

Wood Ash: An Alternative Liming Material for Agricultural Soils

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Jerome Lickacz

Pulse and Oilseed Unit,

Alberta Agriculture, Food and Rural Development

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Many forestry facilities in Alberta use bark, sawdust and yard waste, commonly referred to as "hogfuel", to generate steam, electricity, and heat for plant operations. There are also several facilities that use hogfuel as an energy source to generate electricity. More than 180,000 tonnes of energy system wood ash produced annually at pulp mills, sawmills, oriented strand board, and fibre board plants is currently disposed of in industrial or regional landfills.

With the considerable quantities of product to dispose of, researchers began to investigate the potential for wood ash to be used in agricultural production. Studies have concluded that there are real beneficial effects of wood ash for crop growth. Farmers have often observed improved growth in areas where bush windrows were burned. Soil pH and soil test values for plant nutrients are usually higher in these areas. Wood ash is also an effective liming material, and Alberta Environment, in conjunction with the Alberta Forest Products Association and Alberta Agriculture, is developing land application guidelines for the use of wood ash from energy systems to neutralize soil acidity on agricultural soils. Research is also underway to investigate the availability of plant nutrients in wood ash.

Acid Soils in Western Canada

Acid soils are those having a pH of 6.5 or less. The growth of acid sensitive crops, such as alfalfa and sweet clover, is reduced when the soil pH is less than 6.0, and moderately sensitive crops, such as barley, are affected when pH is less than 5.8. Canola and wheat are moderately tolerant of soil acidity, while oats and the forage grasses, such as timothy and creeping red fescue, are very tolerant and can be grown successfully at a soil pH of 5.0.

Acid soils occur most frequently in the higher precipitation areas of the provinces and, in particular, in areas where tree cover is the dominant vegetation type. Soils developed under these conditions are referred to as Luvisolic or Gray Wooded soils. These soils are characterized by a gray to dark gray topsoil, which is usually moderately to strongly acidic.

Soil acidification is a natural and ongoing process in soils. Factors contributing to soil acidity include the following:

- acidic parent materials;

- presence of deciduous and coniferous vegetative cover;
- decomposition of soil organic matter;
- plant root and organism respiration;
- leaching;
- use of nitrogen fertilizers; and
- absorption of carbon dioxide and sulphur directly from the atmosphere.

Approximately 6.3 million acres of soils in western Canada have a pH of 6.0 or less. An additional 8.5 million acres have a pH of 6.1 to 6.5. Crop production on these soils will be reduced in the future as soil acidification continues. In the Peace River Region of Alberta and British Columbia, approximately 1.35 million acres of cultivated soils are sufficiently acidic to reduce alfalfa growth. Over 90 per cent of the acid soils in western Canada occur in Alberta.

Wood Ash and Agricultural Lime

Calcitic limestone (CaCO_3) is the liming material used most often to neutralize acid soils. Burned lime (quick lime, calcium oxide or CaO) and hydrated lime (slaked lime, builder's lime, calcium hydroxide or $\text{Ca}(\text{OH})_2$) are also used for soil application in Europe. However, the higher cost of these materials limits their use in western Canada. Wood ash contains oxides and hydroxides of calcium, magnesium, potassium, and, to a lesser extent, sodium, making wood ash similar to burned or hydrated lime in its mode of action.

Wood ash also contains many of the nutrients originally absorbed from the soil by tree growth. Therefore, it may improve crop growth through improved nutrition. By comparison, agricultural lime contains only minimal amounts of plant nutrients. A significant amount of phosphorus, calcium, magnesium and potassium (potash) is added to the soil when wood ash is used as a liming material.

Most agricultural soils are deficient in phosphorus, and it is likely that improved crop growth after liming with wood ash may be due, in part, to increased phosphorus availability. Most soils in Alberta have adequate quantities of plant-available calcium and magnesium, and no improvement in crop growth is anticipated from improved soil fertility from these nutrients. Some soils are deficient in potassium, and crop growth may be improved when wood ash is used.

