14	1.81	2.27	4.41	**2.44**
Mean (n=4)	3.13	2.03	0.78	3.91	**1.93**
S.D.	0.74	0.93	1	0.51	**1.81**
Site 2	3.91	0.51	1	4.91	**9.63**
	2.58	1.91	0.01	2.59	**1.36**
	2.3	6.63	0.12	2.42	**0.37**
Mean (n=3)	2.93	3.02	0.38	3.31	**1.1**
S.D.	0.86	3.21	0.54	1.39	**5.08**

4.5.2 Vegetative Reproduction

I was unsuccessful in rooting lowbush blueberry cuttings despite attempts over two years. Several factors may have contributed to the lack of propagation success. Stem cuttings may have been taken too late in the growing season in both years. The cuttings were taken from older, less vigorous shoots; younger shoots are more readily propagated.

Chapter 5 - Discussion

5.1 Community Cooperation

During the tenure of this project, useful contacts were made relating to the sustainable harvesting and marketing of lowbush blueberries in northern Manitoba. Janice Deremiens (Manitoba Agriculture, Carman) is confident that lowbush blueberry management in northern Manitoba is feasible, given adequate financial support and motivated individuals with management skills. Timothy Eaton of I.C.G. Propane is interested in supporting the use of propane burns for right-of-way and lowbush blueberry management. Bruce Holmes (Manitoba Department of Natural Resources, Thompson) supports the idea of sustainable harvesting of non-timber forest products, and showed interest in implementing this practice in northern Manitoba.

In north-central Manitoba, there is significant community interest in proposals related to the management of wild lowbush blueberry stands. Several of the persons that I contacted were interested in supporting this endeavour. For such a management project to succeed, devoted individuals, financial backing, community support, and an established marketing network are necessary. A firm commitment to the project, and cooperation between all the parties involved, are also essential to its success. Finally, a long-term financial commitment will be necessary, since it will undoubtedly take time for both market and production forces to gain momentum.

Northern aboriginals have traditionally collected berries, and in the past berry collection was a significant community event involving both youths and elders (Bjornson and Ceplis 1991). Families would set up camps and harvest berries for the duration of the ripening period. The berries would then be processed on site (dried, pounded, or stewed) and stored for future use (Kirk 1975). Wild blueberry management in northern Manitoba may rekindle this community spirit, and bring back a tradition that has unfortunately been almost forgotten. At present, the collection of wild berries is undertaken by individuals for

personal consumption. As well, the Development Corporation of Nelson House currently pays pickers ca. $10 per litre for berries that are distributed to individuals who are unable to pick for themselves.

5.1.1 Future Studies

Community Based Research

Future studies in lowbush blueberry management should implement community based research strategies to integrate traditional knowledge with experimental methods. Traditional knowledge can be incorporated with the principles of scientific inquiry, by conducting research within the parameters of traditional values. The local people know that blueberries grow in recently burned areas and rock outcrops, and that this food source has sustained their people for generations. Experimental methods have shown that spring burning increases growth and may increase blueberry productivity in following years. These principles can be combined to establish a management plan that resembles the techniques that the eastern aboriginals used before Europeans settled Canada. Once a blueberry market and client base has been established, further research should be directed towards managing natural areas, logged areas and recent burns to increase the harvest yield.

Northern communities should take the opportunity to conduct feasibility studies for sustainably harvesting products from the wild. Further studies may be initiated that allow the communities to create a marketable product in fresh or preserved form, and to explore all the plant products with market potential in their area. This should initially involve a project facilitator until the community members learn the business and the management techniques, so that they can eventually continue the business for themselves. For example, the community of Wabuskang in Ontario harvests lowbush blueberries from the wild, prepares jam, and sells it to local markets.

Marketing

Cost-efficient transportation to and from remote wild blueberry stands in Manitoba is required if management and marketing are to be successful. Given logistic constraints, the 'best' management method may be to conduct controlled burns on cleared sites where wild blueberries are already established. More intensive management strategies, such as irrigation and the addition of chemical herbicides and fertilizers, would probably be impractical in most cases, and would not follow traditional values. A cost-benefit analysis should be conducted to determine the economic viability of sustainable natural biotic resource harvesting in northern Manitoba. Economic diversification will serve to lessen the current dependence on nonrenewable resources.

A marketing facility for sustainably-harvested forest products from northern Manitoba (including lowbush blueberries) should be encouraged. The wild blueberry industry in Manitoba should perhaps evolve as it did in eastern Canada, beginning with personal harvests that are sold to distributors who in turn deliver the product to market. Once an initial and dependable market has been established, the management of larger areas would become more desirable and economically viable.

5.2 Survey of Lowbush Blueberry Habitat

Although an initial aerial habitat survey was conducted as part of this study, a more detailed survey will be necessary to produce accurate maps of wild blueberry habitat and potential areas for management. In northern Manitoba, lowbush blueberries are most frequently found on gravelly or sandy soils in open forests, and on rock outcrops (Ritchie 1956; Johnson et al. 1995). Such areas could be mapped using available surficial geology maps and/or forest inventory maps, together with ground truthing. The burn histories of sites could also be determined using available forest fire maps. It would be logical to begin management projects in established post-burn sites having moderate to high lowbush

blueberry cover. These sites should be reasonably accessible in order minimize transportation costs.

5.3 Lowbush Blueberry Management

5.3.1 Experimental Methods

Percent cover is a relative measure of the amount of space occupied by a plant species. Thus an increase in cover indicates that the plant is more 'vigorous' following the treatment. Changes in stem number reflect the ability of the blueberry clone to replace old stems with new ones, in response to a disturbance. Thus, an increase in stem number indicates that a species is more productive following the treatment, with maximum growth and reproduction in the first two years after pruning (Jordon and Eaton 1995). A significant increase in stem numbers suggests a high berry productivity in the first few years after pruning, since new shoots are more productive than old stems. A favourable management treatment will result in increases in both percent cover and stem number (i.e. the production of several new, vigorous stems). Future studies should perhaps consider other productivity parameters, such as the number of flower buds per stem.

Trevett (1959) determined the potential of various productivity measures to determine treatment responses in managed lowbush blueberry stands. Fruit yield was found to be an unreliable indicator, due to year-to-year variability attributable to confounding factors such as disease, insect pests, pollinator availability, frost, drought and winter injury. Furthermore, fruit yield is a function of the number of flower buds, the degree of fruit set, and fruit size, all of which must be considered in determining a specific treatment effect. Trevett (1959) also noted that blocking small plots on individual blueberry clones (the method used in this study) is useful in determining treatment effects. Blocking implies that all treatments are applied to a given clone, thus accounting for genetic and site differences.

Leonard Eaton of the Nova Scotia Agricultural College suggests that treatment effects should be determined by quantifying increases in vegetative growth. He recommends harvesting the underground rhizomes of lowbush blueberry within randomly selected 1 x 1 m plots. Total rhizome length, and the number of shoots arising from the rhizomes, are then measured to compare growth responses between treatments. In this study, I determined treatment responses by counting stems and estimating percent cover, since the harvesting of rhizomes proved to be impractical and very time-consuming.

5.3.2 Experimental Results

It is not surprising that spring burning resulted in vigorous lowbush blueberry growth, since this management treatment has proven successful in eastern Canada (Sibley 1985). An appropriate rotational burning schedule must be established for north central Manitoba, requiring commitment to longer term studies.

Spring clipping treatments resulted in increased stem numbers, but the cover values suggested that this new growth was not as vigorous as in the burned treatments. Perhaps shoots arising from rhizome buds (following burning) are more vigorous than those arising from remaining aboveground stems. Alternatively, the flush of nutrients from the burn may encourage rapid and vigorous new growth (Eaton and White 1960).

Fall clipping was a successful treatment as well. Since fall clipping stimulates competing vegetation in Ontario (Smith and Hilton 1971), stands in north central Manitoba were expected to show a similar response. Even though blueberry is a stress tolerator, it is a poor competitor for space and nutrients. However, fall clipping did not result in increased cover of associated species, indicating that interspecific competition may not be an issue for blueberry management in northern Manitoba.

Results from fertilizer addition were inconsistent among treatment plots and sites. Studies in the Maritimes have indicated that long-term nutrient addition experiments are necessary to determine the cumulative effects of fertilization (Eaton 1994). Fertilization is

usually most effective if accompanied by adequate weed control (Atlantic Horticultural Crops Committee 1985). Cover values of the sedges (*Carex* spp.) increased in the nutrient addition treatments. Similarly, fertilization has been found to stimulate growth of graminoid species in the commercial lowbush blueberry fields of eastern Canada (Eaton and Patriquin 1988).

Mulching did not result in increased stem numbers or cover values of lowbush blueberries. Mulching was useful in suppressing competing vegetation, and may have been useful in enhancing other growth parameters which could not be measured within the constraints of this study (i.e. rhizome length, flower bud formation). It has previously been shown that rhizome development increases with surface mulching (Kender and Eggert 1966). Longer term experiments and more intensive sampling techniques will be necessary to measure the effects of this treatment on the growth of lowbush blueberries.

