AMENDMENT OF AUSTRALIAN SOILS BY FLY ASH ADDITIONS

Ash Development Association of Australia

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INTRODUCTION

Most Australian soils present in home gardens and in wide-acre and intensively cultivated agricultural areas are not highly productive without some amendment. Soil amendment is achieved by adding a substance to the soil in order to achieve an improvement in its structure, and hence properties like;-

- water transfer and retention, and
- nutrient yield rate or capacity.

Successful amendment generally results in an increase in crop production. This technical note considers past and current research into the use of fly ash in soil amendment. By summarising key findings from this work, the benefits of using fly ash for soil amendment in Australia are demonstrated.

BROAD METHODS OF SOIL AMENDMENT

The intrinsically poor nature of Australian soils is chiefly dictated by a combined result of:-

- The chemistry and physical nature of the underlying rock types,
- The depth of weathering and accumulation by physical and chemical degradation of the parent material,
- The climatic factors influencing the formation processes, and
- Changes brought about by cultivation techniques.

Cultivated soils throughout Australia range from almost pure sand through to heavy clays and most require amendment by additions of fertilizers or other chemical products to maximize ongoing crop production. Two broad methods have been traditionally used to amend soils in Australia; physical and chemical. Examples of these include highly concentrated and expensive additives such as:-

- Super phosphates,
- Sulfate of ammonia, and
- Gypsum.

All of these have been successfully used to increase plant yields through control of the physical or chemical properties of soil.

In undertaking any soil amendment, a general understanding of the mechanisms and resulting actions of the procedure on the local environs is important. Consideration of factors such as changes listed below will provide an increased chance of success in soil amendment:-

- Transfer rates of chemicals in soil groundwater,
- Concentrations of chemical species in soil groundwater
- Critical chemical levels in crops.

REGULATIONS AND GUIDES COVERING SOIL AMENDMENT

As the issue of soil amendment is complex and the science in this area developing, legislation has been introduced from time to time by various departments of environment, and state and municipal entities around Australia. Some examples are provided in the literature (1, 2). The application of any soil amendment programmed for use must strictly conform to any such governing requirements. This may demand more detailed information relating to site and materials specific properties (3).

THE ROLE OF FLY ASH IN SOIL AMENDMENT

Fly ash can be used to successfully amend soils for increased plant growth yield. This has been clearly demonstrated (3 , 4 , 5) on a number of projects where plant growth has been enhanced with soil amendment using fly ash, a byproduct of power generation at coal fired power stations. A recent major study by the University of Technology, Sydney (supported by the Ash Development Association of Australia) has clearly quantified this finding (6).

The Ash Development Association of Australia has supported other research on the use of fly ash in agricultural applications in Western Australia (Fig. 1) and in New South Wales.

Some findings from this work are available in the technical literature (7,8). Guides have been produced on assessment criteria for the use of fly ash in agricultural applications.

Fig. 1: The Byford, WA test site – Analysis of the improvement of soils with different additions of fly ash and/or fertilizer (Ref. 7).

Soil, a byproduct of natural rock, has different compositions and textures depending on its source material. Fly ash is similar in also exhibiting a range of chemical compositions. The intrinsic nature of the coal feed and the firing and cooling conditions of the plant dictate the properties of the ash. The same elements as in soils (silicon, aluminium and iron) form the bulk of the ash. Fly ash is fine and granular and has a predominantly glassy (amorphous) rather than crystalline texture. This results from its history of firing at high temperature, followed by relatively rapid cooling.

Although bulk chemical compositions of various ashes are somewhat similar, the availability of certain nutritional and trace elements conducive to plant well-being may vary considerably. Certain Australian ashes (usually those derived from brown coal) are higher in calcium and sulfate, and may act in a similar way as gypsum under heavy clay soil tillage. Others may, by ion exchange, provide or beneficially control retention and release of necessary bulk and trace elements essential to plant growth. Less reactive ashes may simply improve the grain size distribution within the treated soil such that either water retention or drainage is controlled to the benefit of the planted crop. It is important that both the properties of the soil and the ash are understood and matched to maximise crop yield. Examples of what is possible are shown in Fig 2 and 3.

Fig. 2 – Control pasture showing clover growth without soil amendment (Ref. 7)

Fig. 3 - Pasture improved by use of fly ash and fertiliser showing clover growth (Ref. 7)

SOIL AMENDMENT MECHANISMS AND THE INFLUENCE OF FLY ASH

Soil amendment mechanisms are mostly highly complex and mixed in practice, but they conveniently fall into three basic categories. Changes to soil structure can be done to:-

- Influence moisture movement,
- Influence nutrient levels (through chemical addition), and
- Influence chemical retention and release,

Each of these is discussed in detail in the following sections.

Changes to Soil Structure to Influence Moisture Movement

Addition of fly ash to soils can be beneficial in reducing soil moisture transfer rates and increasing water retention. Pathan et al. (9) compared the hydraulic conductivities and water retention capacities of five fly ash samples and two coarse sands. Hydraulic conductivities of fly ashes were found to be between 105 to 248-fold lower than those in the soils. Water retention capacities at field levels were found to be three times higher in fly ash than those of soils. The work proved that benefits could be achieved at a 10% w/w fly ash amendment in soils (9). It was, however, noted that the considerable variability of fly ashes and soils supported the need for field trials before large scale application of ash from a particular source.

Successful treatment of coarse sand with fly ash is also possible. It has been shown that treatment of the top 150 mm of a coarse sand with fly ash reduced hydraulic conductivity by 25%, thus improving water retention capacity (3). On the other hand, the same treatment of fine textured clayey soil would increase conductivity by up to 20%.

Treatment of heavy clay soils is traditionally done by gypsum addition, but high calcium sulfate fly ash application should always be considered as an alternative. Benefits other than clay dispersion may result from the application of such fly ashes and amongst these are:-

- Possible reduced costs of materials
- Improved dispersion within the soil mass, and
- Introduction of beneficial bulk and trace elements provided by the fly ash.

In general, a significant improvement in water usage can be attained for both sandy and heavy clay soils by the correct addition of fly ash to soil.

Changes to Soil Structure by Chemical Addition

There are benefits in using fly ash to increase the phosphorous content of soil. Summers et al. (4) proved that increases in clover dry matter of between 49 - 278% were achieved, and were attributable to improvement in nutrient and water retention from fly ash treatment. In this case the fly ash provided a substantial amount of phosphorous needed by the clover. No potassium increase could be detected in this study as being contributed by the fly ash.

Whilst some studies also note small increases in trace elements such as cadmium and mercury, such elements often vary naturally at sites and therefore cannot be attributable back to fly ash addition (4). This concurs with the conclusion by Pathan et al. (9) that the potential for release of harmful trace elements from the fly ashes tested was well below regulatory levels.

In general, beneficial elements to plant growth are contributed by fly ash treatments. