SOIL REQUIREMENTS OF BLUEBERRIES IN RELATION TO THEIR NUTRITION

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ABSTRACT

Both highbush and rabbiteye blueberries are acidophile (acid-loving) plants which have exacting soil and nutritional requirements. They normally grow best on acidic, well-aerated sandy soils which are naturally high in organic matter. Their growth optimum on organic soils is normally between pH 4 and 5, but in mineral soils, toxicities of Al and Mn can limit growth at such low pH values. In mineral soils their pH optimum is probably between 5.0 and 5.5. At high pH (5.5) blueberry growth can be limited by deficiences of Fe and Mn whilst the high concentrations of NO_3 and Ca in soils of high pH could also be inhibitory factors.

When planting blueberries into well-drained fertile agricultural soils, additions of soil amendments can greatly improve growth. Elemental S is added to lower soil pH, organic matter such as crushed bark is added to improve soil physical properties and a sawdust mulch can maintain soil moisture in the surface soil. Mycorrhizal inoculation may sometimes be beneficial but should be considered as a precaution against nutrient deficiencies occurring rather than a sure way to increase yields.

INTRODUCTION

Both highbush blueberries (*Vaccinium corymbosum* L.) and rabbiteye blueberries (*V. ashei* Reade) are grown commercially in New Zealand. The rabbiteye blueberries are generally more vigorous and adaptable than their highbush counterparts but both species have similar exacting soil and nutritional requirements.

Like many other members of the Ericaceae family, highbush and rabbiteye blueberries are calcifuge plants and grow best in acidic soils (pH 4.0-5.0) of low to moderate fertility (Haynes, 1986a). Their nutrition is therefore adapted to relatively infertile acid soil conditions. The natural habitat of blueberries is, in fact, on hummocks on peat bogs and on the edge of ponds (Cain and Eck, 1966) where they grow on peaty acid soils with an ample supply of water from below. Thus, successful commercial plantings are often made on peaty acid soils although planting can also be carried out successfully on fertile mineral soils where particular attention must be paid to soil management and nutritional factors.

This paper discusses the soil and nutritional requirements of blueberries in relation to their successful cultivation on both infertile and fertile soils.

OPTIMUM SOIL pH AND NUTRITIONAL REQUIREMENTS

A number of workers have grown blueberries in a range of soils and then tried to relate various soil properties to resulting blueberry growth (Korcak *et al.*, 1982; Reich *et al.*, 1982a; Korcak, 1986ab). As one would expect, growth is generally found to be best in acidic, well aerated sandy soils which are indigenously high in organic matter.

Soil pH has been shown to be a critical factor for optimum growth and cropping of blueberries. A large body of data show that the optimum pH for both highbush and rabbiteye blueberries is between pH 4.0 and 5.5 (Harmer, 1944; Spiers, 1978; Haynes and Swift, 1985ab, 1986a). Results of a greenhouse experiment in which young blueberry plants were grown in peat at different pH values is shown in Fig. 1. Clearly, the optimum pH for growth was between pH 4 and 5. The natural pH of peat deposits is normally in this range.

Nutritional limits to growth at high pH

Bluberries are probably adapted to acidic conditions in many different ways. Several nutritional factors have been implicated in their poor growth in soils above pH 5.5. These include deficiencies of Fe and Mn, the predominance of nitrate (NO_3^-) rather than ammonium (NH_4^+) nutrition and nutrient imbalances caused by high Ca^{2+} uptake.

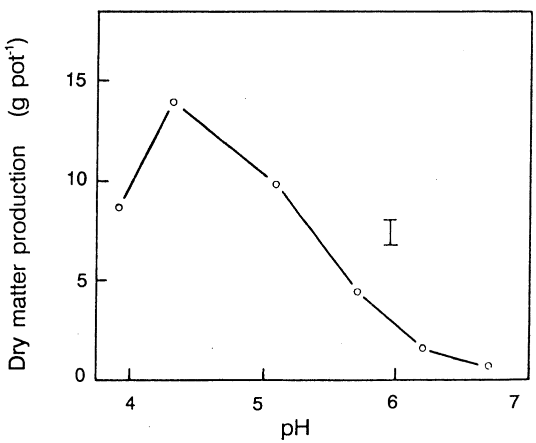

Figure 1: Effect of pH on the dry matter production of young blueberry plants grown in peat.

Iron chlorosis often develops in blueberries grown at soil pH values above 5.5 (Ballinger, 1966) and a major factor limiting blueberries to acid soils is thought to be their inability to utilise Fe efficiently (Holmes, 1960; Brown and Draper, 1980). Iron chlorosis in blueberries can usually be corrected by spraying foliage with iron salts (but only temporarily) (Cain, 1952); new growth is usually chlorotic (Homes and Brown, 955). The importance of Fe nutrition is reflected in the suggestion of Bradley and Smittle (1965) that extractable Fe could be used in conjunction with pH to predict the suitability of a soil or medium for blueberry production.

Deficiencies of other micronutrients, such as Mn, Zn and Cu might also limit blueberry growth above pH 5.5 since, like Fe, their solubility in soil decreases as the pH is raised (Knezek and Ellis, 1980). Indeed, in New Zealand, it is unusual to observe signs of Fe chlorosis except at very high pH values (e.g. > pH 6.5). However, blueberries often have a reddish tinge to their leaves when they are under stress. Some cultivars are more prone to this disorder than others. Red leaves occur particularly when the soil pH is high (>pH 5.5) and levels of leaf mN are low (< 100 ppm) and symptoms can be exacerbated by water stress. It is probable that Mn deficiency can limit blueberry growth at high soil pH.

Nitrogen nutrition also appears to be an important pH-related nutritional factor. Under acid soil conditions NH_4^+ is usually the predominant form of N present. This is because the activity of the autotrophic nitrifying bacteria which convert NH_4^+-N to NO_3^--N in the soil is normally inhibited below pH 5.0 to 5.5. This is demonstrated by the results presented in Fig. 2 where a soil was incubated for 12 weeks at various pH values. Below pH 5.0, nitrification was inhibited and NH_4^+ was the predominant form of mineral N present. Since NH_4^+ is the major form of N present in acid soils, it would not be surprising if blueberries were adapted to use NH_4^+ effectively. In fact, research generally indicates that in nutrient solution blueberries grow better when supplied with NH_4^+ rather than NO_3^--N (Herath and Eaton, 1968; Townsend, 1967, 1969; Petersen *et al.*, 1988). Peterson *et al.* (1988), for example, showed that plants absorbed NH_4^+ more rapidly than NO_3^- and although both forms produced healthy plants, the plants receiving NH_4^+ were twice the size and dry matter yield of the NO_3^- fed plants.

Korcak (1986b) indicated that soils where blueberries grow well have a low exchangeable Ca content and that high Ca uptake may be part of the reason why blueberries do not grow well in some soils. Indeed, there is evidence that the growth of some calcifuge plants is decreased by increasing additions of Ca (Bradshaw *et al.*, 1958).

Thus, at high soil pH, blueberry growth may be limited by a combination of low NH_4^+ and high Ca^{2+} uptake and deficiences of Fe and Mn.

Nutritional limits to growth at low pH

The optimum pH for blueberries in mineral soils can be somewhat higher (e.g. pH 5.0-5.5) than that in peats (e.g. 4.0-5.0). This is because in mineral soils, soil Al and Mn become increasingly soluble as soil pH declines. Below

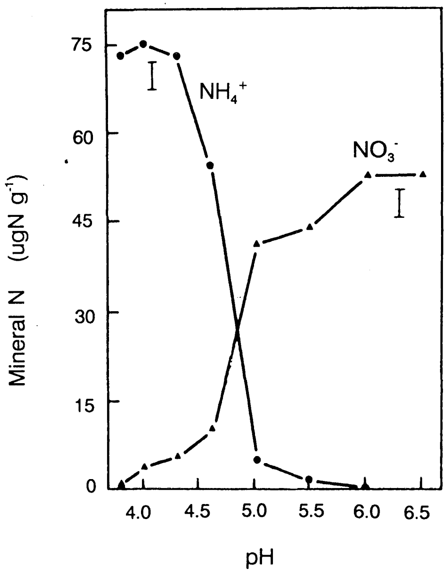

Figure 2: Effect of soil pH on the amount of ammonium (NH_4^+) and nitrate (NO_3^-) accumulated in a soil after incubation for 23 weeks.

