THE EFFECT OF SHADE ON THE LOWBUSH BLUEBERRY (*VACCINIUM ANGUSTIFOLIUM* AIT.) AFTER FIRE-PRUNING

A Thesis

Submitted to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Manfred E. G. Hoefs

1968

ACKNOWLEDGEMENTS

I would like to thank the University of Manitoba and the Manitoba Department of Mines and Natural Resources, Forestry Branch, for financial assistance.

I am also grateful to Dr. J. M. Walker for her helpful advice and criticism. Special thanks are due to Mr. P. Peters, Department of Agriculture and Conservation, and to Mr. Kay, Department of Mines and Natural Resources, Forestry Branch, for their help and continued interest. I am indepted to Mr. R. Smith and other members of the Manitoba Soil Survey, for assistance in soil analyses and to Mr. Walter Kupiak for his efforts in the fieldwork.

ABSTRACT

The first two years of an ARDA-project to determine whether it is possible to manage blueberries on a commercial scale in Manitoba, as undertaken in the Maritime Provinces, revealed that the limiting factors are frost, competing vegetation and drought.

Management in open fields, which is the usual practice in eastern Canada seems to have disadvantages here; therefore this investigation was designed to determine the importance of shade, as a means of minimizing the effects of drought, on a blueberry population when it emerges after fire-pruning.

Five plots (15m by 0.3m) were used. They were comparable in number of blueberry shoots, abundance and composition of competing vegetation, soil, moisture and shade. They were burned in early spring and, immediately after this, shade was provided artifically by wooden screens giving the following range: 0%, 25%, 50%, 75% and 100% shade.

For the lowbush blueberry (Vaccinium angustifolium) it takes two years after fire-pruning to produce the first crop. This investigation was concerned with those vegetative or "first-season" characters, which had in other experiments been found to be positively correlated with yield.

Quadrats with low density of blueberry shoots before the burn showed a higher rate of increase in shoot number than those which were already densely populated, regardless of shade. The time of emergence of shoots after the fire and the time of apical abortion were not influenced by shade. Early dieback resulted in branching (often frost-induced), late dieback in cessation of growth. The final shoot size increased with increasing shade; the percentage of branched shoots, the number of branches per branched shoot and the increase in shoot density showed a negative correlation.

The results are in contrast to those obtained in New Brunswick, and can be explained by the different climate.

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INTRODUCTION

From 1965 to 1969 the Manitoba Government has participated in an "Agricultural Rehabilitation and Development Act" (A. R. D. A.) project to study the feasibility of managing the native blueberry (Vaccinium angustifolium Ait.) on a commercial scale. Since this crop is of considerable economic importance in the Maritime provinces of Canada and in the north east United States, there is a substantial body of information on management practices from these areas.

When this project was started, essentially the same field practices were applied as in Eastern Canada since the same species was involved. After two years it had become clear that the limiting factors were frost damage, competing vegetation and drought. Very little can be done about late frost, but the effects of burning and herbicides on competing vegetation are presently under investigation, as are the importance of irrigation and shade on minimizing the effects of drought.

In comparing open stands of blueberries with those under forest cover several differences were observed. Plants growing under shade were often taller, showed less frost damage, had larger berries and appeared more vigorous. A considerable proportion of the young shoots that emerged after fire-pruning dried up and died at the height of the summer when fully exposed to the sun. The competing vegetation that followed a burn was more abundant in the open; this was particularly the case with bearberry, fireweed and several grass species.

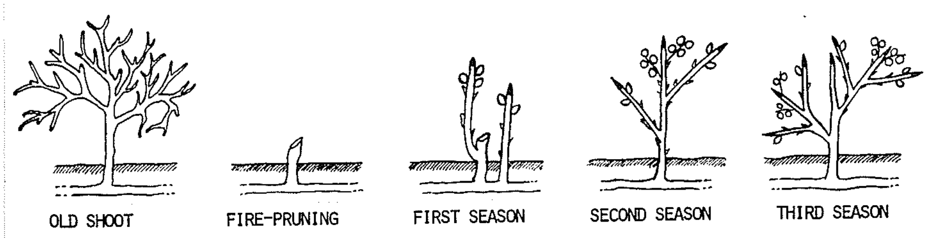
This investigation is a quantitative assessment of the responses of blueberry shoots emerging after fire-pruning to varying degrees of shade.

To appreciate the experimental design it is necessary to briefly review the sequence of responses in V. angustfolium after fire-pruning. This blueberry is a low shrub, growing to a height of 30 cm in Manitoba. The aerial shoots are connected by subterranean rhizomes. Fire-pruning removes the old, relatively unproductive, aerial shoots, and subsequently young, more productive, shoots emerge from buds on the stumps of the pruned shoots and from buds on the rhizomes. Vegetative growth occurs in the first season. Abortion of the apical meristem stops elongation of the shoot. From this time on fruiting buds are initiated in the axils of leaves close to the apex of the shoot, while vegetative buds develop farther down. The following season the fruiting buds give rise to spikes of flowers and the vegetative buds develop into branches. These branches again initiate fruiting buds near their apex and vegetative buds toward their base after apical dieback has occurred. This sequence of branching and dieback is continued season after season and the much-branched appearance of an old shoot is gradually restored. (Barker et al. 1964).

The appearance of a shoot for three seasons after pruning is shown in Figure 1. While a single shoot (Fig. 2.1) is most frequently encountered at the end of the first growing season, Fig. 2 shows other types which are found. If dieback occurs early in the season the shoot may resume growth after a short pause by elongation of a single axillary bud (2), or by development of several branches (3). In very rare cases branching was found prior to the abortion of the "primary" shoot (4).

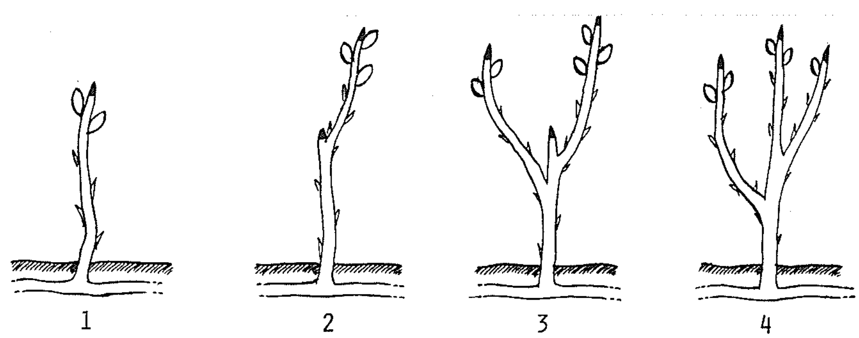
It will be realized now, that at least two seasons' investigations are necessary to fully assess the response of blueberry shoots to shade. This project deals with vegetative aspects, while it is planned to continue during the summer 1968 to investigate the sexual reproductive characters.

Figure 1. Reproduction of Vaccinium angustfolium after fire-pruning.



Black tips indicate aborted apices; fruiting buds are large and swollen; vegetative buds narrow and pointed; the inflorescences are spikes.

Figure 2. Types of one-year-old shoots.



For explanation see text. (Page 2)

LITERATURE REVIEW

This investigation had two facets: the effect of shade, and the consequences of burning on Vaccinium angustifolium.

Shade: Eastern Canada and the north eastern U. S. A. have been the centres of blueberry research. In these areas lowbush blueberries (V. angustifolium and Vaccinium myrtilloides) are grown in open fields and therefore little work has been done on the effects of shade.

Hall (1958) showed that the shade cast by competing vegetation had a detrimental effect on blueberry plants. The size of the shoots, the diameter of the stems and the number of flower buds per shoot decreased in proportion to increasing shade, which he provided artifically by screens. Furthermore, Hall and Ludwig (1961) using three light intensities (5000, 3000 and 2500 foot candle) found that the number of flower buds was reduced significantly by shade. Chandler and Mason (1946) found that more than 80% of full sunlight was required every year for large yields, while Kender and Brightwell (1966) stated that when sunlight intensity was reduced by 70% to 80% with shade cloth, flower bud formation and vegetative growth in highbush blueberries were greatly reduced. During the following season many of the berries on these bushes dropped prematurely or failed to develop normally. When the normal light intensity was reduced by ca. 50%, the effects were not so pronounced but were still quite obvious. These results emphasized the importance of good pruning practices to admit maximum light to all parts of the bush.

Even though these authors seemed to agree that the open habitat is the best from the economic point of view, there are other investigations which restrict this general conclusion.

When studying the floristic changes following the cutting and burning of a woodlot for blueberry production, Hall (1955) considered it important that the change in habitat of Vaccinium angustifolium and V. myrtilloides from the forest to the open should be gradual and slow. He stated: "This study shows that on this site clean-cutting of forest trees when followed in one year by burning failed to give a good stand of blueberries. No blueberry seedling made its appearance. After growing in heavy shade, many of the small blueberry plants will be killed by a subsequent fire. If, however, the burning is delayed several years until vigorous plants develop, greater success will probably be obtained. If there are weak blueberry plants in the ground cover, the forest trees should be selectively cut until enough light enters to encourage vigorous plant development before the plants are subjected to further treatment. Where areas have been thinned by pulpwood cutting, vigorous plants have been found in the woods. These plants when given a favourable environment will act as centers from which new rhizomes will spread. When it is desired to enlarge a producing field by clearing land from adjoining woodland, blueberry growers at Tower Hill (N. B.) have found it best to cut a narrow strip, two or three feet wide, each year. This procedure stimulates the spread of existing plants rather than the growth of seedlings."

Moore and Ink (1964) dealt with the effect of rooting medium, shading, type of cutting, and cold storage of cuttings on the propagation of highbush blueberry varieties. They found that shade was not necessary for successful propagation in Beltsville, Maryland. They mentioned, however, that propagation of blueberries without shade has sometimes been unsuccessful in Michigan and concluded that the necessity of shading needs to be determined for regions of different climatic conditions.

Smith (1962) made an ecological study in Alberta. Vaccinium myrtilloides Michx and V. vitis-idaea L. var. minus Lodd. preferred low light intensities; however, a minimum requirement of light for normal growth and development was indicated. Vaccinium myrtilloides had a wider adaptability in this respect. Smith (1962) explained the disagreement of his results with those of Hall (1958), who worked in New Brunswick, on the basis of climatic differences. Eck and Childers (1966) stated: "Although good light is essential for maximum growth and fruit production, it is not necessary for actual ripening and colour development of the berry." Hindle, Shutak and Christopher (1957) found that berries picked while unripe turned blue in complete darkness. They also covered some blueberry clusters on bushes with light-tight aluminum foil and found that the berries ripened normally with no harm to the flavour.

Fire-Pruning: Pruning by fire influences both the vegetation and the soil and these effects will be discussed separately.

There is general agreement that burning is the cheapest and most effective method of pruning a blueberry field. For example, Barker et al. (1964) stated that "where the fields are managed, either through private ownership or on long term government leases, lowbush blueberries are heavily fire-pruned to keep the shoots vigorous and productive, a procedure that also exerts some control over insects and weeds."

Dow (1955) wrote: "Most blueberry growers burn their fields every two or three years. This is the only practical method that has been found to date for pruning lowbush blueberries. Periodic burning also aids in controlling certain insects and diseases."

In their conclusion Eaton and Hall (1961) indicated: "Strong new shoots are needed each year to ensure continued production. These can only be obtained by severe pruning. The use of fire is accepted as the simplest method of pruning out the old stems." Others who support this view are Hall (1957): "Burning is essentially a pruning process. Old, highly-branched bushes have fewer flower buds and they must be replaced by single shoots that are more productive." and Kinsman (1959): ". . . blueberries are produced on vigorous one-year old shoots, so blueberry plants must be regularly pruned to produce maximum yield. Burning has proved to be the most economical method of pruning."

In considering the effects of fire on the competing vegetation, the Manitoba Government Blueberry report (1966) stated: "There was a decrease in cover of bearberry (Arctostaphylos uva-ursi) by 55% and a decrease of grasses by 14% the first season after the fire-pruning compared to pre-burn conditions." Bearberry and grasses are the main competitors in south eastern Manitoba. Paul (1966) stated: "Blueberry stands in all forest reserves are most affected by the number of bearberry plants present. A strong negative correlation resulted from the analysis of the association between blueberries and bearberries. Sandilands and Agassiz Forest Reserves were surveyed approximately one month later than the Bel-air Forest Reserve, and there is a suggestion from the results that grass species begin to compete with blueberries later in the summer."

Burning, however, has disadvantages. Dow (1965) stated: "On the other hand, burning has some disadvantages in that it prevents an increase of organic matter in the soil and results in the loss of all nitrogen from the burned plants. The fire hazard in burning also is a serious menace to adjoining fields and woodlands." Eaton and Hall (1961) wrote: "Burning may destroy the organic layer and lower the moisture-holding capacity of the soil. It is important to burn the entire area without leaving any "islands", since old plants provide refuge for many insects and fungus pests."

Burning is important because it changes the physical and chemical properties of the soil. A great deal of work has been done on this subject; this review will be restricted to soil types similar to that encountered in this investigation. The severity of changes introduced depend to a large extent on the temperature of the fire, and it can well be for this reason that there are contrasting records in the literature on almost every characteristic investigated.

Temperatures of up to 850° F in forest fires have been reported by Hoffman (1924), which resulted in the complete destruction of all soil organic matter. Fire also effects the temperature of the soil for some time after its occurrence. This is partially the result of removing the insulating vegetation; more significantly, it is the result of increased light absorption by the blackened surface and by the presence of charcoal in the soil. (Boyce (1925), Isaac (1929), Isaac (1930), Lutz (1934), and Tryon (1948).

The role of fire in increasing erosion and surface runoff, and in changing soil moisture characteristics has been investigated by many authors. In general there is agreement that a fire in wooded areas increases erosion. Bell (1889), Preble (1908), Kolok (1931), Lutz (1934), Trimble and Tripp (1949), Buch (1951). No increase in erosion was reported by: Veihmeyer and Johnson (1944), Adams, Ewing and Huberty (1947), and Biswell and Schulz (1957).

Whether a burn increases the fertility of the soil depends largely on the severity of the fire and subsequent erosion and leaching. When the topography is level at least a temporary improvement is expected. Since ash is rich in alkaline minerals, its leaching into the ground with the rain water will decrease the acidity of the soil solution. This increase of the pH and the addition of minerals will increase the fertility. The following workers support this statement: Alway (1928), Barnette and Hester (1930), Isaac and Hopkins (1937), Uggla (1949), Ferrell and Olson (1952). However, no significant change in soil acidity after a burn was reported by Lutz (1934), Beadle (1940), Beard and Darby (1951).

The duration and temperature of the burn will determine to what extent soil organic matter is destroyed. Closely interrelated with the organic matter is the soil nitrogen, and any change in the former will effect the latter. Nitrogen does not always follow the same trend, since an increase of nutrients in the soil through the ash increases the microbial activity including that of nitrogen-fixing bacteria. Results are therefore only comparable if the samples are taken immediately after the burn. This is one reason for controversial reports in the literature as to nitrogen changes. A loss of soil organic matter with burning was shown by Osborn (1931), Fowells and Stephenson (1933), Donahue (1942), and Trimble and Tripp (1949). No loss of soil organic matter was reported by Wicht (1948), Beard and Darby (1951), and Bruce (1951).

A decrease in nitrogen was revealed by the investigations of Barnette and Hester (1930), Osborn (1931), Lutz (1934), and Trimble and Tripp (1949), while the work of Heyward and Barnette (1934), Garren (1943), Tryon (1948), and Lunt (1951), indicated an increase in nitrogen.

A few of the more important cations (Ca, P, K, Mg) will be briefly discussed.