Site 1 vs. Site 2

There were several differences between the two study sites. At site 1, there were notable increases in stem numbers in response to burning and fall clipping, but there were only minor increases in cover values. At site 2, there were notable increases in cover values, but there were no increases in stem numbers in response to treatment. The blueberry plants at site 1 (rocky) allocated more energy into fruit production, and the plants were generally more robust than those at site 2 (sandy). The depressions in the bedrock create 'pockets' that accumulate water, nutrients, and organic matter. Lowbush blueberry plants occupying these 'pockets' typically show high fruit productivity. Blueberry cover on rocky sites is patchy, with uplands of bare rock alternating with blueberry-dominated depressions. Since the plants are limited by space in these pockets, perhaps more energy is allocated to sexual (fruit) reproduction than to clonal (rhizome) reproduction.

The lowbush blueberries at site 2 (sandy) are evenly distributed spatially, since the substrate is uniform. Fruit production is less variable spatially, but is significantly lower

than at site 1. Management treatments are easily implemented on flat sandy sites due to their even topography and relatively sparse vegetation cover (i.e. few competitors). Although, the results suggest that sedges may be potential competitors in managed lowbush blueberry stands on sandy sites in northern Manitoba. It is evident that blueberry stands on sandy sites require regular burning to replace old stems with new, more productive ones. The lowbush blueberries at this site may experience stronger interspecific competition than those at the rocky site. In addition, the site is well-drained, resulting in very dry soil conditions by late summer. It was observed that burned plants often did not produce stems from rhizome buds, a result that may be attributable to low soil moisture content. Burning also results in a decrease of soil albedo (proportion of insolation reflected back into the atmosphere, i.e. higher proportion on reflective surface), resulting in further evaporative soil moisture loss. By contrast, spring clipping may not have decreased soil albedo as much as in the burned plots, but it would have promoted branching from aboveground stem buds.

5.3.3 Management Recommendations for Manitoba

The results of this study indicate that burning and fall clipping are effective methods for increasing lowbush blueberry productivity (based on greater stem production and/or increased percent cover). Regular burning has also proven to be an effective management treatment in eastern North America. In Maine, burning every three years resulted in vigorous stem production and high fruit yields for at least seven harvest seasons, and increased stem numbers for 12 years or more (Kender et al. 1964). Fall clipping has similar effects in the short term, but it also stimulates the growth of competing plant species and is therefore not recommended in the Maritimes (Smith and Hilton 1971). Since competitors were not a problem in the stands in northern Manitoba, fall clipping should be considered. Burning appears to be the most appropriate management strategy for lowbush blueberry stands in north-central Manitoba. Controlled burns are cost-effective and easily

implemented, although care must be taken to ensure that the fire does not spread into adjacent forested areas. Future studies should be directed toward determining the appropriate fire cycle, and the optimal burn intensity, for Manitoba populations of lowbush blueberry.

The mechanisms by which burning stimulates lowbush blueberry productivity are well understood. Lowbush blueberry is a disturbance-adapted species that requires frequent disturbances to maintain stand vigour. Burning of the aboveground biomass stimulates the production of vigorous new shoots from established underground rhizomes (Vander Kloet 1988). In addition, burning increases nitrogen availability in soils, provided that the fire temperature does not exceed ca. 400°C (Warman 1987; Eaton 1986). Finally, burning is detrimental to most competing plant species, thus allowing lowbush blueberry clones to consolidate their dominance in stands that are burned on a regular basis (Nova Scotia Blueberry Industry Tour 1988). When establishing new stands, lowbush blueberry species will colonize more rapidly, and be more vigorous, if clearing and burning are not conducted in the same year (Hall 1955). The forest should be cleared in narrow strips to allow for the invasion of blueberry rhizomes. Following the establishment of a new stand, further management may subsequently be required to control potential competitors such as bunchberry (*Cornus canadensis*), wild sarsaparilla (*Aralia nudicaulis*), balsam poplar (*Populus balsamifera*), alders (*Alnus* spp.), sedges, and grasses (Hoefs and Shay 1981; Hall 1955).

Previous studies of wild lowbush blueberry stands in the prairie provinces indicate that the plants are often water-stressed, and that late-summer droughts reduce fruit production and quality (Hoefs and Shay 1981; Ivanochko 1993b). In the present study, mulching did not increase wild blueberry productivity, but a long-term study would be required to confirm this finding. The low berry production noted at site 2 (sandy) was probably attributable to soil moisture limitations. Irrigation should therefore be considered in stands adjacent to a water source (e.g. lake or river). However, irrigated wild blueberry

plants may grow taller and thus be more susceptible to winter injury (Benoit et al. 1984). In addition, irrigation may benefit the competing vegetation at the expense of lowbush blueberries.

The Blueberry Summary for Nova Scotia's Blueberry Industry Tour (1988) indicates that managed wild lowbush blueberry stands may take from five to ten years to reach maximum productivity. Productive fields can be formed from stands having an initial ground cover of 10-20%, by repeated mowing or burning. Productive stands in Nova Scotia yield on average ca. 1 700 kg/ha of fresh berries annually (maximum of ca. 4 500 kg/ha) (Nova Scotia Blueberry Industry Tour 1988). Field trials in La Ronge, Saskatchewan by contrast, yielded on average ca. 900 kg/ha of fruit annually (maximum of ca. 1 700 kg/ha), which was not considered economically viable. However, there are opportunities for wild lowbush blueberry production in the prairie provinces, provided that growing conditions can be optimized (Ivanochko 1993b). The harvesting and management of other wild berry crops, such as lingonberry and bog cranberry, should also be considered.

5.3.4 Competition

In the Maritimes, the most aggressive competitors in managed lowbush blueberry fields are the hay-scented fern and sheep laurel. These 'weeds' are generally eradicated using a systemic herbicide. In fact, the use of herbicides is deemed essential to maximizing stand productivity (Eaton 1994). Results from the present study indicate that lowbush blueberry populations in north-central Manitoba have relatively few native competitors. Lowbush blueberry stands in the boreal forest may eventually be overtopped and shaded out by woody shrubs and trees (Ivanochko 1988), but these can be easily held in check using V-blading and related methods. My results suggest that graminoids (sedges and grasses) may become a problem in managed stands, but further investigations will be

required to confirm this. Graminoids are strong competitors in some managed stands in eastern Canada (Smith and Hilton 1971).

It appears that herbicide use is probably not necessary in northern Manitoba lowbush blueberry stands. I also feel that the application of chemical pesticides (also used widely in the Maritimes) should be avoided. The use of such chemicals is quite costly, and their use would disrupt the natural ecosystem balance that is held in such high regard by native peoples. The advantage of burning as a management technique is that it is a 'natural' disturbance to which species of the boreal forest are well adapted. Avoiding the use of chemical herbicides and pesticides would also be advantageous in marketing the harvested crop because it could be marketed as an organic product once organic certification is obtained.

5.3.5 Breeding Programs

A breeding program to develop hardy, high-yielding lowbush blueberry varieties suitable for the northern Manitoba environment should be encouraged. The 'half-high' varieties developed for the mid-western United States are unfortunately not fully hardy in Manitoba (Wildung et al. 1996). The development of lowbush varieties combining the hardiness of *Vaccinium myrtilloides* and the superior reproduction potential of *V. angustifolium* should be considered instead. Native *V. angustifolium* varieties recently discovered in central Manitoba (K. Johnson, pers. comm.) may prove to be an important genetic resource in such a breeding program.

5.3.6 Future Studies

The long-term response of lowbush blueberry stands to various management practices could not be addressed in this study (which was funded for a two-year period). Since the lowbush blueberry is a long-lived shrub species, long-term experimental management studies are to be encouraged. Thus far there has been no other research on

lowbush blueberry management in northern Manitoba. Appropriate management methods and schedules must therefore be inferred from the literature. In the Maritimes, it has been demonstrated that *V. myrtilloides* takes ca. 3 growing seasons to dominate a site following a disturbance (Vander Kloet 1994). In experiments conducted near La Ronge, Saskatchewan, native lowbush blueberry stands were most productive in the third growing season following pruning (Ivanochko 1993a). The main factors reducing productivity in Saskatchewan were winterkill, spring drought, and summer drought. Sites with few competitors, and areas that are not prone to frost, were recommended for further management. In northern Manitoba, different management treatments and various site types should be monitored in order to develop appropriate management methods and schedules.

A simple lowbush blueberry productivity management model for northern Manitoba is outlined in **Fig. 5.1**. The model illustrates the predicted relationship between time since disturbance (in this case, fire) and lowbush blueberry fruit production. No fruit are produced in the year immediately following a fire. Production increases over the next few years to a maximum (the productive phase), and then declines as interspecific competition becomes important and clonal senescence occurs (the competition phase). Fruit production will continue to decline unless the manager intervenes and burns the stand, starting the cycle over again. If the stand is not managed in this way, a forest canopy will develop and lowbush blueberry cover and fruit productivity will rapidly decline. The management goal is therefore to create a disturbance regime that maximizes lowbush blueberry fruit yield over the long term.