pH 5.0, levels may reach those that are toxic to blueberry growth. Toxicities of both Al and Mn have been implicated in reduced growth of blueberries in mineral soils at low pH (Korcak *et al.*, 1982; Haynes and Swift, 1986ab). It is therefore not usual to acidify mineral soils much below pH 5.5. Such toxic effects are not normally a problem in peaty soils since peats contain a very small mineral component (which contains the Al and Mn). The peat also tends to complex with soluble Al thus detoxifying it.

Mycorrhizal inoculation

Blueberries possess a shallow, fibrous root system which is devoid of root hairs (Eck, 1966) and is probably not very efficient at exploiting soil reserves of nutrients and water. However, the roots of wild plants are virtually all infected with ericaceous endomycorrhizal fungi (Eck, 1966; Bayer *et al.*, 1982) and the extensive hyphae of these fungi form a loose network in the soil so that the volume of soil explored by the plant is greatly increased (Read, 1983). Such an infection is of particular value to the plant where a deficiency of one or more nutrients is limiting their growth.

When nursery-grown stock are planted out into orchards there is often very little mycorrhizal infection of blueberry roots (Powell, 1981; Bayer *et al.*, 1982). This is because if there have been no ericaceous plants grown at the site before then there will be little or no ericaceous mycorrhizal inoculum in the soil. In some cases mycorrhizal inoculation and infection of cultivated blueberries has increased growth and yields (Powell and Bates, 1981; Powell, 1982) but in others it has had no effect (Reich *et al.*, 1982ab; Haynes and Swift, 1985c). In general, the major advantage of mycorrhizal infection for ericaceous plants is enhancement of the uptake of the relatively immobile NH_4^+ ion which, as already noted, predominates over NO_3^- under acidic soil conditions (Stribley and Read, 1976). Other positive effects include increased phosphate uptake and the ability of plants to use simple organic nitrogenous and phosphate compounds (Read, 1983). With adequate fertilizer applications, however, uninoculated plants will often grow well so that mycorrhizal inoculation should be considered as a precaution against nutrient deficiences limiting growth rather than a sure way to boost production.

Research suggests that to improve growth in soils of high pH, mycorrhizal inoculation cannot substitute for soil acidification. At high pH inoculation may not lead to successful mycorrhizal infection. Hayes and Swift (1985c), for example, observed that mycorrhizal infection was very poor at pH 6.5. This is probably because, like the blueberry itself, the ericaceous mycorrhizal fungi have evolved in and adapted to acid soil conditions.

SOIL AMENDMENTS

Three types of soil amendments are commonly employed to improve blueberry growth on mineral soils. These are: (1) acidifying agents such as elemental sulphur which are added to lower soil pH, (2) organic materials such as peat or crushed pine bark mixed into the planting hole to improve soil physical conditions, and (3) sawdust mulches that are applied over the soil surface to retain soil moisture.

(1) Acidifying agents

Soil pH can be lowered by the addition of a number of materials to the soil. Elemental S is the most commonly used material although aluminium and iron sulphates are also used on a small scale. Elemental S is oxidized to sulphuric acid by sulphur oxidizing bacteria in the soil. The amount of S required to lower soil pH by one unit varies from soil to soil but is usually in the vicinity of 100-150 g m^{-2}.

There are two forms of elemental S available in New Zealand, granular (agricultural) S and the more expensive finely ground S (flowers of S). Soil acidification in blueberry orchards has often involved incorporating agricultural S into the surface few centimeters of soil before or during plant establishment. However, after several years, soil pH in the surface 15 cm of soil in such orchards has usually decreased by only 0.1 to 0.2 of a pH unit. The plants still often show poor thrift and have reddish leaves. Research (Haynes, 1986b) has shown that there are two reasons for this. Firstly, the oxidation rate of elemental S decreases as particle size increases (that is as surface area in contact with the soil decreases). Consequently, oxidation of agricultural S (in which 75% of particles are >2 mm diameter) is slow. Oxidation of flowers of S is much more rapid because it is more finely ground. Secondly, it is very difficult to acidify the soil below the depth to which the acidifying agent has been incorporated.