The change in calcium content is closely correlated with soil acidity. An increase was found by Barnette and Hester (1930), Powells and Stephenson (1933), Isaac and Hopkins (1937), and Garren (1943). On the other hand, Seaver and Clark (1912) showed a decrease in available calcium. An increase in phosphorus was indicated by Lutz (1934), Lunt (1951), and Uggla (1958). No significant change in soil phosphorus after a burn was reported by Fowells and Stephenson (1933), Lutz (1934), and Isaac and Hopkins (1937). An increase of potassium was revealed in the publications of Isaac and Hopkins (1937), Kivekäs (1939), Lutz (1956), and Uggla (1958). No increase in soil potassium after a burn--presumably because of subsequent leaching--was shown by Finn (1934). Austin and Baisinger (1955), mentioned an increase of available magnessium following a forest fire.

Very little work has been done on minor elements. Ahlgren and Ahlgren (1960).

SETTING OF THE AREA

a) Location

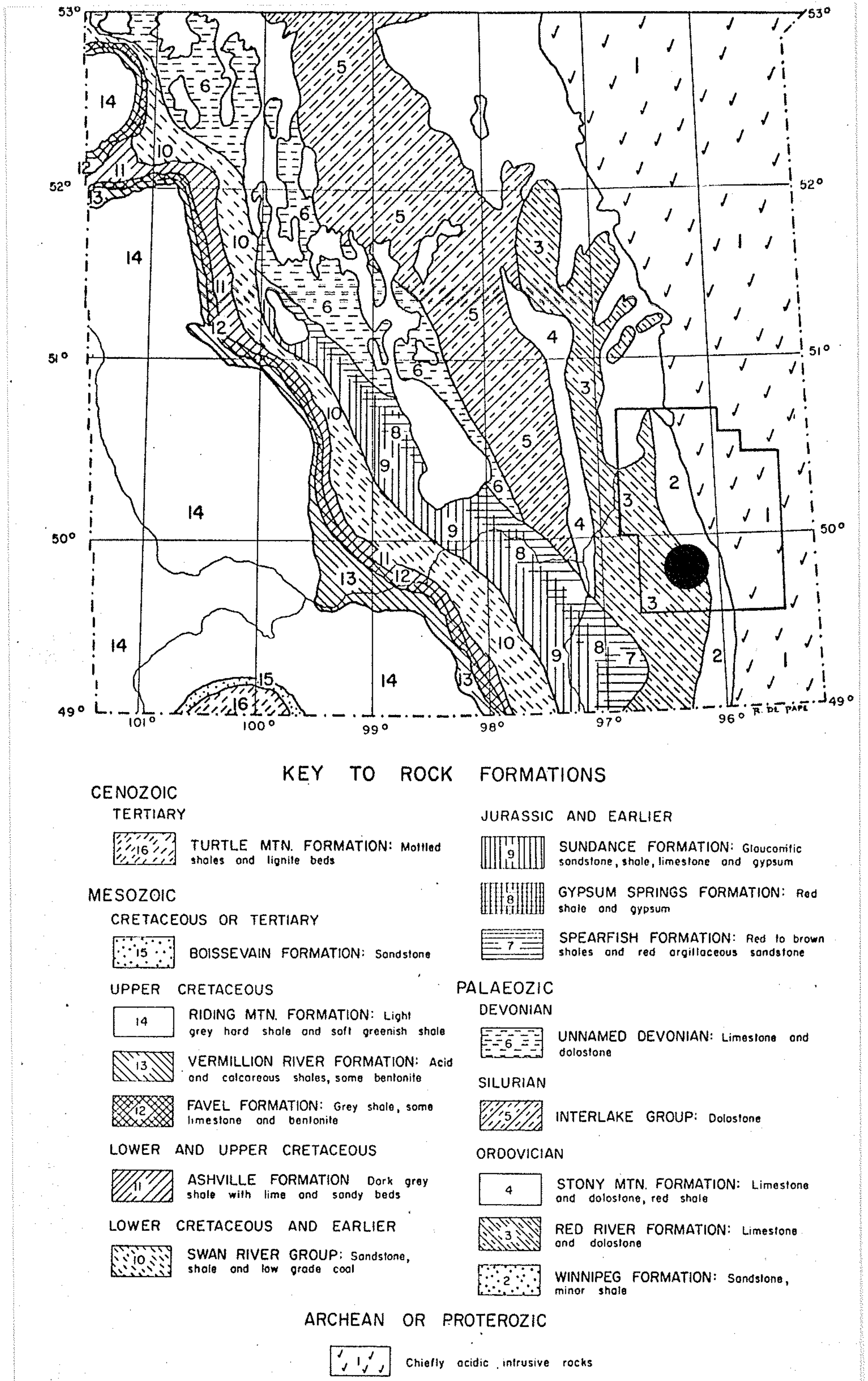
The study area was located in the Agassiz Forest Reserve in the south east corner of Manitoba, approximately 60 km east of Winnipeg. The exact location was 96° west, 50° north, township 11, range 10, sections 28 and 29. It falls into the south eastern "Lake Terrace" area of the physiographic subdivision "Manitoba Lowland" (Weir, 1960), and into the "Lac du Bonnet" map sheet of the Manitoba soil survey (Smith and Ehrlich, 1967).

b) Geology and Physiography

The bedrock formations of southern Manitoba with respect to their surface contact are shown in Fig. 3. The western part of the area is underlain by limestone, dolostone and minor quantities of shale and evaporite of the Red River Formation and the eastern part by sandstone and some shale of the Winnipeg Formation of the Ordovician Period. These sedimentary rocks plus acidic intrusive rocks from the Precambian Shield have all contributed to the glacial drift deposited here.

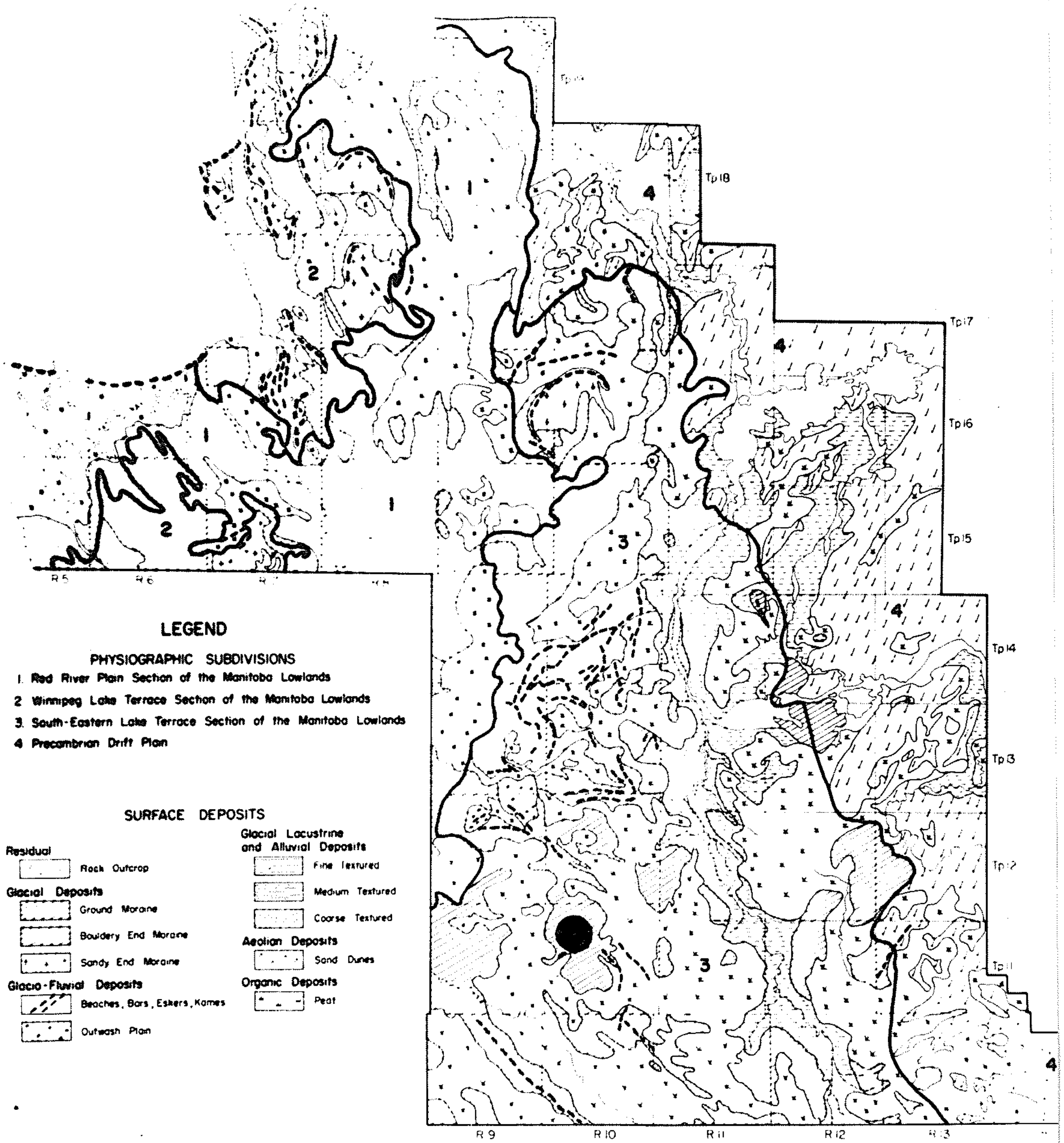
The south eastern "Lake Terrace" (Fig. 4) lies between the flat lacustrine plain of the Red River valley and the Precambian Shield. It is part of the Lake Agassiz basin. The terrain is a complex of landforms that have resulted from the deposition of glacial till, glacio-fluvial outwash, the scouring of the higher sites by wave action, deposition of lacustrine sediments and the ponding and swamping of depositional sites. A surface mantle of unconsolidated

Figure 3. Bedrock Formations of Southern Manitoba.



Black circle indicates study area.

Figure 4. Physiographic Divisions and Surface Deposits.



Black circle indicates study area.

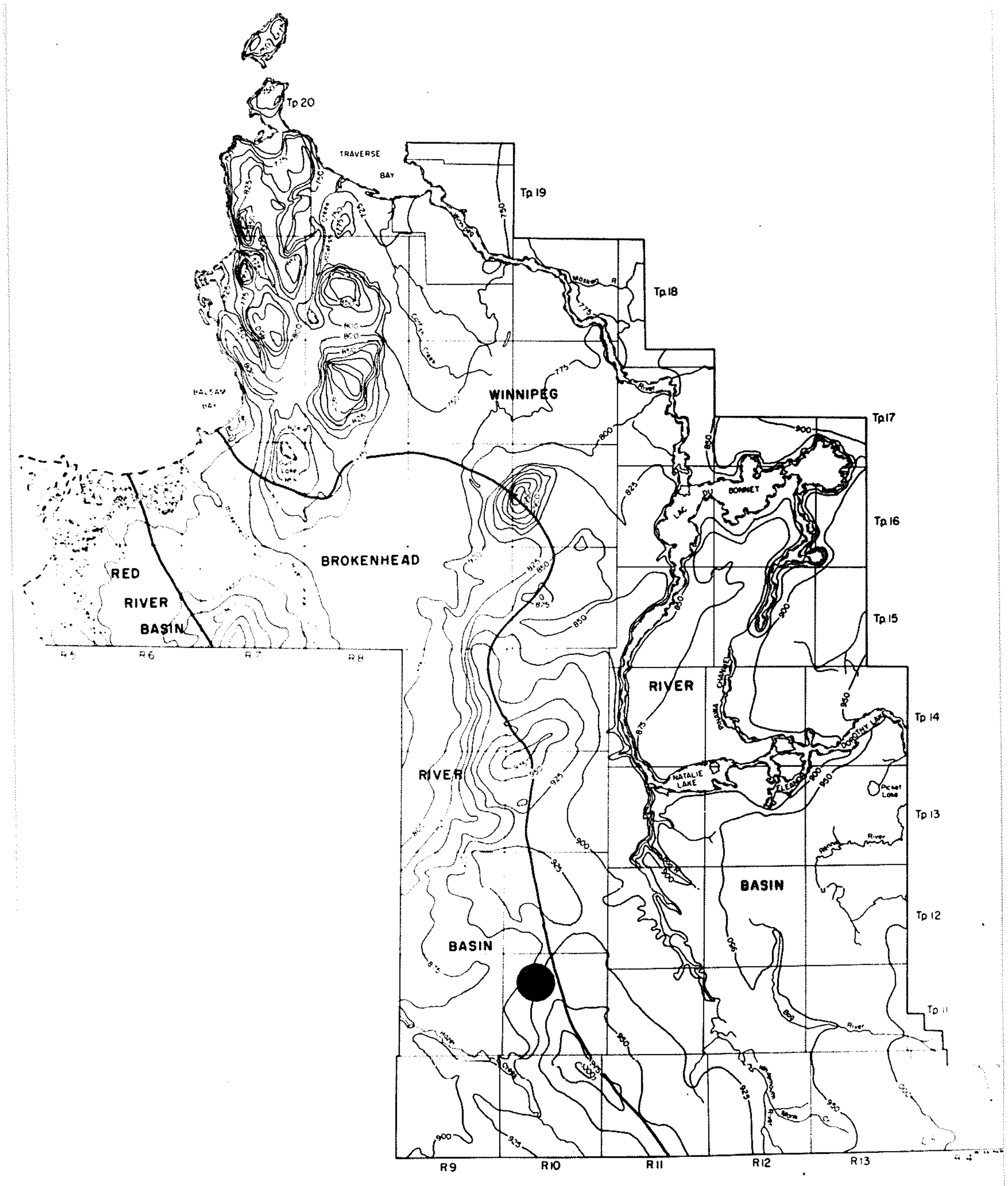
material covers the bedrock formation through most of the area. These unconsolidated materials--drift, glacio-fluvial outwash and lacustrine sediments--constitute the parent material from which the soils have developed. Smith et al. (1967).