Surveys of native blueberry stands in different habitat types, and at various 'successional' stages (i.e. time since fire), must be conducted to determine the management time frame (horizontal axis of model) and blueberry fruit yields (vertical axis of model) in northern Manitoba. A long-term, replicated management experiment should also be conducted to determine the most appropriate and economically viable management strategy for wild lowbush blueberry stands.

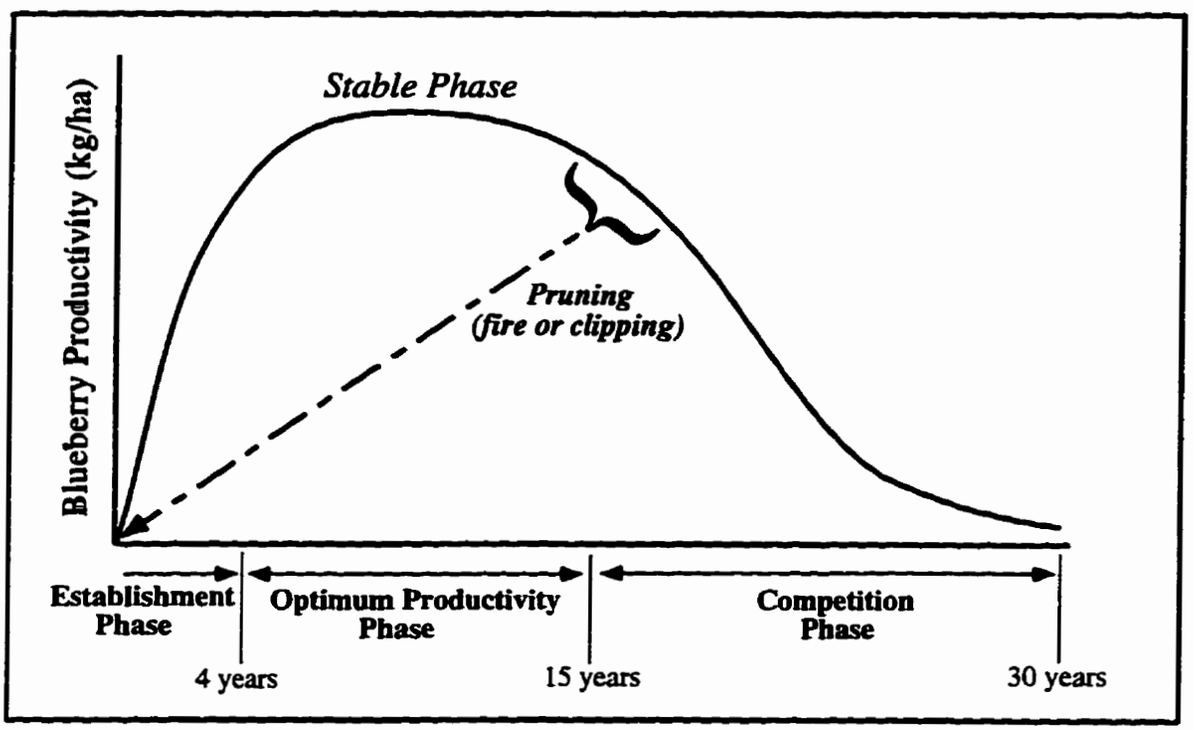


Fig. 5.1 Proposed lowbush blueberry productivity model and management strategy for northern Manitoba populations.

Design of Future Studies

The experimental design of future studies should incorporate:

- the development of fertilizer recommendations based on soil and leaf tissue samples from productive blueberry stands in northern Manitoba.
- bigger treatment plots covering a larger area.
- more sites of different types (e.g. recently burned, recently logged, west facing slope).

5.3.7 Lowbush Blueberry Management on Hydro Rights-of-Way

The phrase "arresting succession" is often used when describing lowbush blueberry management and stable shrub communities. Niering and Goodwin (1974) note that the term "succession" implies a simple course of events that eventually leads to a 'climax' community. The phrase "vegetation dynamics" is therefore preferred, as it allows for a more realistic interpretation of the long-term changes that take place in a community.

Previous studies have shown that the establishment of stable shrub communities dominated by *Vaccinium* species can reduce the need for rights-of-way management (Niering and Goodwin 1974; Pound and Egler 1953). Shrub-dominated vegetation tends to resist the invasion of tree seedlings on rights-of-way (Niering and Egler 1955). Manipulating vegetation dynamics on rights-of-way results in lower maintenance costs than chemical and physical control and conserves natural biodiversity.

Fire is a natural disturbance in the boreal forest of north-central Manitoba, making controlled burning the most viable and environmentally-friendly method for establishing and maintaining stable shrub communities on Hydro rights-of-way. Burning will increase the cover and productivity of lowbush blueberry shrub stands along rights-of-way, thus increasing the potential for commercial harvesting. Further surveys are required to determine which areas along rights-of-way are most suited to such a management strategy.

5.4 Soil Nutrients

Guidelines and recommendations are available for optimum soil conditions of lowbush blueberry stands in the Maritimes. According to these guidelines, the soils of my Manitoba study sites are highly deficient in phosphate (and probably nitrogen), and somewhat deficient in organic matter content. Since the samples were taken in late July, much of the nitrogen is expected to be within the leaf tissue. As well, nitrogen levels in the soil tend to fluctuate widely. Well-drained soils of the boreal forest are characteristically nutrient-deficient, and it is questionable whether guidelines developed for the Maritimes are directly applicable to northern Manitoba.

In the Maritimes, researchers found it necessary to conduct long-term nutrient addition experiments in order to determine the most effective nutrient enhancement program. It was found that fertilizer application was only useful when combined with herbicide application, since nutrient addition alone favoured mainly competing species (Eaton 1994). In Saskatchewan field trials, fertilizer application did not significantly increase lowbush blueberry productivity (Ivanochko 1993a). Since lowbush blueberries in Atlantic Canada are poor competitors in nutrient-rich soils, fertilizer application levels should be kept low (Hepler and Ismail 1985). In Manitoba, long-term nutrient addition experiments should be undertaken to determine the nutrient levels that maximize lowbush blueberry productivity, while minimizing growth of potential competitors.

5.5 Population Biology of Lowbush Blueberry

5.5.1 Seed Bank

The soil seed bank at site 1 (rocky site) was reflective of the vegetation present, with the exception of pink corydalis (*Corydalis sempervirens*). This species was abundant in the seed bank, but had low percent cover at the site. At site 2, the soil seed bank accurately reflected the vegetation present. Lowbush blueberry was common in the seed

banks of both sites. Sedges (*Carex* spp.) were also common, suggesting that they may be potential competitors in managed stands.

Seed germination and seedling establishment does not appear to contribute significantly to stand expansion in managed lowbush blueberry stands in eastern Canada. Vander Kloet (1976a) observed that fewer seedlings were present in Ontario lowbush blueberry stands than those in Nova Scotia. He hypothesized that seed dispersal methods may differ between these locations, and that natural selection may select against high fruit (seed) production in more continental populations (Vander Kloet 1985). The frequency of germination may also vary according to different types of disturbance regimes. Vegetative (clonal) growth appears to be the predominant mode of 'reproduction' in most established lowbush blueberry stands, a further indication that the lowbush blueberry is a stress tolerator. Clonal growth results in rapid population growth, but leads to low genotypic variation (Bruederle et al. 1991).

5.5.2 Phenology

The growing season of lowbush blueberry in Manitoba begins about three weeks later than in the Maritimes. Bud break occurs in early May in the Maritimes (Tirmenstein 1990), but did not occur until late May in the Thompson, Manitoba area. Fruit harvesting in the Maritimes usually begins in early August, whereas the fruit crop in Manitoba is not fully ripe until the end of August. The milder Maritime climate is undoubtedly responsible for these phenological differences.

Pruned lowbush blueberry plants did not produce fruit in the first growing season. Stem regrowth began ca. 2-3 weeks after pruning, and vegetative growth ceased about six weeks later. Burned plants developed stems from underground rhizome buds, whereas clipped plants regenerated from buds on the remaining stems. Pruned plants developed vegetative and flowering buds in the fall. This sequence of events in the life history of the

managed lowbush blueberry plants is similar to that observed in eastern Canada (Tirmenstein 1990).

Spring frost damage significantly reduces fruit production in Maritime populations of *V. angustifolium* and European populations of *V. myrtillus* (Ögren 1996). Spring frost damage can be determined by the presence of black pistils on lowbush blueberry flowers (Shoemaker 1978). Since flowering does not occur until early June in northern Manitoba, the probability of a late frost may be significantly reduced. I did not observe signs of frost damage at either study site during the 1995 or 1996 growing seasons.