Field trials show a more rapid change in soil pH when wood ash is used as a liming material compared to using limestone. This factor may be advantageous for a farmer who plans to seed an acid-sensitive crop, such as alfalfa, soon after liming an acidic soil.

Liming Material Quality

The quality of agricultural lime is determined by three factors:

- moisture;
- purity; and
- particle size

Purity and particle size determine the equivalent neutralizing value (ENV) of agricultural lime. The moisture content of agricultural lime is ignored when determining ENV because it is usually less than 2 per cent, and does not have a significant effect on the rate of application. With wood ash, the moisture and purity need to be assessed when determining application rates. Particle size is not considered since these materials are small, and field-testing has shown they are very reactive when incorporated into soil.

Purity

The neutralizing value of liming materials is reported as the per cent calcium carbonate equivalence (%CCE). The %CCE for calcium carbonate, burned, and hydrated lime are 100%, 180%, and 136%, respectively. While the range for wood ash is 55% to 65% at some facilities, values up to 100% have been determined.

When materials with a low %CCE are used, the rate of application must be increased to compensate for low purity. The use of low purity materials will increase the cost of transportation on a per acre basis, and may increase the level of trace metals and organic compounds in soils. Additions of plant nutrients such as phosphorus are increased when higher rates of low quality ash are used. Materials with a high %CCE are advantageous when transporting ash long distances.

Variability in the %CCE of ash from different facilities is due to the degree of combustion achieved in the energy recovery system. In highly controlled energy systems, the liming value of wood ash is relatively constant. However, ash produced in beehive burners is highly variable, and has limited potential as a liming material for agricultural soils.

Fineness

Fineness refers to the particle size of the liming material. The fineness of agricultural lime is determined by weighing and screening the sample, then determining the per cent retained on screens of various mesh sizes. Materials passing through a 60-mesh sieve have an excellent liming capability. However, some coarser fractions are easier to handle. The reactivity of these size fractions is related to the surface area of the particles exposed to the soil. Materials with small particle size are very reactive because of their large surface area.

Wood ash originating from highly controlled burner systems will consist of very small particle sizes, and will be very reactive when incorporated into soil. Field studies near Peace River, Manning, Edson, and Drayton Valley, AB, have shown wood ash is an excellent liming material when compared with agricultural lime.

Moisture content

The moisture content of agricultural lime is usually less than 2%. Therefore, it is not considered when application rates of agricultural lime are determined. Some moisture is desirable to reduce dusting during application. The moisture content of ash varies depending on the process used in the energy recovery system, and the length of time the ash is exposed to precipitation before application. Per cent moisture may vary from less than 1 per cent for recently produced ash to more than 10 per cent when water is added to cool the ash and reduce the fire risk.

When ash is recovered from a landfill, or an outdoor storage facility, an assessment of the extent of wetting should be made. In most instances, moisture penetration into the pile is relatively shallow. In addition, when the moisture is mixed with underlying materials, its effect on liming value is minimal.

Longevity of Lime

No studies exist to show the long-term benefit of using ash as a liming material. A trial was established in west-central Alberta in 1970 using agricultural lime. There continued to be a significant increase in yield of barley until 1993 when trial monitoring was discontinued (Figure 1). Since the mode of activity of ash is similar to that of agricultural lime, it is believed the long-term benefit of ash would be similar to that of agricultural lime.