The investigation area has an altitude of ca. 900 feet and lies close to the divide between the Brokenhead River and the Winnipeg River basins. The principal relief and drainage features are shown in Figure 5. The Brokenhead River drains most of the Agassiz Forest Reserve, flowing from the swampy lowlands of the south eastern Lake Terrace into Lake Winnipeg. The upper portion of the river and a tributary, Hazel Creek, meander through poorly-defined valleys and overflow their banks frequently. In its lower region the river flows in and is confined to a channel averaging more than 3 meters in depth. Smith et al. (1967).

c) Soil

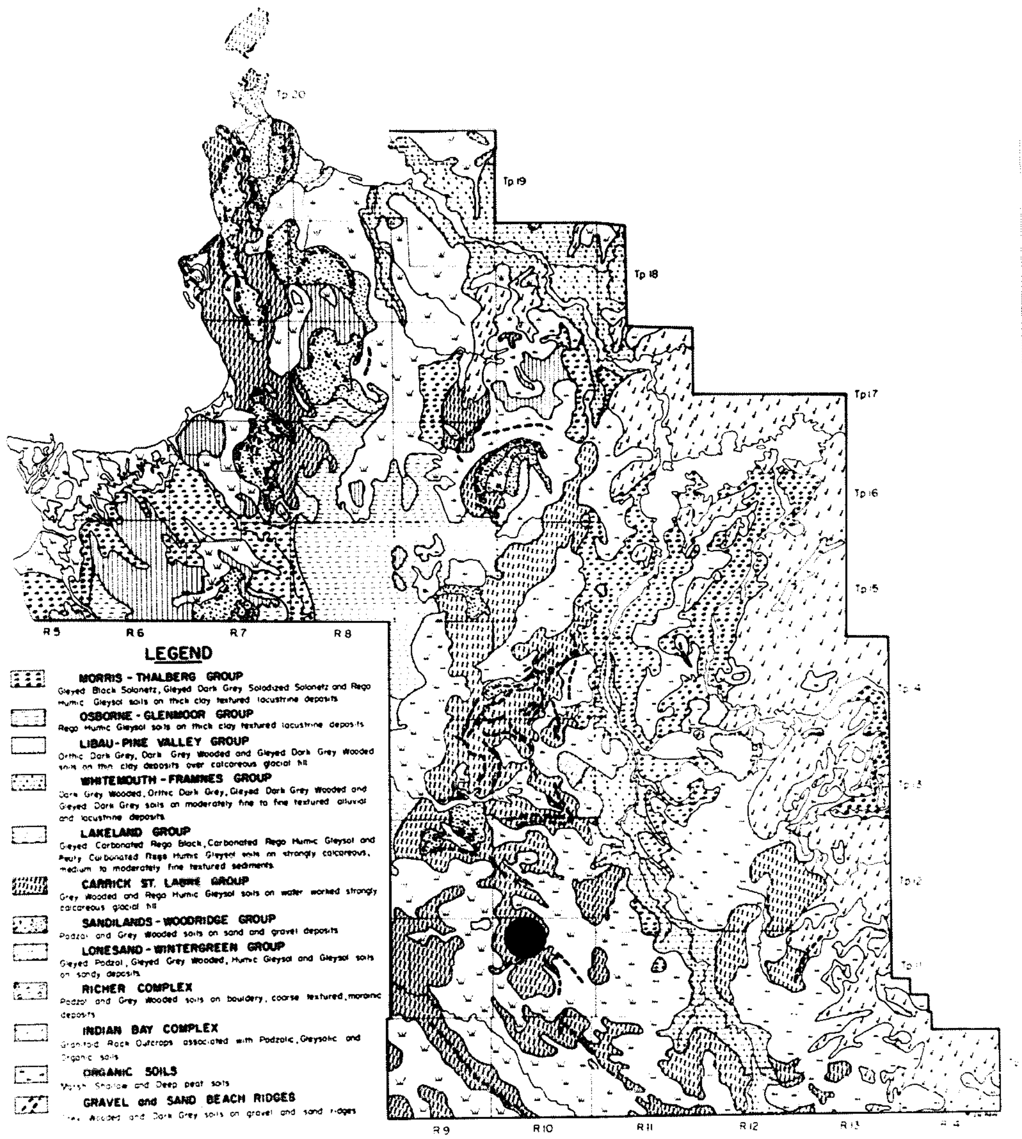
The soil of the study area has developed on a ground moraine. A surface layer of 30 to 90 cm of coarse sand grades into typical "boulder till". In the "Lac du Bonnet" soil map, the area falls into the Carrick-St. Labre soil group, (Fig. 6) characterized by Grey Wooded and Rego Humic Gleysol soils on water-worked strongly calcareous glacial till. However, profile analysis (Fig. 7, Table IX) show it to be a Gleyed Podzol (Stobbe, 1966). According to Smith (1968) this soil is characteristic of the Lone-sand-Wintergreen soil group. Smith et al. (1967) described it as follows: "The Lone-sand series consists of imperfectly-drained Gleyed Podzol soils developed

Figure 5. Topography of Lac du Bonnet Area.



Black circle indicates study area.

Figure 6. Soil Groups of the Lac du Bonnet Area



Black circle indicates study area.

Figure 7. Soil Profile. (Representative form all profiles taken.)

on siliceous sandy outwash. They are associated with numerous moraines that extend from the hamlet of Contour in the south, through Milner Ridge in the central section to Victoria Beach in the north of the area mapped. The topography is generally level to irregular and very gently sloping. Surface drainage is slow and internal drainage is impeded by a high water table.

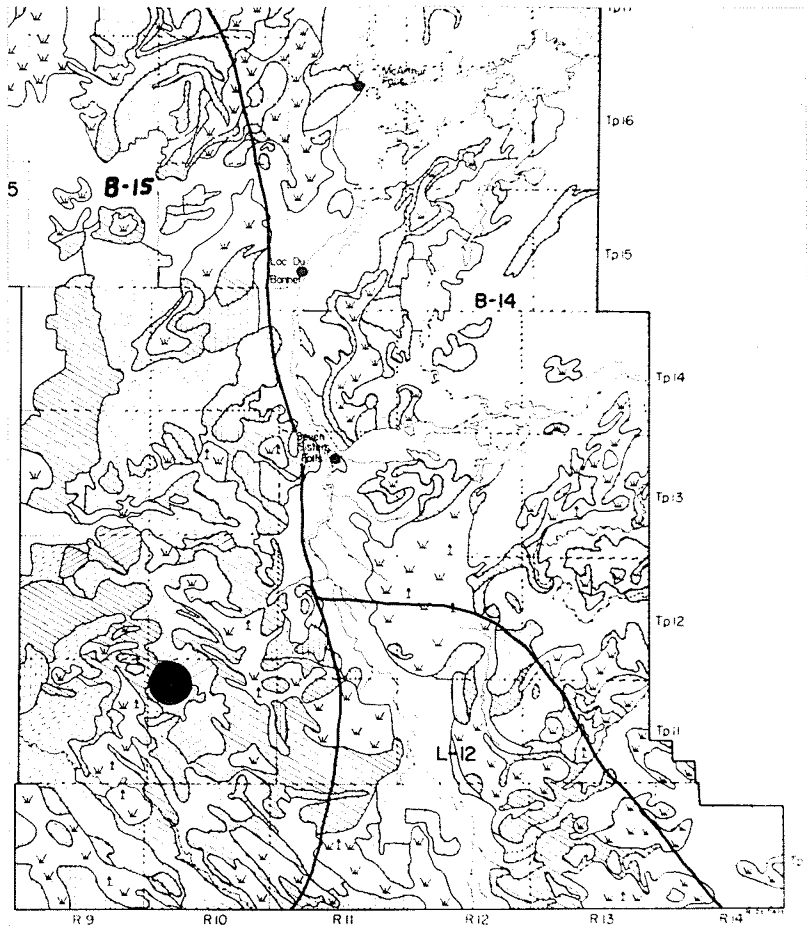
The Lonesand soil profile has a light grey, iron-stained, strongly acid Aeg horizon and a loose to very friable, brown, strongly acid, iron-stained B horizon with a weak concentration of iron and organic matter. The C horizon is acid to a depth of about 1m to 1.2m where traces of lime carbonate are encountered."

d) Native Vegetation

Using Rowe's (1959) classification of Canadian Forests, the Agassiz Forest Reserve is in the "Manitoba Lowland" section of the "Boreal Forest" region--B 15 (Fig. 8).

The prevailing vegetation on the flat, poorly-drained sites consists of patches of black spruce (Picea mariana), with intervening grass and sedge swamps. Well-drained sites usually have a tree cover of white spruce (Picea glauca), aspen (Populus tremuloides), and balsam poplar (Populus balsamifera); sometimes mixed with balsam fir (Abies balsamea) and white birch (Betula papyrifera). Very well-drained sites, like the study area, support jack pine (Pinus banksiana). Other species present locally in this section are elm (Ulmus americana), green ash (Fraxinus Pennsylvanica), Manitoba maple (Acer negundo var. interius), and eastern white cedar (Thuja occidentalis).

Figure 8. Native Vegetation of the Lac du Bonnet Area.



Black circle indicates study area.

LEGEND

- Jack Pine
- Spruce, Balsam Fir, Cedar
- Mixed Softwood and Hardwood
- Hardwood (Mainly Aspen)
- Treed Muskeg - Marshland

Forest Regions:

L.12 Rainy River Section of Great Lakes - St. Lawrence Forest Region

B.14 Lower English River Section of Boreal Forest Region

B.15 Manitoba Lowlands Section of Boreal Forest Region

e) Climate

In relation to world-wide conditions the Agassiz Forest Reserve is within the Dfb climatic region by Köppen (1936). The climate is typically "continental", being a great distance from the oceans and their moderating effect. Summer temperatures are higher, winter temperatures are lower, and the annual temperature range is much greater than the world average for this latitude.

There is a definite summer maximum of precipitation, approximately 70% falling as rain during the period of April to October and about 30% as snow during the winter months. The mean monthly winter temperature is below 0°C, while the mean summer temperature is above 10°C. Transition from winter is abrupt, occurring normally in April, and the change from summer to winter is usually in October. Temperatures are particularly variable during the spring, fall and winter seasons when the area is affected by frequent frontal disturbances between cold "continental polar" air from the north and warm dry "marine polar" air from the south. In winter frontal activity is generally more complex and intensive. (Weir, 1960).

Referring specifically to the Agassiz Forest Reserve, the average frost-free period ranges between 111 and 127 days, while the annual precipitation is slightly below 51 cm (20 inches). Most of the precipitation, both in summer and winter, is frontal in origin accompanying numerous successions of slow-moving cyclonic storms or areas of low pressure.

Table I compares the more important eco-climatic parameters of Manitoban Blueberry areas with those from eastern Canada. The effects of the more continental climate are obvious: precipitation is less in Manitoba, mean July temperature, evapotranspiration and water deficit are greater.

TABLE I

METEOROGICAL DATA
for
BLUEBERRY GROWING

	Belair Man.	Woodridge Man.	Tower Hill N. B.	N. S.	Lac St. John Quebec	Cape Breton N. S.
Frost free days	120	90	120-140	100-120	100-120	120
Degree days above 42°F	2500-2750	2500-2750	2500-2750	2500-2750	2250	2500
End of growing season	Oct. 11-16	Oct. 11-16	Oct. 26-31	Oct. 31	Oct. 11-16	Oct. 31-Nov. 5
Jan. mean temperature °F	0-2	0-2	16-20	18-20	0-5	22
Start of growing season potential	Apr. 25-30	Apr. 25-30	Apr. 25	Apr. 25-30	May 5	May 5
Evapotranspiration	22	22	21	21	20	20
Water surplus 4 inches	2-4	2-4	20	25	12-14	30
Water deficiency	4	4	0	0	0	0
May - Sept. precipitation in inches	12	14	16	18	18	20
Mean July temp. °F	68	66	66	64	64	62
Annual precipitation in inches	18-20	20	40	50	32	50

Source: Manitoba Blueberry Report 1966.

METHODS AND MATERIALS

a) Selection and Subsequent Preparation of the Plots

An area in the Agassiz Forest Reserve had been prepared for burning in the spring 1967 and was used as the site of this investigation.

It was decided to use 5 plots 30.5 cm (1 foot) wide and 15.5 m (50 feet) long to take into account clonal variation. Trevett (1962), Barker et al. (1964). The competing vegetation on these plots was of comparable abundance and composition (Table VI). Further points taken into consideration were uniform topography, comparable soils, a similar water table depth and the absence of decaying tree trunks or stumps, which would have provided a more fertile substrate for blueberry shoots growing close by. It was further assured that the light conditions were uniform before the trees were cut, so that the clones to be exposed to varying degree of shade had had a similar history.

The plots were divided into fifty 930 cm^2 (1 $foot^2$) quadrats, which were numbered 1 to 50, going from west to east. All plots contained between 550 and 650 blueberry shoots and all had a density range from 1 shoot per 930 cm^2 to 30 shoots per 930 cm^2 in their quadrats. Of the 50 quadrats 10 were selected for a detailed study from each plot. Selection was made with regard to a desired range of densities, since several blueberry characters have been described as density-dependent. Trevett (1962). Table II lists the selected quadrats in each plot with their densities and location. Low-density quadrats were duplicated as a precaution against sampling

TABLE II

QUADRATS SELECTED FOR DETAILED STUDY

% - Shade Plots	Quadrat No.	1	2	3	4	5	6	7	8	9	10	Total
0%	Location	22 E*	35 E	45 E	16 E	24 E	7 E	29 E	19 E	5 E	4 E	
	Density	1	1	5	5	10	11	16	20	24	29	122
25%	Location	24 E	30 E	10 E	49 E	36 E	50 E	12 E	2 E	39 E	35 E	
	Density	1	1	5	5	10	10	15	20	25	30	122
50%	Location	7 E	1 E	3 E	11 E	29 E	49 E	38 E	35 E	33 E	37 E	
	Density	1	2	4	7	10	10	15	21	25	27	122
75%	Location	1 E	2 E	14 E	47 E	3 E	32 E	19 E	24 E	22 E	28 E	
	Density	1	1	5	5	10	10	15	20	24	31	122
100%	Location	49 E	15 E	8 E	22 E	23 E	28 E	4 E	47 E	42 E	2 E	
	Density	1	3	5	5	10	9	15	19	23	32	122
	Desired Density	1	1	5	5	10	10	15	20	25	30	122

* 22 E Refers to The 22nd Quadrat East of Zero.

loss. The total number of shoots selected for detailed study was 122 per plot. This was considered an adequate sample size (Paul, personal communication), since a further increase in shoot number of 60% to 80% was expected after the burn. To relocate the plots after the fire, boundaries were marked with aluminum stakes. The blueberry shoots were then fire-pruned with a propane burner mounted on a tractor. The ground temperature was 125°C to 250°C, sufficient to prune the blueberry shoots, but not to destroy the organic surface horizon of the soil.

After the burn the plots were re-established by connecting the aluminum stakes with string. Individual quadrats were marked with wooden stakes. Shade was then provided over these plots artifically through wooden screens. The slats of the screens and the spaces between them alternated in such a way as to give the range in shade intensities shown in Table III.

TABLE III

Plot Numbers and Treatments

Plot No.	Treatment
1	0% shade (open conditions)
2	25% shade
3	50% shade
4	75% shade
5	100% shade

The individual units of the screens were 120 by 120 cm, and 14 of these were used for each plot. The orientation of the plots was east-west; a wooden framework (5 x 10 cm timber) supported the screens at a height of 30 cm above the ground on the south side rising to 80 cm on the north side. (Fig. 9).

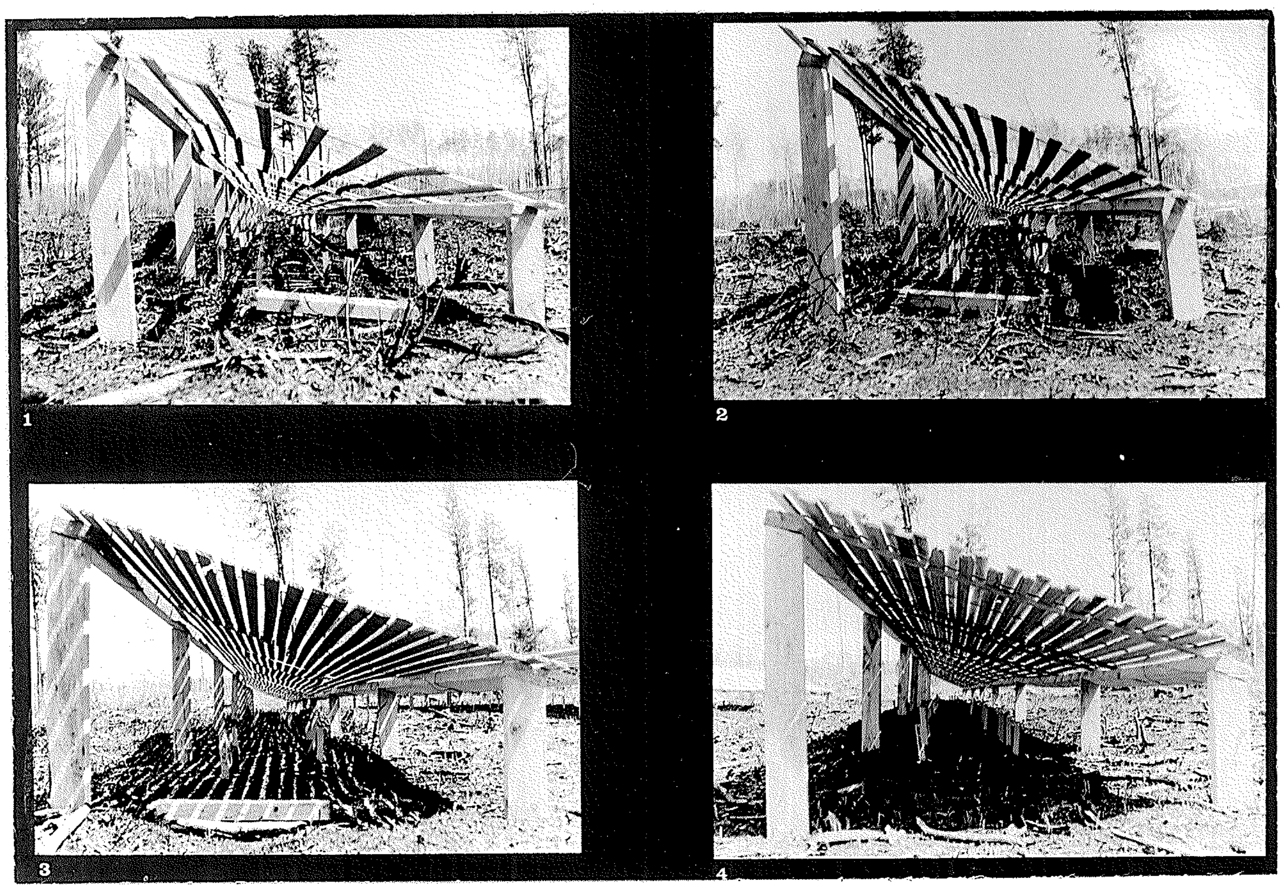
This design had the following advantages: (a) The desired alternation of light and shade was experienced over most of the day. (b) The screens were high enough to allow measurements to be taken under them without removing them. (c) Free air movement--important for temperature and humidity exchange--was possible, and (d) The narrow and inclined screens did not greatly interfere with precipitation; however, they were wide enough, compared to the width of the plots, to prevent an "edge-effect" (Odum, 1959) on the latter.

To prevent the translocation of water and nutrients into and out of the plots through the blueberry rhizomes, a 20 cm deep cut was made around each plot at a distance of 60 cm from the boundaries. The average depth of rhizomes was found to be 6 cm, determined from 20 randomly selected plants. (Table IV). The complete sequence of events from the appearance of the site before the burn to the erected screens is shown in the photographs in Fig. 10. A comparative side view of the different shade percentage screens is given in Fig. 9.

b) Analysis of Blueberry Characters

All 10 quadrats in each plot were investigated twice each week in June and July and once each week during the remainder of the season. For each quadrat a map was made and emerging shoots were plotted and numbered. Time of emergence, size, time of apical abortion, frost damage and amount of branching were recorded in a Table accompanying each map. (Table V). Tagging had been used in

Figure 9. Side View of Screens



1) 25% shade, 2) 50% shade, 3) 75% shade, 4) 100% shade screens.

Figure 10. Preparation of the Plots

Appearance of Plots Before the Burn

Figure 10 Continued

Burning of the Plots

Appearance of the Plots After the Burn

Figure 10 Continued

Supporting Framework for Screens

Appearance of 75% Shade Screen (left), 50% and 25% Shade Screens (right).

TABLE IV

DEPTH OF RHIZOMES IN CM.

Plant No.	0	15	30	45	60	75	90	105	120	135	150	165
	Distance from plant in cm:											
1	9.4	12.1	10.7	4.9	3.6	5.2						
2	6.4	5.8	10.3	9.7	8.8	7.6						
3	7.3	6.7	6.1	6.4	4.0	5.5	3.3	3.3	3.3	8.5		
4	7.6	6.4	7.3	6.7	9.4	9.7	10.9	12.8	12.8	12.8	14.3	18.0
5	1.5	2.1	4.3	6.1	4.6	6.4	8.1	7.3	5.7			
6	1.5	2.4	2.4	2.7	4.9	6.1	4.6	1.5	4.6	3.6		
7	3.6	6.1	9.4	9.7	7.6	6.1	7.3	10.3				
8	0.0	4.6	10.3	13.4	18.4	19.7	10.9	8.8				
9	0.6	1.5	1.5	3.0	3.6	6.1	7.3	5.2	7.3	6.7	3.0	
10	3.0	3.0	5.5	8.5	7.9	7.6	9.4	9.7				
11	3.0	5.[illegible]	3.3	2.4	3.6	7.9	3.0					
12	0.3	1.9	3.0	3.0								
13	0.3	[illegible].1	3.0	3.7	7.6							
14	0.6	3.0	3.7	3.7	1.8	2.6	3.0	5.5				
15	0.6	7.3	9.7	10.7	10.7							
16	0.3	1.2	3.7	6.1	10.9	12.8						
17	1.5	3.3	4.6	15.2	3.7	7.6	6.7	4.3	3.0			
18	1.5	13.7	12.2	12.2	12.2							
19	1.5	3.0	3.0	4.9	3.0							
20	1.5	3.0	8.2	4.9	7.6	6.1	6.7	9.7	6.7	6.1		

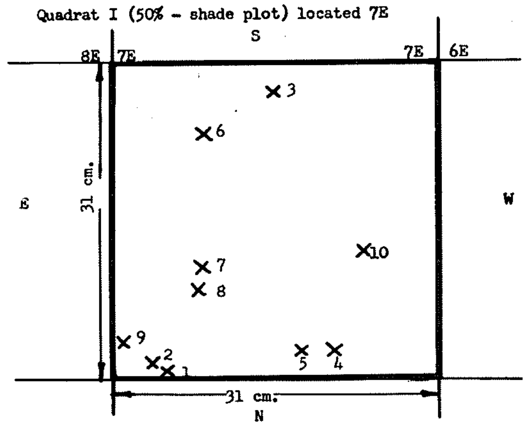
Average rhizome depth 5.9 cm (range 0.0 to 18.0 cm)
Average length of a rhizome 101 cm (range 45 cm to 165 cm)

TABLE V

METHOD OF RECORDING SHOOT NUMBER, SIZE, EMERGENCE, DIE BACK AND BRANCHING

A. "MAP" OF PLOT

Quadrat I (50% - shade plot) located 7E



B. "DIARY" OF QUADRAT I (50% SHADE PLOT)

APPEARANCE, DIEBACK (□), SIZE OF SHOOTS AT DATES INDICATED. ▬ - FROST DAMAGE

Shoot No.	June 5/67	9/67	14/67	16/67	20/67	23/67	26/67	30/67	July 3/67	10/67	14/67	17/67	21/67	28/67	Aug. 4/67	11/67	17/67	29/67	Sept. 5/67	20/67	Size Converted to cm.	No. of Branches
1	-	.4	.8	.8	1.0	1.2	[1.2]	.8	1.1	1.3	1.8	2.4	2.6	2.5	3.0	2.8	3.0	3.0	3.0	3.1	9.6	2
2	-	.5	1.0	1.0	1.5	1.8	[1.7]	1.5	1.5	1.4	1.5	2.2	2.3	2.5	2.7	2.6	2.6	2.7	2.7	2.6	8.1	3
3	-	.4	.7	.7	1.0	1.0	1.2	[1.0]	1.0	1.4	1.7	1.6	2.1	2.0	2.4	2.3	3.1	3.3	3.5	3.1	9.6	2
4	-	.1	.6	.8	1.2	1.5	1.5	[1.5]	1.4	1.3	1.5	2.1	2.4	2.4	2.5	2.5	2.4	2.5	2.6	2.6	8.1	1
5		-	.4	.5	.9	1.5	2.0	2.5	3.0	4.0	4.2	4.7	[5.0]	5.1	5.3	5.3	5.2	5.2	5.2	5.3	16.4	1
6			-	.2	.5	.8	1.4	1.5	2.0	2.5	2.6	3.0	[3.4]	3.8	4.0	4.0	4.3	4.9	4.6	4.5	14.0	1
7			-	.3	.7	1.1	1.3	1.4	1.5	2.0	2.2	[2.4]	2.6	2.5	2.5	2.7	3.2	3.4	3.6	3.5	10.9	1
8				-	.1	.4	.7	1.0	1.2	1.4	[1.5]	1.7	1.5	1.9	2.1	2.4	2.6	2.5	2.6	2.6	8.1	2
9									-	1.2	[1.7]	1.9	2.6	2.8	2.8	3.0	2.9	2.8	3.0	3.0	9.3	2
10													1.0	2.0	3.1	4.0	5.0	[5.0]	5.0	4.0	12.4	1

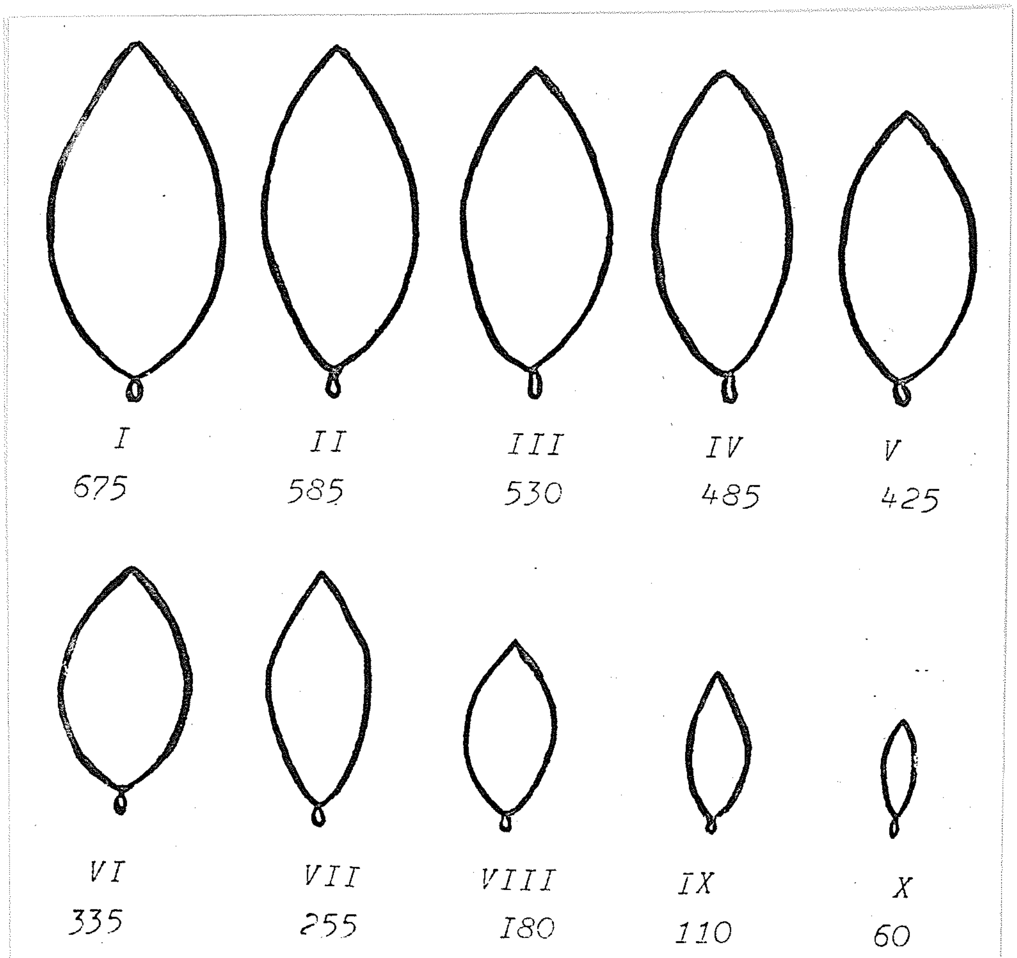
Manitoba in previous years, but this seemed to have a harmful effect on sensitive young shoots. Tags also may affect or even prevent the emergence of new shoots directly under them because of their weight and the elimination of light, and this would introduce errors.

Since the selection of quadrats was not random, at the end of the growing season all 50 quadrats in each plot were investigated for number of emerged shoots, final size of shoots and amount of branching. No significant difference was found between these results and those from the 10 "selected" quadrats. It can therefore be assumed that the sample size was representative.

To be able to compare the response of Vaccinium angustifolium to shade in Manitoba with results obtained by Hall (1958) and Hall and Ludwig (1961), who worked with the same species and a similar experimental design in New Brunswick, fifty blueberry shoots were selected randomly in each plot, and the shoot size, stem diameter at the soil surface, average leaf size and internodal length were determined. Leaf size was estimated by removing the leaf from the shoot and comparing it on a diagram with 10 "grades" of predetermined leaf sizes, drawn from a previous collection. Fig. 11 gives the grades and the corresponding areas in mm^2, which were used in the subsequent analysis.

A computer was used to assist in the statistical analysis of the data. Every numbered shoot had been allotted a card, onto which all important characters had been punched. This is a permanent record to which data from the summer 1968 and subsequent information can be added.

Figure 11. Leaf Type Variation and Areas (mm^2).



c) Treatment of the Competing Vegetation

It should be emphasized at this stage, that the plots were laid out for a detailed analysis of *Vaccinium angustifolium* in an area where competing vegetation was of little importance. The results obtained will therefore not give a representative picture of the competition problem in Manitoba's blueberry areas.

The competing vegetation was analyzed three times: (a) before the April burn; (b) after the burn at the end of June; and (c) at the end of August. The first assessment was part of the method for establishing the plots.

A summary of the pre-burn investigation is reproduced in Table VI. Only woody species, evergreens and mosses could be identified with any degree of accuracy at this early date. Cover and frequency values were determined for each quadrat in each plot. A modification of Braun-Blanquet's (1932) cover values was applied. This is given in Table VII. The June analysis was made to determine the spring competitors or the pioneer species, which emerge first after a forest fire. The August analysis was done to check whether there was any change in composition of the competing vegetation as the season advanced.

Attempts were made to correlate competing vegetation with shade and with blueberry performance. An index of competition was worked out by multiplying the frequency by the average cover value for each species, which were subsequently rated as to their importance as competitors.

TABLE VI

FREQUENCY OF COMPETING VEGETATION BEFORE THE BURN

Plot	Moss	Gaultheria	Grass	Pyrola	Cornus	Fragaria	Rosa	Ledum	Fern	Lycopodium
0%	46	44	22	4	36	22	16	2		
25%	20	40	42	2	62	10	4			
50%	40	48	22	8	46	8				
75%	72	62	42	38	36	28				10
100%	70	32	64	52	12	40	4	10	16	

TABLE VII

COVER VALUES (Modified from Braun-Blanquet, 1932)

1 = presence and up to 5% cover

2 = 6% to 25%

3 = 26% to 50%

4 = 51% to 75%

5 = 76% to 100%

Decimals used for conversion when using cover value scale:

0 = 0%	1.8 = 5%	3.6 = 41%
0.2 = 0.2%	2.0 = 6%	3.8 = 46%
0.4 = 0.4%	2.2 = 10%	4.0 = 51%
0.6 = 0.6%	2.4 = 14%	4.2 = 55%
0.8 = 0.8%	2.6 = 18%	4.4 = 60%
1.0 = 1%	2.8 = 22%	4.6 = 65%
1.2 = 2%	3.0 = 26%	4.8 = 70%
1.4 = 3%	3.2 = 31%	5.0 = 75% and higher
1.6 = 4%	3.4 = 36%	

d) Treatment of the Soil

Soil samples were obtained from 8 sites; 3 from a comparable unburned area surrounding the investigation plots, and 5 composite samples from the 5 burned plots, all selected at random. At each site a sample was collected from each horizon (L-H, Aej, Bmgj, B-C, Cgj), (Smith, 1967). Soil pits were dug in the unburned area, while auger cores were used in the plots to avoid undue disturbance. The composite samples for each plot consisted of mixtures of 3 randomly selected core samples.

Mechanical and chemical analyses were undertaken in the Department of Soil Science, University of Manitoba. The soil texture was determined through the sedimentation technique (pipette analysis) outlined by Kilmer and Alexander (1949). Methods used by Burns (1952) and Beaton (1959) were employed to determine water infiltration rates. A steel cylinder, 20 cm high, with a cross sectional area of 125 cm^2 was driven 10 cm into the mineral soil. A piece of wire screen, fitted to the inside, was put on the ground to prevent disturbance of the soil which would introduce an error in time taking, when water was poured into the cylinder. The time required for 1000 ml of water to pass into the soil was measured to the nearest sec. Twenty replications were done in both burned and unburned areas in a random manner.

Using the methods outlined by Atkinson, Giles, MacLean and Wright (1958), the following chemical properties of the soil were determined: pH, conductivity in mmhos per cm, percent calcium carbonate equivalent, percent organic matter, percent total nitrogen, sodium bicarbonate extractable phosphorus in ppm, cation exchange capacity in meq. per 100 g., and the exchangeable cations (Ca, Mg, K, Na) in meq. per 100 g.

e) Determination of Micro-Climatic Factors Under the Screens

A series of measurements on light (duration and intensity), temperature and moisture were made to find out to what extent the conditions under the screens differed from those in the open.

1) Light: The east-west orientation and the inclination of the screens to the south influenced the duration of light and shade received under them by the plots. They caused a relatively rapid alternation of light and shade in the mornings and evenings, since at these times the sun's path crossed the screens, while at mid-day light and shade alternated slowly. At this time the sun's path more or less paralled the direction of the plots.

The exact lengths of time during which a point came into light and remained in it, before becoming shaded again, was measured at regular intervals over the entire day to the nearest minute. This was done for the 75% shade screens and the 50% shade screens, and interpolated for the 25% shade screen. Two instruments were used to measure the actual light intensity received under the screens. The Weston Illumination Meter (Model 756) proved very useful, since its measuring or sensitive area corresponds closely to the area covered by a blueberry shoot (ca. 13 cm^2), in its first growing season after fire-pruning. Since only one instrument was available, measurements were made when light conditions were constant for a period of time, sufficiently long to take several readings. Under the screens both the greatest light intensity on the illuminated strips and the lowest light intensity in the shaded strips were measured. A weighted mean intensity was then computed by considering both the intensity and the duration of each. This procedure was repeated for each plot and served well for comparisons.

Light intensity was always measured by putting the instrument's measuring panel flat on the ground with the sensitive cells pointing vertically upward. Measuring directly against the sun was not accurate, since on a bright day this light intensity would exceed the sensitive range of the instrument. Three measurements were taken in a short sequence, one at the ground in the open, the second under the screen on a shaded strip and the last under the screen on an illuminated strip. Shade was defined as reduction in light intensity and computed by subtracting the weighted mean light intensity under the screens from that measured in the open.

The second instrument used for light measurements was the pyrheliometer of the Belfort Instrument Company. Compared to the Weston Light Meter this instrument was not as useful since the sensitive black and light metal plates are many times larger than the area covered by a blueberry shoot. Also, in the 50% shade plot, they extended over two light and one dark strip. The values measured were therefore averages. Two pyrheliometers were used. They were first checked for deviation by setting them up under the same light condition. One was then left in the open at an elevation of 10 cm above the ground, the other was set up under a screen at the same elevation. A 10 cm height was chosen to prevent the shading influence of vegetation. After a two-day run the instruments were moved to the next plot until all plots had been investigated. A Polar Planimeter (Hughes-Owens Model 29012) was used to compute the areas under the lines of the charts recorded by the instruments. Again, shade was considered as reduction of "open" light intensities and expressed as a percentage.

2) Temperature: The extent to which the temperatures under the screens differed from those in the open was investigated using a Tele-thermometer (YSI Model 42 SC). This was connected to a 12 line switch box, which allowed the simultaneous recording of up to 12 thermistors. To obtain a complete "profile" of temperatures in the open and under the screens, thermistors were established at following levels: (a) one at a height of 120 cm. This is the elevation at which temperatures are usually recorded by weather bureaus and since this was above the screens only one thermistor was required. Pairs were then set up at (b) 30 cm, (c) 3 cm, (d) at the soil/air interphase, (e) 3 cm below the ground, and (f) 20 cm below the ground. Temperatures were measured simultaneously over the entire day at intervals determined by the frequency of alternations of light and shade. In other words, an attempt was made to measure "extremes". For instance, the temperature of a spot was measured which had been in the light for the maximum length of time, just before it was covered by shade, or, at the other extreme, the temperature when it had been in the shade for the maximum

length of time. This method was repeated for all plots over a period of several days. A temperature of 32°C at 120 cm height was then selected to compare the trends under the different screens. This temperature had been measured on 3 plots and was interpolated for the remaining 2 plots. For comparative purposes, a weighted mean temperature was computed, taking into account the values obtained on the light and on the dark strips and the duration of each under the screen in question.

3) Moisture: Attempts were made to compare the moisture relationships on the plots, and to find out, whether and to what extent the screens interfered with precipitation. Two methods were employed. Firstly, the rain was measured in the open and under the screens by using large funnels of 20 cm diameter directed into 1000 ml bottles which contained 20 ml paraffin oil to prevent evaporation of the collected water. Unfortunately only 3 runs of measurements could be made using 6 funnels at a time, then the area was closed off because of forest fire dange, prohibiting the completion of recording the data on this study.

The second method used was the indirect determination of available soil moisture with a Bouyoucos Moisture Meter (Model BN-2B). Gypsum blocks were buried in the soil at depths of 2, 8, 16 and 30 cm. Records were made throughout the summer. These moisture blocks proved somewhat unreliable in this coarse-textured soil, but served well for comparative purposes. The instrument was calibrated in the laboratory using the same type of soil. In the section on results and discussion tables with moisture meter readings are reproduced to show the effects of the screens on the available soil moisture after a period of drought.

RESULTS AND DISCUSSION

a) Analysis of Blueberry Characters.

Emergence and Apical Dieback: All plots were burned on April 28 and the first shoots emerged on June 3. Fifty percent of all shoots emerged during the following 2 weeks, while the remainder were spread over the rest of the growing season. Apical abortion was detected first on June 18 and by July 14 had occurred in 50% of all primary shoots. Both emergence and dieback showed a normal distribution, if frost-induced dieback was not considered (Fig. 12). If June 17 and July 14 were taken as the average dates of emergence and dieback then the time of elongation of the primary shoot was about one month. No difference was observed between the shoots under various percentages of shade in this respect. Shoots that emerged early died back early; in shoots which emerged late, apical abortion occurred late.

However, early dieback did not necessarily result in cessation of growth. If it occurred before June 30, then 75% of the aborted shoots developed several branches, while the remainder resumed growth through elongation of a single axillary bud. If dieback occurred later than July 28, then 75% of the aborted shoots ceased growth. Between these two dates abortion was followed more than half of the time by further growth of a single axillary bud; the proportion of branched shoots decreased, while the proportion of shoots with no further growth increased as the season advanced (Fig. 13). This figure includes frost-induced dieback, which caused the secondary peak around June 26. The fact that apical

Figure 12.

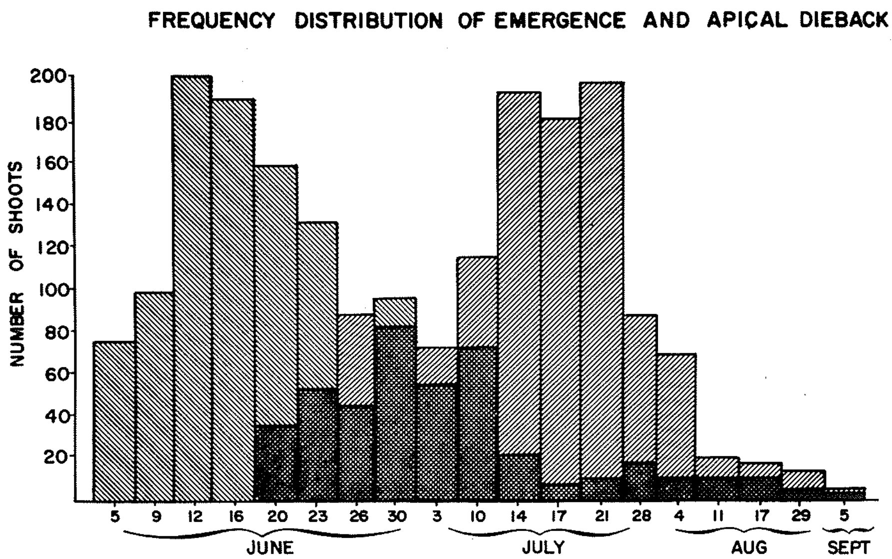
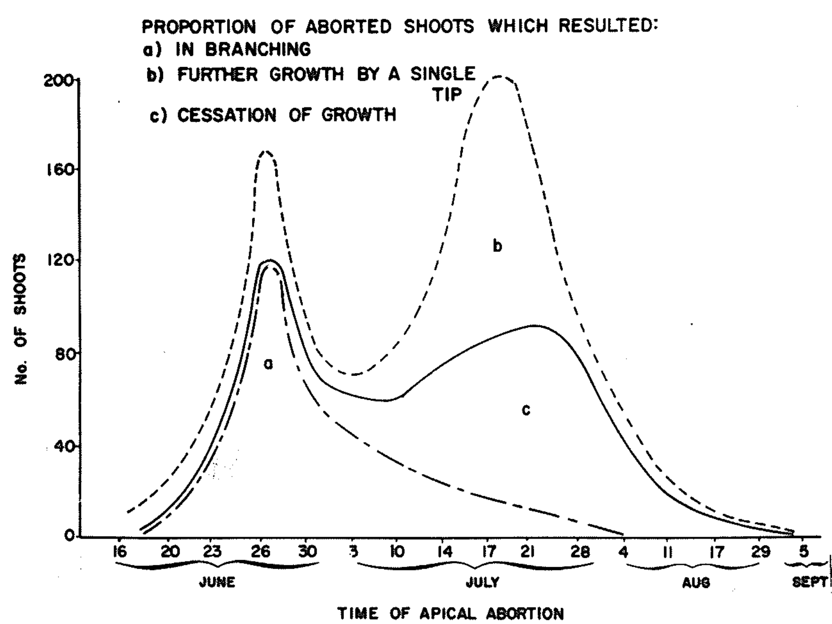


Figure 13.



abortion spread over the entire season supports the conclusion of Barker and Collin (1963) that it is not controlled photoperiodically. This trend has practical implications. If it were possible to artificially induce abortion early in the season, the proportion of branched shoots could have been increased.

Shoots Per Unit Area: The increase in number of shoots per unit area over pre-burn density was highest in the open and decreased progressively as the shade became more intense. The open plot showed an increase of 97% over the pre-burn density, while the 75% shade plot showed an increase of only 73%. For all practical purposes the 75% shade plot will be taken as the limit, 100% shade has never been observed in a natural blueberry stand and has therefore no significance (Fig. 14). The increase in number of shoots is also influenced by the density of the quadrat before the burn (Fig. 15). Quadrats of a low pre-burn density increased at a much faster rate than those which already had a high density before the burn. The relationship is logarithmic. A quadrat containing 1 to 5 shoots per 930 cm^2 (1 $foot^2$) increased its density by 175%; a quadrat which already had 35 to 40 shoots per 930 cm^2 increased by only 35%.

The practical importance of this trend is that the "patchiness" which is observed in a natural stand (Trevett, 1962; Barker et al. 1964) would gradually give rise to a more uniform and continuous population after repeated burning.

Figure 14.

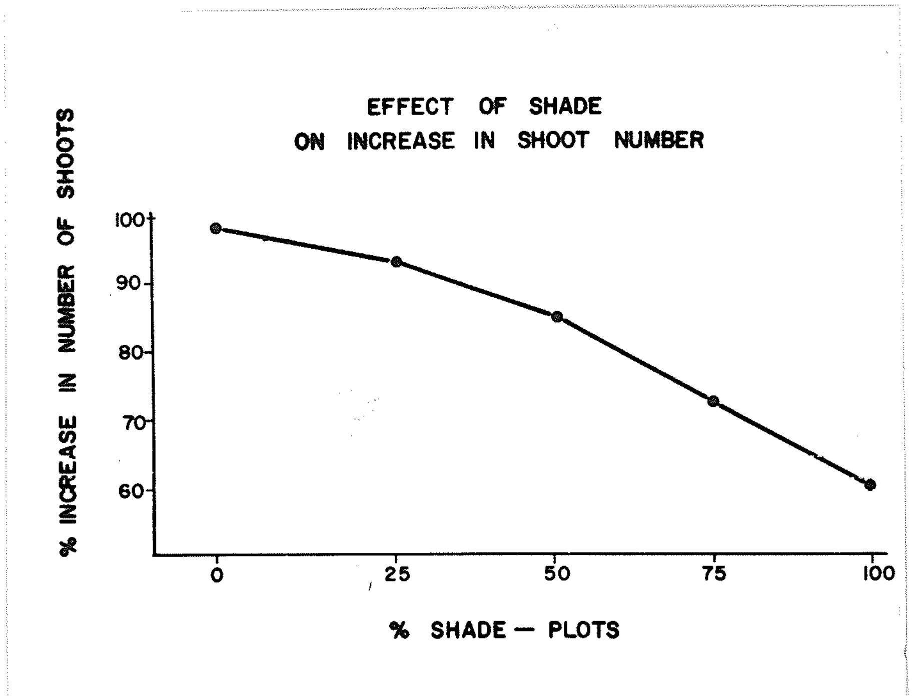
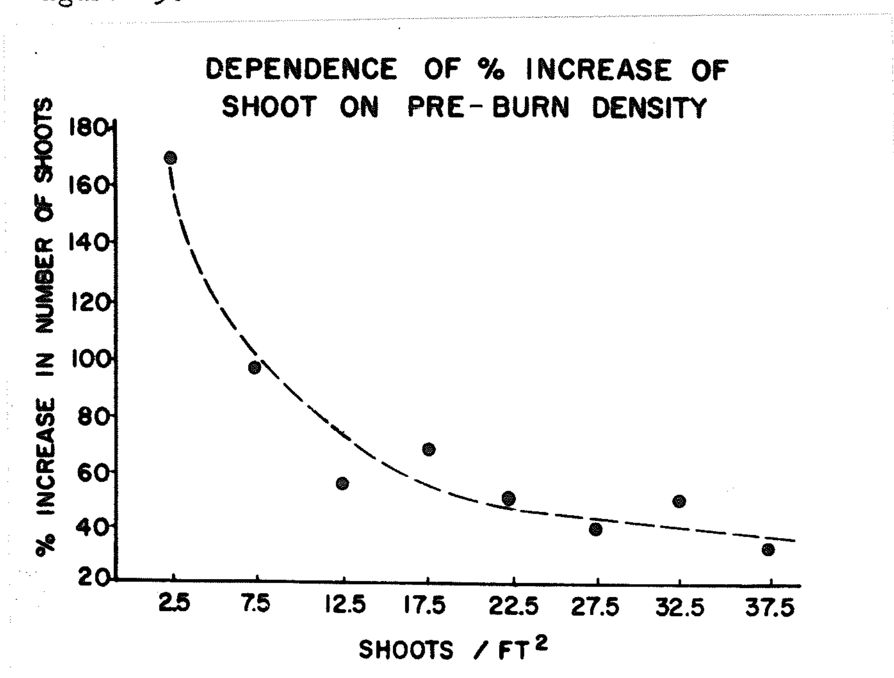


Figure 15.



Final Shoot Size and Growth Rates: The final shoot size increased as the amount of shade increased. There is a positive correlation up to the 75% shade level, followed by a sharp drop toward the 100% shade level. However, as already mentioned, 100% shade is not found in a natural stand and need not be considered. The average shoot size in the 75% shade plot was 12.9 cm compared to 11.0 cm in the open plot. (Fig. 16). Taller shoots have following two advantages: (1) they have more branches, and (2) they have more fruiting buds than shorter shoots. Trevett (1962). This trend is in contrast to the findings of Hall (1958) and supports in part the conclusion of Smith (1962).