5.5.3 Reproductive Allocation and Fruit Yield

Fruit productivity at the two study sites in northern Manitoba (ca. 60 and 26 kg/ha respectively) is lower than in commercial fields of eastern Canada (1 700 kg/ha), and in managed stands in Saskatchewan (ca. 900kg/ha). Commercial fields are burned every other year, while natural stands in Manitoba have a burn frequency of 50 to 100 years. Low productivity is probably attributable to the infrequency of disturbance in Manitoba stands. Older stems lack vigour, and are unproductive compared to newly regenerated stems. Lowbush blueberry productivity and cover are effectively increased by burning older stands, as this stimulates new shoot production (Hoefs and Shay 1981; Shoemaker 1978). Because lowbush blueberries in general, are well adapted to regular, repeated burning, such conditions must be simulated if plants are to reach their full reproductive potential. As well, summer droughts can negatively impact on fruit set and development. The lack of adequate soil moisture may be a major factor limiting lowbush blueberry production and yield in northern Manitoba.

The maximum recorded value at site 1 (ca. 1 400 kg/ha) is lower than the mean yield of 1 700 kg/ha for commercial lowbush blueberry fields in Atlantic Canada. In Nova Scotia, *V. angustifolium* fruit productivity is consistently higher than that of *V. myrtilloides*. Under an appropriate management regime, I believe that sites in northern

Manitoba can achieve annual fruit yields that would support a local market. At the Tin Can Lake site, high berry productivity was observed 12 years after a natural forest fire. Adequate soil moisture levels during the growing season are necessary to ensure a productive and dependable berry harvest (Hoefs and Shay 1981; Ivanochko 1993a).

5.5.4 Biomass Allocation

In eastern Canada, ca. 70% of the dry biomass of lowbush blueberry is rhizome tissue (Smagula and Hepler 1978), and ca. 85% of the total biomass is below-ground (Galletta and Himelrick 1990). Below-ground biomass allocation values at my two study sites (33% at site 1, 43% at site 2) are significantly lower. This suggests that productive managed stands in the Maritimes allocate much of their growth to underground parts, perhaps due to a deeper soil profile. By contrast, undisturbed natural stands in northern Manitoba allocate the majority of their biomass to above-ground parts.

5.6 Lowbush Blueberry Propagation

It has been suggested that the selection of superior seedlings can help preserve genetic diversity, and increase fruit yields, in managed lowbush blueberry stands (Hepler and Yarborough 1991). However, Hall (1955) was of the opinion that seedlings should not be considered in establishing lowbush blueberry stands. Based on my experiences in germinating seeds and establishing seedlings, I feel that propagation from seeds is not worth pursuing at this time, unless the objective is to develop varieties to enhance fruit productivity in northern Manitoba.

The results of my propagation experiments suggest that the presence of a mycorrhizal associate may be necessary for vigorous seedling growth. Seedlings grown in native soil exhibited more vigorous growth than those grown in greenhouse soil, suggesting that pH, soil composition and/or mycorrhizal infection were factors affecting germination success and seedling vigour. Studies in Maine reveal that plants inoculated

with mycorrhizae exhibit minor increases in overall growth, larger plants at the rooting phase, and taller, more highly branched shoots (Litten et al. 1992).

A seed germination rate of ca. 30% for *Vaccinium myrtilloides* was obtained in this study. Bruederle et al. (1991) obtained a germination rate of ca. 3%, but their results were based on all seeds, whereas I attempted to germinate only the largest seeds. The seed germination rate of the closely-related *V. angustifolium* is much higher, averaging ca. 80% (Hall et al. 1970, 1978). The higher germination rate for *V. angustifolium* may be attributable to its higher ploidy level (2n = 48, compared to 2n = 24 in *V. myrtilloides*) (Galetta and Himelrick 1990).

Based on the results of these initial germination experiments, a number of specific recommendations can be made. Germination should take place on native soil using ca. 30 seeds per pot. Alternatively, surface soil can be collected and plants germinated from the seed bank. Pots should be lightly watered on a daily basis. After ca. six months of growth, plants should be exposed to a cold/dark treatment for about eight weeks to promote the formation of new buds. This cold treatment should be repeated yearly for approximately three years. Once the plants have established an adequate root system (ca. 3 to 4 growing seasons), they can be planted in the field. Since this process is time-consuming and labour-intensive, the management of extant stands of lowbush blueberry should be considered instead.

Vegetation propagation (stem or root cuttings) of lowbush blueberry is also feasible, although transplanted cuttings often do not produce rhizomes as readily as do seedlings (Shoemaker 1978). The propagation trials were undertaken using sterilized greenhouse soil. Future attempts may therefore include treating cuttings with a fungicide-free rooting medium, and planting the cuttings in native soil. Material to be propagated vegetatively should be collected in the late summer from vigorous plants that have not experienced dieback.