Effect of Lime on Yield of Barley (kg/ha) at Tomahawk, Alberta (1971 - 1993)

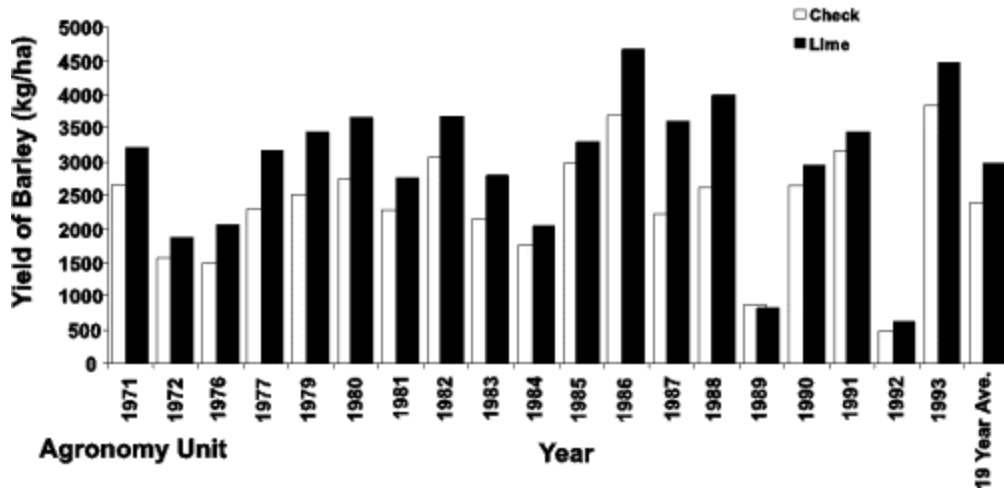


Figure 1. Effect of lime on yield of barley at Tomahawk, Alberta

Other Wood Ash Benefits

The objective of most research studies with agricultural lime and wood ash was to evaluate the potential use of ash to increase soil pH, therefore, increasing the yield of acid sensitive crops. Some research was conducted to show the effect of liming materials on soil tilth, and research is currently underway to investigate the availability of phosphorus in wood ash. The following is a brief discussion of the other benefits of liming.

Tilth

Farmers have often observed an improvement in soil tilth after liming, particularly on soils low in organic matter (Luvisolic soils), or soils high in sodium (Solonetzic soils). Farmers observed that, after liming, soils are less prone to crusting, have reduced power requirements for tillage, and water entry into the soil was much more efficient.

This improvement in soil tilth is due to the ability of calcium to bind individual sand, silt, and clay particles into stable soil aggregates. In more productive soils, such as those in the Black soil zone, organic matter is primarily responsible for maintaining stable soil structure. Soils with stable structure are also well aerated, which is particularly important for optimal nitrogen fixation by legumes.

Research conducted by Agriculture and Agri-Food Canada shows increases in the yield of canola and barley when two soils, near Valleyview, AB, were limed to pH 5.5, 6.0, 6.5, 7.0, and 7.5. Increases in yield due to reduced soil acidity would not be expected above pH 6.0, since canola and barley are moderately tolerant to soil acidity. The researchers attributed the yield increase to improved soil tilth. It is believed this improvement in soil tilth would be a long-term benefit of liming.

Soil fertility

As trees grow, plant nutrients are absorbed from the soil and incorporated into the living plant tissue. When hogfuel is burned, most of the nitrogen and sulphur are released into the atmosphere while much of the phosphorus and potassium is retained in the ash. When ash is applied to soil, a significant amount of plant nutrients are also added.

Liming may improve soil fertility by several mechanisms. An increase in soil pH may increase the decomposition rate of soil organic matter by soil bacteria. In turn, this speeds up the rate of release of plant nutrients such as nitrogen. This temporary benefit may be observed for two or three years after liming.

Liming acid soils increases phosphorus availability. Below pH 6.0, iron and aluminum reduce phosphorus availability. Over-liming may also reduce phosphorus availability as well as that of the micronutrients. Above pH 7.0,

calcium and magnesium precipitate phosphorus to form compounds of low solubility, which means reduced availability for crop growth.

Research completed in Alberta shows that most soils are deficient in phosphorus. Therefore, a real benefit of applying wood ash is that a significant amount of phosphorus is added to soil. Field research shows phosphorus soil test values increased after liming with ash. Plus, a substantial amount of potassium that would be beneficial on potassium-deficient soils is also supplemented.

Increased crop growth may also be due to improved availability of sulphur after liming with ash. This particularly occurs for crops that have a high sulphur requirement, such as alfalfa and canola. Ash also contains calcium, magnesium and micronutrients. However, most soils have an adequate supply of these nutrients.

Research is underway in central Alberta to compare the benefits of wood ash and agricultural lime. In addition, studies are underway to investigate the availability of phosphorus in wood ash when barley and mixed forages are grown. Preliminary results (Figure 2) show ash is an effective liming material and the availability of phosphorus is greater than previously thought. Crop yield was higher on soils that received wood ash than on soils that received agricultural lime plus phosphate fertilizer. In addition to increased phosphorus fertility, the

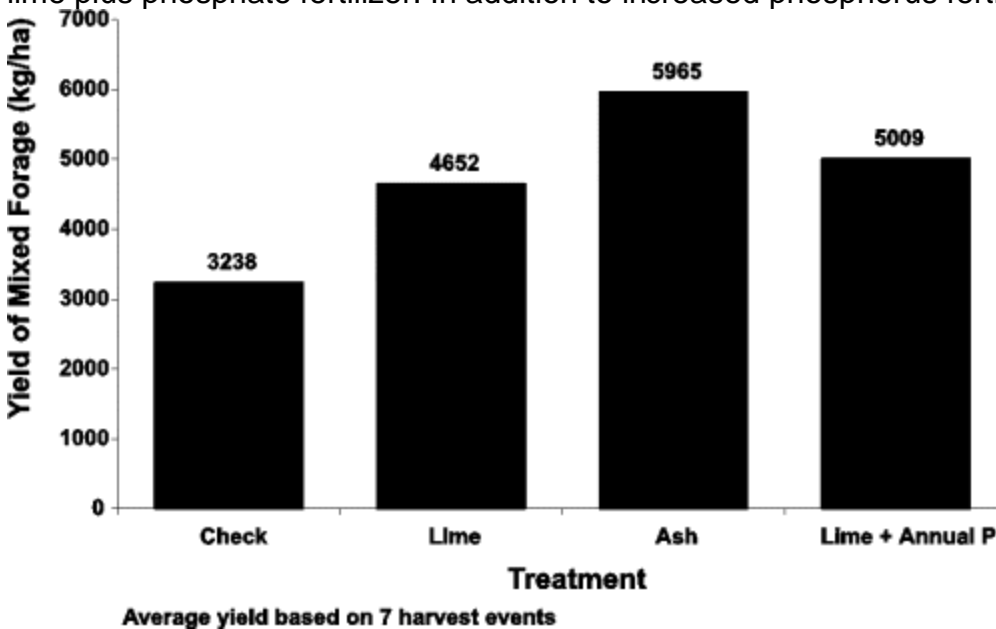


Figure 2. Comparison of Wood ash, Lime and fertilizer Phosphorous on Forage Yield (1999-2000)

increased yield may also be due, in part, to a more rapid change in soil pH when ash is used. Ash may be the preferred liming material when acid sensitive crops are to be grown soon after the application of a liming material.

The long-term benefit of liming acid soils is well documented. However, the role of the nutrients in ash on crop nutrition is not well understood.

Crop response to a large single application of phosphate fertilizer has persisted for two to three years on soils with a high fixation capacity, and for five to ten years, or more, on soils with a low phosphorus fixation capacity. The long-term benefit of phosphorus, and other nutrients, in ash needs to be assessed on typical acid soils in Alberta.