The growth rates of the shoots in the open and in the 75% shade plots are shown in Figure 17. The larger final size in the shade was due to two factors: (1) a steeper gradient or faster growth rate, and (2) a slightly longer growing season. The average time of emergence was the same. Figure 17 includes the elongation of branches. The final shoot size is positively correlated to the time of emergence (Fig. 18). This supports the findings of Eaton and White (1960) of the economic importance of an early burn. Lastly, the density of the quadrat in which a shoot grew influenced its final size. This has already been stated by Trevett (1962). Figure 19 shows the negative correlation. Shoots growing in quadrats with densities 1 to 5 shoots per 930 cm^2 attained an average height of 15 cm, while those growing in densely populated quadrats (35 to 40) averaged 12 cm. Higher densities were normally not encountered. When they did occur, it was the result of exceptionally favorable

Figure 16.

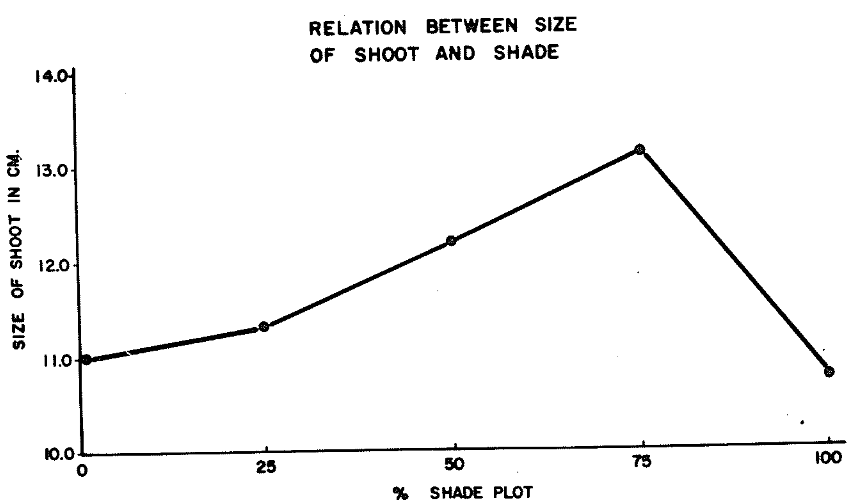


Figure 17.

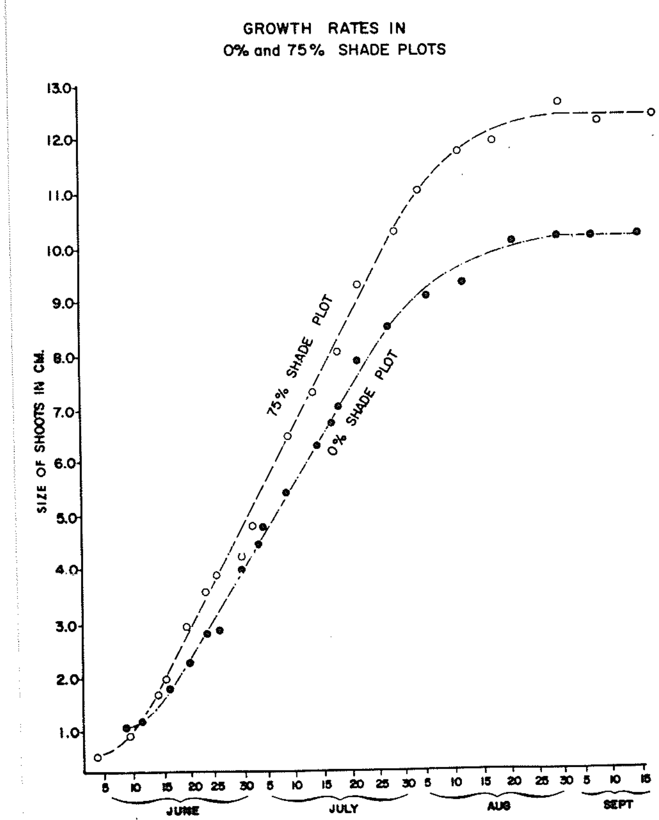


Figure 18.

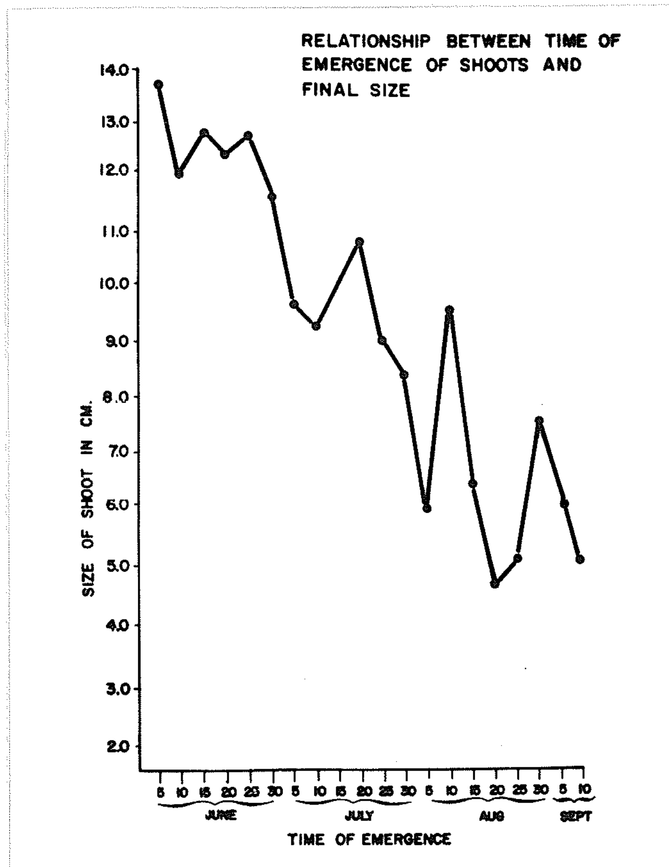
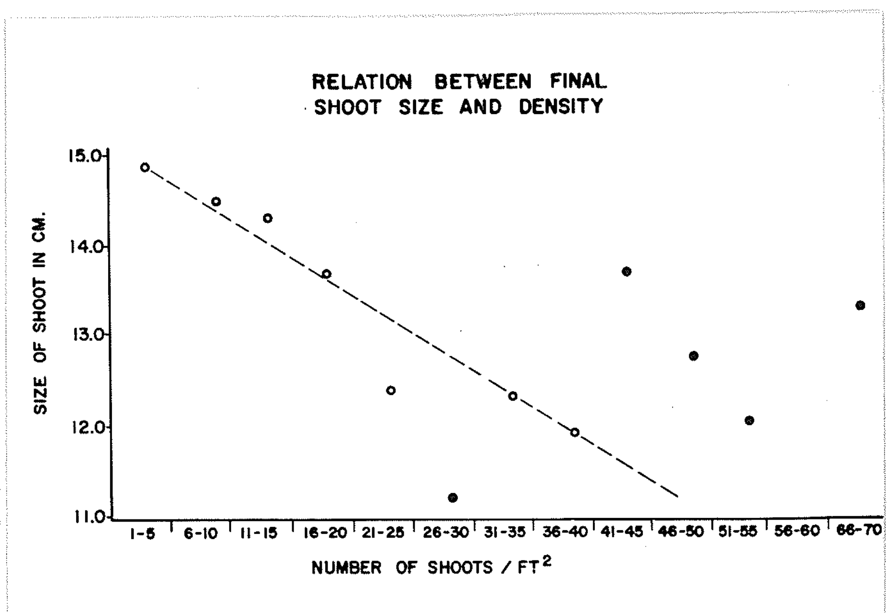


Figure 19.



○ composite observation
● single observation

soil conditions. Under those condition the shoots were also taller than expected and did not follow the above trend. These plots are shown as solid dots in Figure 19; they are based on single observations and were not considered when drawing the regression line.

Branching: Forty per cent of the shoots in the open had branches compared to only 18% of the shoots under 75% shade. The negative correlation is linear. (Fig. 20). A significant proportion of the branching was frost-induced. A heavy frost on June 26 damaged 27% of all the shoots in the open, which had at the time emerged, 17% in the 25% shade plot and 7% in the 50% shade plot. No damage was observed in the remaining two plots. Frost damage never resulted in death of the shoot, but 65% of the affected shoots developed branches. Thus, without frost influence the differences in percentage of branched shoots between the open and the shaded habitat would have been less pronounced. Not only was the percentage of branched shoots higher in the open, but also the number of branches per branched shoot was greater (Fig. 21). The average number of branches per branched shoot in the open was 3.2 compared to 2.4 under 75% shade. Branched shoots have more fruiting buds (Trevett, 1962) thus these two characteristics put the open habitat in this respect into an advantageous position from the commercial point of view.

Comparison of Responses in Manitoba and New Brunswick: The almost opposite trends in certain characters of *Vaccinium angustifolium* when exposed to varying degrees of shade in Manitoba and in New Brunswick is shown in Figure 22. Attention should be directed to trends rather than

Figure 20.

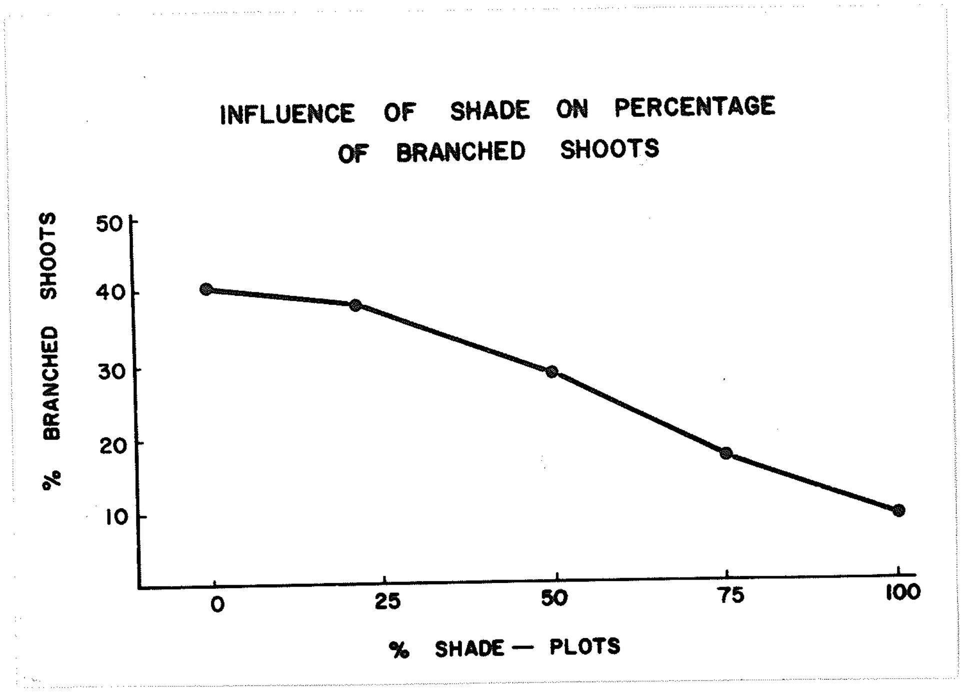
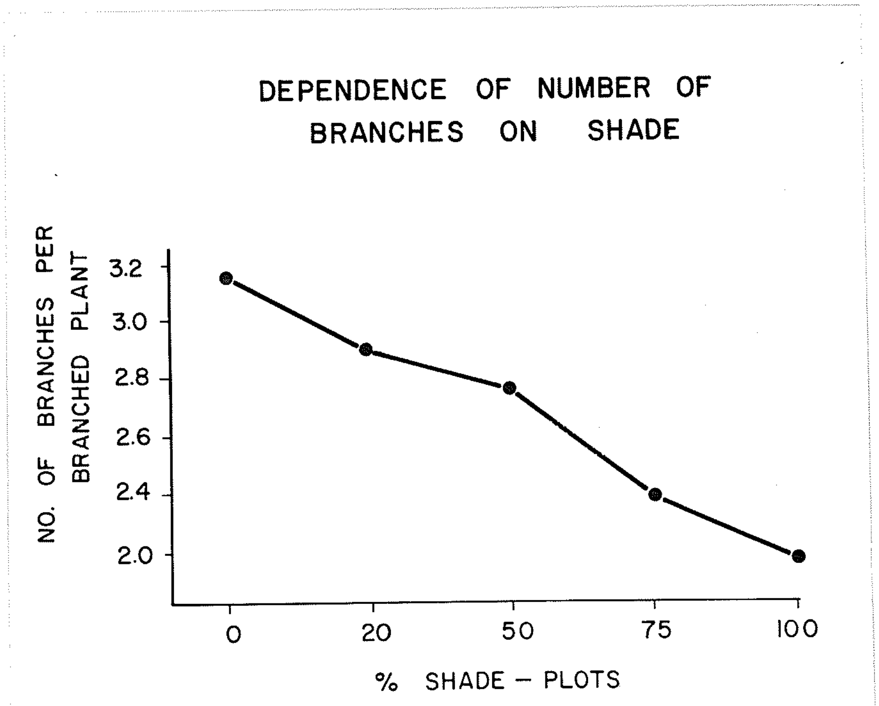


Figure 21.



to absolute amounts, since it was not possible to repeat the experiments of Hall (1958) and Hall and Ludwig (1961) in every detail. This contrast can only be explained through the influence of the more continental climate of Manitoba, a conclusion already obtained by Smith (1962).

b) Analysis of the Competing Vegetation

Frequencies and Cover Values: Since there was no significant difference in composition or abundance of the main competitors between the different shade-percentage plots, Table VIII is in essence a summary. It lists the total frequencies and cover values of the 10 quadrats in each plot, analyzed on June 30 (J) and August 30 (A).

Salix, Populus, Alnus, Pteridium, Petasites, Melampyrum, Apocynum, and Ledum were found in only one or two of the plots, and their frequencies were always less than 10%. They were therefore of little importance as competitors.

In general competition became more intense as the season advanced. Only a few important spring species, Maianthemum, Epilobium, Anemone, and Lathyrus showed a significant reduction in cover values between June and August. This was more than compensated for by a great increase particularly of Cornus, Diervilla, Fragaria and Gaultheria. The most important competitors in the spring were Maianthemum, Cornus, Diervilla, Epilobium, Grass sp., Anemone, and Fragaria. These were early fire-followers and often appeared before the first blueberry shoots emerged. In August the rank of importance was: Cornus, Diervilla, Maianthemum, Gaultheria, Fragaria, Grass sp.,

Figure 22.