Summary

Lowbush blueberries prefer marginal habitats of low nutrient availability and acidic soils, which are common upland site conditions in the boreal forest of Manitoba, particularly on the Canadian Shield. They thrive as a pioneer species in disturbed habitats of northern Manitoba, where fire and/or clearing has occurred. In eastern Canada it has been demonstrated that arresting this early successional stage using appropriate management techniques results in an increase in productivity of the lowbush blueberry. A burn cycle of five to six years has been recommended for northern Manitoba (S. P. Vander Kloet, Acadia University), but more research must be conducted to determine an appropriate cycle.

Managing native stands of lowbush blueberries is a more efficient and cost-effective method than plantings, to expand the stands and increase productivity. The ability of *V. myrtilloides* to establish a stable shrub community must be monitored over a long time period. Literature states that once established, *Vaccinium* species will dominate disturbed areas for ca. 20 years.

It has been shown that pruning, in the form of spring burns and fall clipping, increases the stem numbers of the lowbush blueberry on rocky sites. An increase in stem numbers can be translated to an increase in berry production for a few seasons following pruning. Cover values did not increase for these sites, although cover may increase in response to treatment in the following growing seasons. Treatments conducted on the sandy site exhibited highly variable responses in stem numbers, although cover values seemed to increase for fertilized treatments and the spring clip with fertilizer treatments. There may be other confounding factors that resulted in the variable responses to treatment at the sandy study site i.e. stand age, exposure to wind and sun, lack of water. Cover values of *Carex* spp. (sedges) increased in response to the fertilizer treatments at this site. A

survey of a post-fire area at Tin Can Lake indicated that sandy sites will exhibit high blueberry productivity up to twelve years following a burn.

Seedling establishment is more vigorous when native soils are used in the germination process. It is suggested that sterilized greenhouse soils do not contain the necessary components ideal for germination. Stem cuttings were not successful in laboratory conditions. Although germination is successful under laboratory conditions, managing extant stands of lowbush blueberry is a more cost-effective and efficient method of cultivation.

A long-term study is necessary to examine the response of management treatments (particularly fire) on this long lived shrub. This study should include larger treatment plots in a variety of regions in Manitoba. Based on preliminary results, spring burns, fall clipping, spring clipping, fertilization and irrigation should be examined in detail on a greater temporal scale. A study at a larger spatial scale would be beneficial in order to minimize the variation in the treatment responses and to determine the response of species in the sapling stage, such as *Alnus*, *Populus* and *Salix*, which pose a potential threat to the safety of the hydro-electric lines. These experiments should also examine the best management option to reduce competition from other shrubs, trees, grasses and sedges in order to create a stable shrub community of *V. myrtilloides*.

It would also be useful to conduct a large-scale survey of all the recently burned and logged areas in northern Manitoba for blueberry cover. The areas that are accessible should be examined for harvest potential. Areas along Manitoba Hydro rights-of-way could be harvested as well.

Environmental parameters (i.e. soil, shading, competition) in areas with the highest lowbush blueberry productivity should be measured to determine optimal growing conditions. The seasonal climatic conditions that contribute to a decrease in blueberry productivity should be identified i.e. late frost, wet spring, summer drought.

Blueberry productivity and cover in areas that are in various stages of recovery from disturbances such as fire or clearing should be monitored and surveyed in order to create a productivity model. By surveying areas of different successional stages, a relationship between the time since disturbance, and blueberry productivity can be estimated. **Fig. 5.1** shows the proposed model based on initial observation of lowbush blueberry sites in northern Manitoba. The time scale is speculative and the productivity scale is unknown. The suggested time of redisturbance (pruning) should occur when the blueberry shrubs have entered the competition phase, in order to return the community to the establishment phase. The optimum productivity phase can also be considered a stable phase, where cover values are optimum as well.

A market potential survey for lowbush blueberries in Manitoba should be conducted and the support of other organizations should be solicited in such an endeavour i.e. provincial and federal government, First Nations. Issues such as economic viability, processing methodology, sustainability and management should be examined. Using the model outlined above, blueberry productivity during the optimum productivity phase must be high enough to offset the costs incurred by transportation, processing, harvesting and management. The market survey would further encourage the harvest of other non-timber forest products in Manitoba (i.e. lingonberry and other berries, reindeer moss, medicinal herbs), especially with First Nations communities who may want to utilize Treaty Land Entitlements for economic purposes. Personal communications from individuals at Nelson House First Nation have indicated an interest in utilizing Treaty Land Entitlements for economic purposes, specifically in tourism and harvesting of non-timber forest products. Current uses of TLE include hunting, dog sledding, fishing, the collection of traditional plant medicines, camping and berry collecting. Berries are currently collected for personal consumption, or sold to the Development Corporation for distribution to community elders.

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