It is therefore important to acidify the soil before planting out blueberries. Where acidification of one pH unit or more is required, a mixture of a rapid acidifying agent (e.g. flowers of S) and a slower agent with greater residual effect (e.g. agricultural S) is advisable. Incorporation of S to a depth of 15 to 30 cm before planting would seem appropriate.

(2) Organic materials

Incorporation of organic materials such as peat, crushed bark or even sawdust into the planting hole is common practice on well drained mineral soils and on very sandy soils. These materials improve water holding capacity which is important on sandy soils and they also improve drainage and increase aeration which are particularly important limiting factors on well drained heavier soils. Many workers have recorded increased growth and yields of blueberries from additions of organic amendments (e.g. Cummings *et al.*, 1981; Spiers, 1986; Haynes and Swift, 1986b). Whilst peat is usually quoted as the best amendment to use, Haynes and Swift (1986b) showed that crushed bark represented a cheaper, relatively inert, alternative which produced a comparable or better growth response than peat.

Blueberries are not suited to heavy mineral soils where poor drainage occurs. Indeed they are particularly sensitive to waterlogged soil conditions. Incorporating organic materials into the planting hole on such soils is inappropriate since it will exacerbate the drainage problem by creating a "soak Hole" in the plant root zone.

(3) Mulching

Sawdust is the material most commonly used to mulch around blueberries. Mulching has been shown to increase blueberry growth and yield (Haynes and Swift, 1986b; Spiers, 1986). The mulch maintains soil moisture and encourages root growth close to the surface. It can result in a uniform root distribution from the plant crown outward with a concentration of roots in the upper 15 cm of soil (Spiers, 1986). Under a sawdust mulch, irrigation water spreads out over the soil surface in a greater radius from trickle emitters than under non-mulched conditions (Haynes and Swift, 1986b). Thus a larger volume of soil (and thus potential rooting volume) is wetted and this encourages more extensive growth.

(4) Combination of treatments

The results of a field trial carried out at Lincoln demonstrate the successful use of soil amendments. In the trial there were five treatments; control and four amendments (elemental S, peat, crushed pine bark or crushed pine bark plus elemental S) mixed into the hole. One half of the treatments had a sawdust mulch applied over the surface. The soil used was a well-drained Templeton silt loam (0-45cm) on gravels with a sandy matrix.

Results (Fig. 3) clearly demonstrate the benefit of adding amendments to a mineral soil for blueberry production. A combination of bark plus S mixed into the planting hole gave best results whilst crushed bark, peat or sulphur alone, gave intermediate yields. The addition of sawdust mulch gave a small benefit in yield in all treatments.

CONCLUSIONS

Blueberries are calcifuge plants which have exacting soils and nutritional requirements because of their

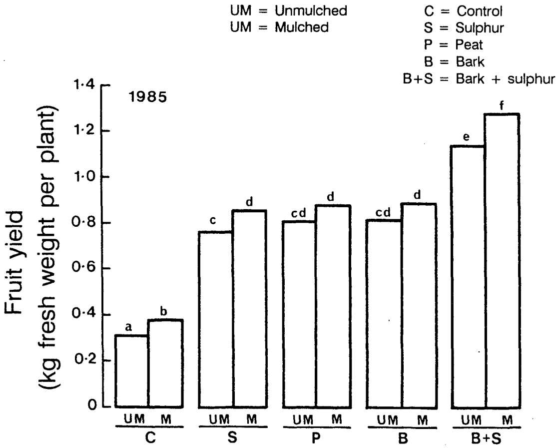

Figure 3: Effect of soil amendments and sawdust mulching on blueberry fruit yields in the third season of a field trials.

adaptation to infertile peaty acid soil conditions. They can however be grown successfully on fertile soils when soil amendments are used. Soil acidification is achieved by adding elemental S to the soil, soil physical conditions are improved by adding crushed bark to the planting hole and soil moisture is conserved by using a sawdust mulch.

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