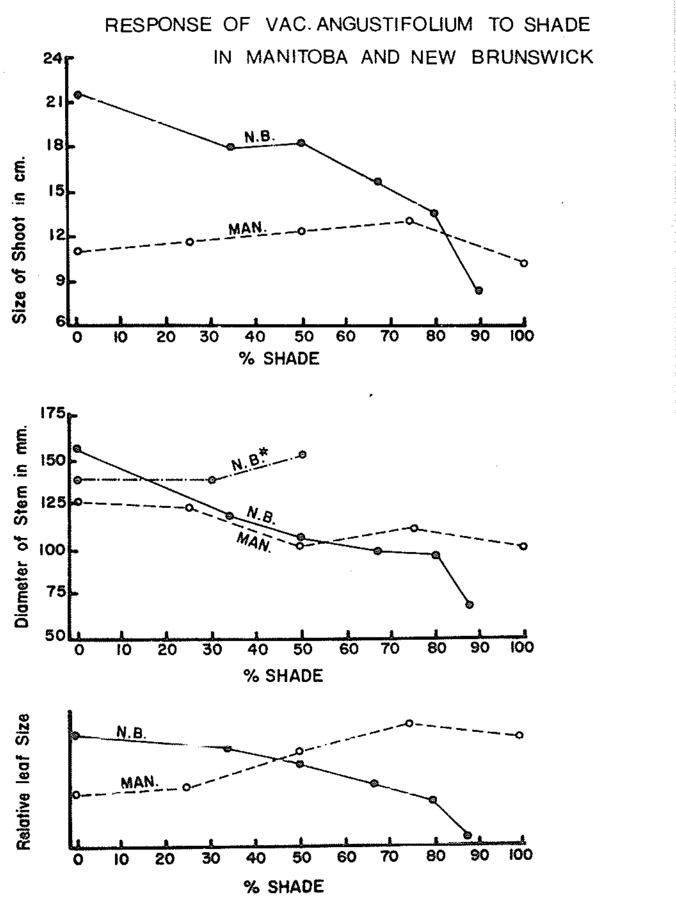

RESPONSE OF VAC. ANGUSTIFOLIUM TO SHADE
IN MANITOBA AND NEW BRUNSWICK
Size of Shoot in cm.
24
21
18
15
12
9
6
N.B.
MAN.
0 10 20 30 40 50 60 70 80 90 100
% SHADE
Diameter of Stem in mm.
175
150
125
100
75
50
N.B*
N.B.
MAN.
0 10 20 30 40 50 60 70 80 90 100
% SHADE
Relative leaf Size
N.B.
MAN.
0 10 20 30 40 50 60 70 80 90 100
% SHADE

TABLE VIII

TOTALS OF COMPETING VEGETATION FOR ALL FIVE PLOTS

Species		Frequency Shade % - Plot 0	25	50	75	100	Average Total Freq. %	Cover % Shade % - Plot 0 %	25 %	50 %	75 %	100 %	Average Cover %	Cover %	Index of Competition	Rank of Importance
Maianthemum	J	100	80	100	80	100	92	8.0	18.0	5.0	8.0	20.0	11.8)	-5.9	1090	1
	A	100	80	80	90	100	90	6.0	6.0	2.0	5.5	10.0	5.9)		348	3
Epilobium	J	20	40	40	40	0	28	2.5	10.0	5.0	4.5	0	4.4)	-2.2	123	4
	A	30	40	50	30	20	34	1.0	4.0	4.0	1.0	1.0	2.2)		75	7
Cornus	J	40	80	80	100	80	76	0.6	2.0	4.0	5.5	3.5	3.1	+6.9	236	2
	A	90	100	90	100	100	96	12.0	8.0	6.0	14.0	10.0	10.0		960	1
Salix	J	10	0	0	0	0	2	26.0					5.2	+4.8	10	11
	A	10	0	0	0	0	2	50.0					10.0		20	13
Diervilla	J	60	90	50	90	30	64	1.0	5.0	1.0	2.5	0.6	2.0	+6.1	128	3
	A	70	90	90	90	70	82	14.0	8.0	5.5	10.0	3.0	8.1		664	2
Grass	J	30	50	40	20	90	46	1.0	1.0	1.0	6.0	2.5	2.3	+0.2	106	5
	A	30	50	30	20	90	44	1.0	2.0	1.0	6.0	2.5	2.5		110	6
Anemone	J	60	40	20	10	30	32	1.0	10.0	3.5	0.5	1.0	3.2	-2.5	102	6
	A	10	30	20	20	10	18	0.2	1.0	1.0	1.0	0.3	0.7		13	14
Rosa	J	10	10	10	0	0	6	0.5	0.6	6.0	0	0	1.4	+0.8	8	13
	A	20	20	10	10	30	18	3.5	1.0	1.0	1.0	4.5	2.2		40	9
Fragaria	J	30	20	30	40	50	34	0.8	0.8	2.5	0.9	0.8	1.2	+ 2.4	41	7
	A	40	30	30	70	90	52	4.5	4.5	1.0	3.0	5.0	3.6		187	5
Gaultheria	J	0	0	40	40	10	18	0	0	2.0	0.8	0.5	0.6	+3.2	11	10
	A	60	30	60	80	40	54	3.5	2.5	5.0	3.5	4.5	3.8		205	4
Populus	J	0	0	0	0	0	0	0					0	+0.2	0	19
	A	10	0	0	0	0	2	1.0					0.2		1	22

J - June 30
A - August 30

Cont'd

Table VIII - Totals of Competing Vegetation for All Five Plots (Cont'd)

Species		Frequency: Shade % - Plot 0	25	50	75	100	Average Total Freq. %	Cover %: Shade % - Plot 0 %	25 %	50 %	75 %	100 %	Average Cover %	Cover %	Index of Competition	Rank of Importance
Linnaea	J	0	0	10	0	10	4	0	0	6.0		0.3	1.3	+0.3	5	15
	A	10	20	10	0	30	14	1.0	3.5	1.0		2.5	1.6		22	11
Pyrola	J	0	0	0	30	20	10	0		0	1.0	2.5	0.7	+1.4	7	14
	A	10	0	30	30	30	20	1.0		1.0	2.5	6.0	2.1		42	8
Lathyrus	J	10	40	0	20	20	18	0	5.0		3.5	1.0	1.9	-1.3	34	8
	A	0	30	0	10	10	10	1.0	0.8		0.5	0.5	0.6		6	16
Alnus	J	0	0	10	0	0	2			26.0			5.2	+4.8	10	12
	A	0	0	10	0	0	2			50.0			10.0		20	12
Equisetum	J	0	10	20	0	10	8		6.0	1.0		1.0	1.6	-0.6	13	9
	A	0	10	10	0	20	8		1.0	0.5		3.5	1.0		8	15
Pteridium	J	0	0	0	0	0	0					0	0	+6.6	0	20
	A	0	0	0	0	30	6					33.0	6.6		40	10
Aster	J	0	0	0	0	10	2		0		0	6.0	1.2	-0.6	2	16
	A	0	10	0	10	10	6		1.0		1.0	1.0	0.6		4	18
Petasites	J	0	0	0	0	10	2				0	1.0	0.2	+1.0	1	17
	A	0	0	0	0	20	4					6.0	1.2		5	17
Melampyrum	J	0	0	10	0	0	2			1.0	0	0	0.2	+0.2	1	18
	A	0	0	0	20	20	8			0	1.0	1.0	0.4		3	19
Apocynum	J	0	0	0	0	0	0				0		0	+1.2	0	21
	A	0	0	0	10	0	2				6.0		1.2		2	20
Ledum	J	0	0	0	0	0	0					0	0	+1.2	0	22
	A	0	0	0	0	10	2					6.0	1.2		2	21

J - June 30
A - August 30

and Epilobium. The same main species were involved but Gaultheria and Fragaria had become more important.

Correlation with Blueberry Performance: No correlation was found between blueberry density or vigor and abundance or composition of associated vegetation. It was surprising to find that shade had no influence on the latter; however, the performance of individual plants was not checked, as had been done with blueberry shoots. It was possible that enough daylight came onto the plots from the sides so that all plants could survive, even though they may not naturally be found in deep shade (e. g. Epilobium, Lathyrus, Grass sp.). Of the plants encountered, Populus, Pteridium and Cornus were also listed as important "weed" species in blueberry fields in eastern Canada. (Barker et al. 1964).

It should be born in mind, that these plots were established because of blueberry density and not with regard to competing vegetation. This is obvious from the fact that bearberry (Arctostaphylos uva-ursi), the main competitor in Manitoba's blueberry areas (Paul, 1966) was not present.

c) Analysis of the Soil

A brief profile description is given in the section on "setting of the area". Table IX lists the chemical properties of the horizons and the changes caused by the burning. From the standpoint of agriculture the soil is poor in nutrients except for the surface L-H horizon. It should be remembered though, that nutrient deficiency is a relative term. Blueberries do very well on this type of soil

TABLE IX

THE EFFECT OF BURNING ON SOME OF THE CHEMICAL PROPERTIES OF THE SOIL

Horizons	Treatment	pH Range	pH Mean	Conductivity in mmhos/cm Range	Conductivity in mmhos/cm Mean	% $CaCO_3$ Equivalent Range	% $CaCO_3$ Equivalent Mean
L-H	Unburned	4.83 5.60	5.13	0.36 0.47	0.42	0.59 0.71	0.65
	Burned	5.23 5.53	5.36	0.42 2.18	0.98	0.48 0.93	0.72
Aej	Unburned	4.30 5.23	4.70	0.17 0.24	0.21	0.09 0.25	0.15
	Burned	4.37 4.93	4.59	0.11 0.17	0.17	0.00 0.52	0.17
Bmgj	Unburned	4.78 5.80	5.12	0.20 0.26	0.22	--	
	Burned	5.10 5.60	5.25	0.08 0.11	0.10	--	
B.C.gj	Unburned	4.95 6.62	5.46	0.20 0.26	0.23	--	
	Burned	5.23 6.27	5.74	0.04 0.08	0.06	--	
Cgj	Unburned	4.87 7.01	5.86	0.14 0.25	0.22	--	
	Burned	6.00 6.70	6.37	0.04 0.11	0.06	---	

(Cont'd)

Table IX - The Effect of Burning on Some of the Chemical Properties of the Soil (Cont'd)

Horizons	Treatment	% Organic Matter	% Total Nitrogen	$NaHCO_3$ Extractable Phosphorus ppm	Cation Exchange Capacity m. eq.
L-H	Unburned	55.64 58.70 62.19	0.80 0.94 1.10	39.9 66.7 91.8	44.94 55.01 61.60
	Burned	61.01 68.20 79.27	1.11 1.27 1.45	81.7 111.0 136.8	53.65 65.68 76.41
Aej	Unburned	0.53 1.17 1.44	0.019 0.033 0.038	7.4 12.6 12.1	2.19 3.64 4.46
	Burned	1.10 1.42 1.81	0.030 0.039 0.046	6.2 7.8 9.2	3.60 4.31 4.86
Bmgj	Unburned	0.18 0.40 0.83	0.014 0.024 0.030	7.8 22.7 38.9	2.83 3.68 4.01
	Burned	0.36 0.54 0.72	0.016 0.022 0.026	19.4 25.7 34.6	3.04 3.80 4.57
B.C.gj	Unburned	0.14 0.28 0.43	0.014 0.018 0.022	2.6 13.1 24.2	1.43 2.51 3.22
	Burned	0.29 0.62 1.35	0.011 0.016 0.019	4.6 11.9 18.1	1.22 2.08 3.10
Cgj	Unburned	0.40 0.70 0.95	0.009 0.011 0.012	4.2 6.8 14.2	0.89 1.38 2.00
	Burned	0.30 0.49 0.95	0.005 0.008 0.009	3.0 5.8 6.9	0.68 1.21 2.23

(Cont'd)

Table IX - The Effect of Burning on Some of the Chemical Properties of the Soil (Cont'd)

Horizons	Treatment	Exchangeable Cations m. eq./100 g..				Sum of Exchangeable Cations
		Ca	Mg	K	Na	
L-H	Unburned	21.9 27.90 35.4	5.9 7.30 8.6	1.05 1.52 1.78	0.15 0.19 0.28	29.34 36.91 45.73
	Burned	32.2 38.80 45.8	8.4 9.80 10.6	1.62 1.78 2.06	0.06 0.07 0.09	42.29 50.45 58.53
Aej	Unburned	0.76 1.07 1.40	0.10 0.45 0.98	0.06 0.09 0.11	0.02 0.04 0.10	1.15 1.65 2.17
	Burned	0.84 1.02 1.36	0.28 0.38 0.60	0.09 0.11 0.13	0.02 0.02 0.03	1.29 1.53 1.79
Bmgj	Unburned	0.80 1.00 2.20	0.16 0.30 0.42	0.05 0.08 0.12	0.03 0.05 0.06	1.31 1.43 2.47
	Burned	0.80 1.05 1.14	0.16 0.23 0.30	0.09 0.11 0.13	0.02 0.02 0.02	1.15 1.41 1.73
B.C.gj	Unburned	0.80 1.04 1.40	0.24 0.31 0.44	0.03 0.05 0.07	0.02 0.04 0.04	1.12 1.44 1.95
	Burned	0.52 0.75 1.00	0.04 0.22 0.42	0.03 0.05 0.08	0.01 0.01 0.01	0.64 1.03 1.49
Cgj	Unburned	0.07 0.43 0.32	0.04 0.17 0.26	0.02 0.04 0.05	0.02 0.03 0.04	0.40 0.67 1.34
	Burned	0.28 0.58 0.44	0.00 0.12 0.20	0.03 0.04 0.06	0.01 0.02 0.02	0.49 0.76 1.36

and it has been described by Trevett (1962) and Eck and Childers (1966) as being the typical soil for this plant.

<u>Effects of Burning</u>: No drastic alterations have occurred through burning. In general, changes are caused by 3 factors: (a) intensity and duration of the fire; the hotter a burn and the longer it acts, the more organic matter will be destroyed. (b) the amount of combustible fuel present on the soil; this will influence the intensity and duration of the fire and also the amount of ash deposited on the ground. (c) the time between the burn and the sampling for analysis and the weather conditions prevailing during this time. Dry and windy weather will remove a great proportion of the ash before it becomes incorporated into the soil, and the deeper horizons will show little change. Wet weather stabilizes the ash and washes it into the soil with the rain water. The observed changes will be greater. Too long a period between burning and sampling will show a reduced effect, since microbes, plant roots and leaching remove minerals and add H^+ ions, and the general trend is to re-establish the former conditions.

In this study a moderate temperature had been applied for the sole purpose of pruning the old blueberry shoots. The soil was not effected and little ash had been added. The weather had been dry between burning and sampling the soil. Any observable changes, therefore, were restricted to the surface L-H horizon; changes in the others were due to natural variations, as can be seen from the ranges given for each property investigated.

The surface horizon shows a slight increase in pH, conductivity, N, P, total minerals and cation exchange capacity. However, only in the case of Ca and P was the increase significant at the 5% level. A larger sample size would have been necessary to detect changes in the other properties. The trends observed are supported by the literature. An increase in cations supplied by the ash is generally accepted. Alway (1928), Barnette and Hesters (1930), Isaac and Hopkins (1937), and Uggla (1949). The accompanying increase in pH and conductivity is reported by the same authors. As to N and P the opinions vary. Lutz (1934), Osborn (1931), Garren (1943), Lunt (1951).

Organic matter cannot increase by burning. These data, again, reflect too small a sample size. The result of the mechanical analysis are incorporated in the profile description given before. These analyses plus width and colours of the horizons make this soil a "Gleyed Podzol". Stobbe (1966).

Infiltration: The average infiltration rates for 1000 ml water per 125 cm^2 area were 2 minutes and 2 seconds, for unburned soils, and 2 minutes and 38 seconds for burned ones. Great variation was observed in both, so that the computed differences in means were not significant. Scotter (1964), who worked with a similar soil, also did not find differences in infiltration rates caused by forest fires.

It can be concluded that improved blueberry performance after the burn was not due to an improved soil fertility. Changes in the soil were restricted to the surface horizon while the bulk of the blueberry root system was located at deeper levels. Hall (1957).

d) Analysis of the Microclimate Under the Screens

Light: The duration of light under the screens relative to the time of day is shown in Figure 23. It can also be used to compute the duration of shade by applying following conversion factors: for the 25% shade screen (x 1/3), for the 50% shade screen (x 1), and for the 75% shade screen (x 3).

The screens influenced the light received by the plots for a daily period of about 12 hours. Considering the 50% screen, the alternation of light and shade took place at 8 minute intervals at 08.00 hr. and increased in a logarithmic manner to a maximum interval of 1 hour and 48 minutes at 14.00 hr. This was followed by a similar reduction in alternation time in the afternoon. The general sequence was the same for the 25% and 75% shade plots, only the magnitude differed. (Fig. 23).

Any plant which came into a light strip at 12.00 hr. remained in it for a relatively long period. (Fig. 23). Since midday is also the time of maximum insolation, the environment of this plant will be markedly different from that of a plant, which is shaded at this time. The change in inclination of the sun is not rapid enough to compensate for this "strip effect", therefore the screens were changed at weekly intervals, giving light where there had been shade at the same time the previous week.