Weed control

Weed encroachment into cropland may occur when the competitive ability of the crop is reduced because of unfavourable crop growing conditions. Research has shown that increasing soil fertility reduced the severity of infestations of ox-eye daisy, wild caraway, dandelion, Canada thistle, common tansy, yellow toadflax and scentless chamomile. Farmers have also observed reduced infestations of scentless chamomile and corn spurry after liming. The use of ash as a soil amendment provides a unique opportunity to increase the competitive ability of crop growth by increasing soil pH, and increasing soil fertility.

Application of ash

When ash is used as a liming material, special attention must be given to the following:

- soil sampling;
- the lime requirement test; and
- application and incorporation of the ash

A thorough understanding of each factor is essential to achieve the maximum benefit from the use of wood ash.

Soil sampling

A number of techniques are used to achieve a representative soil sample from the field to be limed. The objective of soil sampling is to determine the variability in a field, and provide lime recommendations for each soil type.

The most common sampling method used is random sampling of homogenous units within a field. This method is the traditional approach used in agriculture. A field is divided into sampling units based on topographic position (knolls, mid-slopes, and depression areas), differences in soil colour, soil texture (per cent sand, silt and clay in the soil) and per cent organic matter. From each unit, a composite topsoil sample (0 to 6 in.) is obtained by randomly sampling the soil at 15 to 20 locations.

Lumps must be broken, the sample mixed, and a small sub-sample taken and air-dried before submitting the sample to an accredited laboratory for analysis. Moist samples may be shipped directly to a laboratory providing the time in transit is short.

Laboratory personnel will dry these samples before analysis. Samples from the 6 to 12 in., and 12 to 24 in., depths should also be obtained to help identify other crop production limitations.

Soil analysis

When samples are submitted for a lime requirement, the analysis must be done using the incubation method. This method is recommended by Alberta Environment. The lime requirement is converted to an ash recommendation by the following calculation.

Rate of ash required =

$$100/\text{CCE of the ash}^{\text{a}} \times 100/100 - \% \text{H}_2\text{O}^{\text{b}} \times \text{Lime requirement (tonnes per acre)}^{\text{c}}$$

Where:

-a CCE refers to the calcium carbonate equivalence of the wood ash. CCE is a measure of purity of the ash and is available from the generator of the wood ash.
-b Refers to per cent moisture in the ash and is available from the generator of the ash. -c is the lime requirement as provided by the soil testing laboratory. If recommendations are made in metric measure, the appropriate corrections must be made if imperial measures are the preferred units.

Example Lime requirement is 3 tonnes per acre.
CCE of ash is 65%

Per cent moisture is 5%

Rate of ash required = $100/65 \times 100/(100 - 5) \times 3$ tonnes per acre = 4.8 tonnes per acre

Application

Wood ash can be applied with any equipment that provides a uniform coverage over the soil surface. Lime spreaders can be used, and many of the newer models of fertilizer spreaders can also spread wood ash.

Wood ash should be incorporated into the soil. Incorporation should be done within a reasonable time to minimize dusting from wind or removal by water flowing over the soil. Application of ash to perennial forage is not recommended since incorporation is not possible. Agricultural lime and, to a lesser extent, wood

ash is relatively insoluble and hence, immobile. Movement into the soil without soil tillage is minimal, so the benefits of ash would not be realized when it is applied to perennial forages.

Wood ash must not be applied in locations that likely would result in contamination of surface or groundwater. Ash should not be applied within 50 metres of water wells or permanent bodies of water. It should also not be applied to frozen soil, or under any conditions where incorporation within three days is not possible. Wood ash is a very caustic material. As with the handling of other agricultural chemicals, proper protective equipment should be worn to protect the health of the applicator.

Conclusion

While many factors, such as the kind of crop, soil type, and climate, influence responses to lime, it can be generally stated that the application of lime should be considered on all strongly acid soils, and on many moderately acid soils to improve and maintain productivity. Where liming is an established practice, it is applied to maintain soils in the most suitable pH range for the crops and soils in the area. Additional information on the management of acid soils is contained in the following fact sheet: *Liming Acid Soils*, Agdex 534-1