Table X lists a comparison of the three methods employed to determine shade. A desired gradient was obtained. One reason why no closer correspondence was achieved, was that both instruments also responded to "day light", while the screens were made to interfere with sunshine only. For instance, the 100% shade screen, under which no direct sun light was received, showed values of 96% shade for the Weston light meter and 91% for the pyrheliometer, indicating the influence of "indirect light" or daylight.

TABLE X

COMPARISON OF THREE METHODS FOR DETERMINING "SHADE"

Screen	0%	25%	50%	75%	100%
Weston Light Meter	0%	26%	41%	65%	96%
Pyrheliometer	0%	42%*	53%	68%	91%

*This unexpected high value was obtained, because the space between the slats in the 25%-shade-screen exceeded the dimensions of the Pyrheliometer. In order not to record "open" conditions the instrument had to be placed under one of the slats of the screen, which covered one-third of the instrument's metal plates. This shade value would therefore more closely represent a 33%-shade-screen.

The maximum and minimum light intensities measured under the screens are reproduced in Fig. 24. All values were converted to % of total light (open conditions). The computed average light intensities take into account maximum and minimum as well as the duration of each, using Weston light meter values. No only did the duration of light and shade (Fig. 23) result in a lowering of the weighted mean light intensity when passing from the open to the 100% shade plot, but also the light received on the "illuminated strips" became less intense and the shade in the dark strips became more severe; both resulted in lowering the mean light intensity.

Figure 23. Duration of Light and Shade Under the Screens

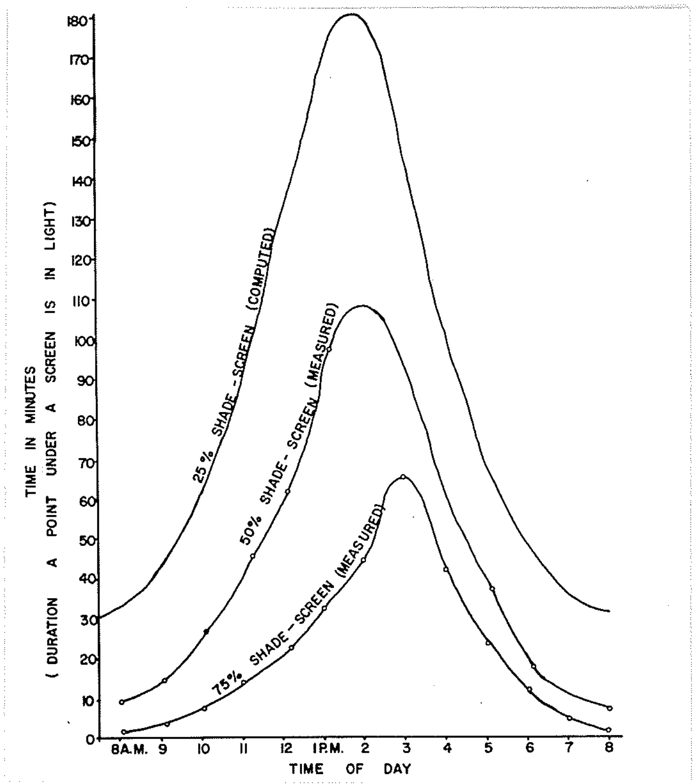
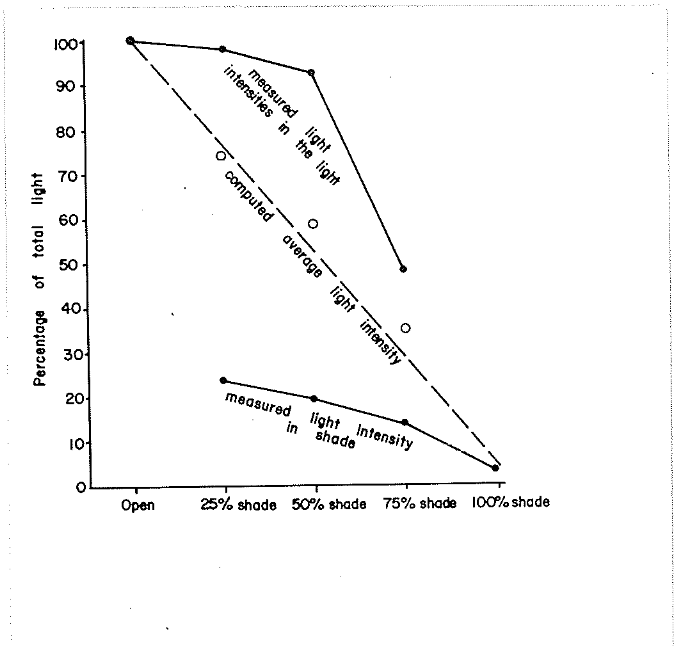


Figure 24. Light Intensities Received at Ground Level



Temperature: Figure 25 shows a comparison of the temperature changes introduced by the screens. Weighted mean temperatures were used, which took into account maximum and minimum values and durations. The differences were most marked at the ground level, being 25°C between the open and the 100% shade plot. The sequences of temperature changes at the ground was as follows: When a particular spot came into light more radiation was received than emitted, its temperature gradually rose and reached the highest value just before this spot came into shade again. The longer the insolation could act, as at midday, the greater was the temperature increase. On the other hand, when in the shade, more radiation was emitted than received, and the temperature dropped to reach its lowest value shortly before this spot passed into light again. The maximum and minimum temperatures which could be obtained were those prevailing in the open and under 100% shade. These were never reached under the 25%, 50% and 75% shade screens because of the constant alternation of light and shade (Fig. 24). This relationship between light and temperature is well know, this experiment served only to establish the quantities involved. Fig. 26 shows the correlation.

Moisture: It was only possible to do 3 sets of precipitation measurements using large funnels. The average values obtained were 375 ml in the open, compared to 334 ml under the 50% shade screen and 226 ml under 75 % shade.

Available soil moisture measurements with gypsum blocks were

Figure 25. Comparison of Average Temperatures Under the Screens

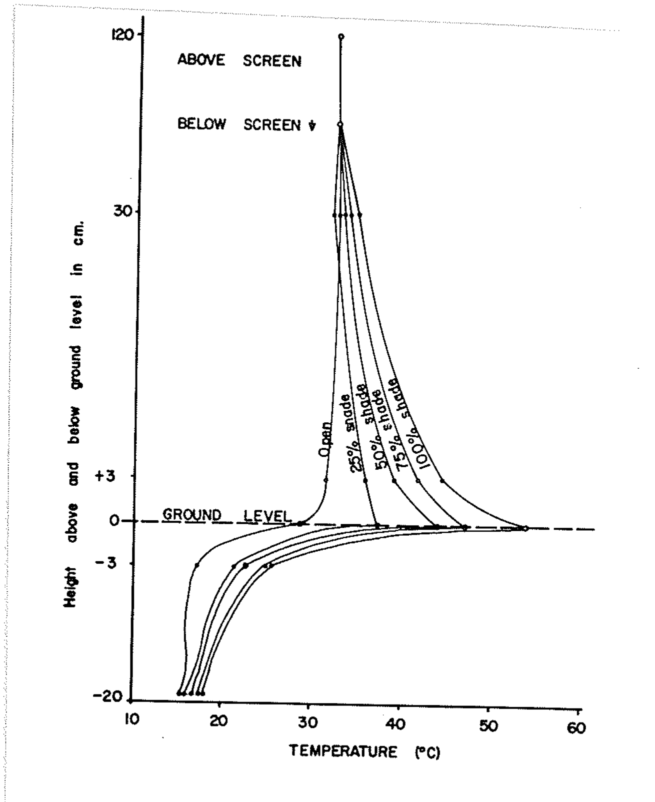
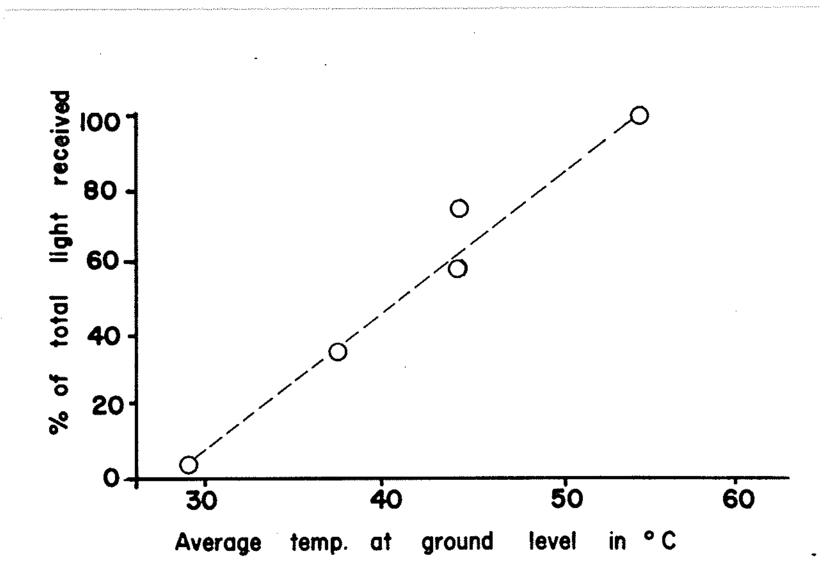


Figure 26. Correlation Between Light and Temperature



made over the entire season. These blocks were not too reliable in the coarse-textured soil. The force with which water is held in a soil is inversely proportional to the pore size. Yong and Warkentin (1966). It is therefore reasonable to assume that the gypsum blocks held water with greater force or longer than the coarser-textured soil surrounding them, thus indicating too high a water content during drying. On the other hand, once they were dry, water entered them more slowly than it percolated through the sand, because the velocity of water flow through a soil is proportional to the square of the radius of the soil pores. Yong and Warkentin (1966). Under these conditions the blocks would indicate too low a value until equilibrium was established. However, the errors introduced by this method were the same for each plot, because the same soil was involved and comparisons could still be made. Table XI gives moisture meter readings for three dates after a drought period to show the trends observed under the different screens.

The data reveal that more moisture was available for a longer period of time as the amount of shade increased. This trend indicates that the screens did not decrease the available soil moisture. Enough water must have come to the plots through the spaces in the screens, from the open north and south sides and through horizontal movement within the soil. The screens might even have improved the "water balance" of the plots by decreasing the temperature at the soil surface and thus evapotranspiration rate.

TABLE XI

MOISTURE METER READINGS FROM THREE DATES SHOWING GRADUAL DEPLETION OF AVAILABLE SOIL MOISTURE AFTER A DROUGHT PERIOD

August 4, 1967: 1.23 cm rain had fallen the previous night.

Depth	0% Shade	25% Shade	50% Shade	75% Shade	100% Shade
2 cm	100%	100%	98%	100%	100%
8 cm	100%	97%	94%	100%	100%
16 cm	100%	100%	96%	100%	100%
30 cm	100%	100%	98%	100%	100%

August 28, 1967: No rain had fallen.

Depth	0% Shade	25% Shade	50% Shade	75% Shade	100% Shade
2 cm	15%	15%	34%	20%	20%
8 cm	15%	18%	49%	70%	50%
16 cm	38%	42%	86%	76%	82%
30 cm	87%	81%	96%	98%	100%

September 5, 1967: No rain had fallen.

Depth	0% Shade	25% Shade	50% Shade	75% Shade	100% Shade
2 cm	15%	15%	19%	15%	15%
8 cm	15%	15%	20%	32%	22%
16 cm	15%	20%	62%	41%	33%
30 cm	46%	22%	73%	95%	100%

SUMMARY

As the soil and competing vegetation did not vary significantly between the plots, it is reasonable to assume that any change in blueberry performance was due to the direct or indirect influence of shade. The most important indirect effect of shade was the decrease in temperature, which is turn lowered the evapotranspiration and thus improved the "water economy" under the screens.

Vaccinium angustifolium exhibited a great tolerance range with regard to shade. It grew well under open conditions, as well as under complete shade. When light intensity was reduced, typical "shade characters" (larger leaves, longer internodes and thinner stems) became more pronounced, but typical "symptoms" of etiolation (loss of chlorophyll, greatly elongated internodes, spindly growth and immature, unexpanded leaves) were not encountered.

Of the characters investigated, emergence and apical abortion did not show any correlation with shade. On all plots, shoots began to emerge five weeks after fire-pruning. Dieback occurred four weeks after emergence. Usually, early dieback resulted in branching and late dieback in cessation of the season's growth. At intermediate times growth was often resumed through elongation of a single branch.

Table XII gives a summary of those characters (computer results), which have been shown to be positively correlated with yield.

TABLE XII

SUMMARY OF ECONOMICALLY IMPORTANT CHARACTERS

Plot	% Increase In Shoot Number After Burning	Final Shoot Size in cm	% of Branched Shoots	No. of Branches On Branched Shoots
0% Shade	96%	10.90	39.6	3.14
25% Shade	91%	11.20	37.4	2.87+
50% Shade	87%+	12.20++	38.5++	2.75
75% Shade	75%++	13.00++	18.0++	2.37+
100% Shade	58%++	10.80++	6.9++	2.06+

Significantly different from preceding value at 0.05 level +
at 0.01 level ++

Two opposing trends were observed. Shoot size was positively correlated with shade, while branching and increase in shoot number after fire-pruning showed a negative correlation. Frost damage also showed a negative correlation. In the open 27% of the shoots were effected; 17% of the shoots under 25% shade, and 7% under 50% shade. No damage was observed under 75% and 100% shade. Branching was observed in 65% of the effected shoots. It can therefore be assumed that without the influence of frost the differences observed between the plots may not have been significant.

Another assumption that can be made is that with repeated burning the density of a blueberry stand proceeds towards a maximum, which is the carrying capacity of the site. When this is reached, it is doubtful whether shade would have any effect. The final shoot size increases with increasing shade; here the data obtained are in favour of the "shade" habitat.

Most of the trends observed are in contrast with those found in New Brunswick and can be explained by the different climatic conditions of these two regions. (Table I; Fig. 22). While shade is considered detrimental for blueberry production in the Maritime Provinces, it appears that in Manitoba it is essential for maximum growth of this plant.

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APPENDIX

Scientific names of plants referred to in the text (after Scoggan, 1957).

1. Abies balsamea (L.) Mill.
2. Acer negundo var. interius (Britt.) Sarg.
3. Alnus crispa (Ait.) Pursh.
4. Anemone quinquefolia L. var. interior Fern.
5. Apocynum androsaemifolium L.
6. Arctostaphylos uva-ursi (L.) Spreng.
7. Aster ciliolatus Lindle.
8. Betula papyrifera Marsh.
9. Cornus canadensis L.
10. Diervilla lonicera Mill.
11. Epilobium angustifolium L.
12. Equisetum arvense L.
13. Gaultheria procumbens L.
14. Fragaria virginiana Duchesne.
15. Fraxinus pennsylvanica Marsh. var. austini Fern.
16. Lathyrus japonicus Willd. var. glaber (Ser.) Fern.
17. Linnaea borealis L. var. americana (Forbes) Rehd.
18. Ledum groenlandicum Oeder.
19. Lycopodium complanatum L.
20. Maianthemum canadense Dest.
21. Melampyrum lineare Desr.
22. Petasites palmatus (Ait.) Gray

23. Picea glauca (Moench) Voss

24. Picea mariana (Mill.) BSP.

25. Pinus banksiana Lamb.

26. Populus balsamifera L.

27. Populus tremuloides Michx.

28. Pteridium aquilinum (L.) Kuhn var. latiusculum (Desr.) Underw.

29. Pyrola secunda L.

30. Rosa acicularis Lindl.

31. Salix humilis Marsh.

32. Thuja occidentalis L.

33. Ulmus americana L.

34. Vaccinium angustifolium Ait.

35. Vaccinium myrtilloides Michx.

36. Vaccinium vitis-idaea L. var. minus Lodd.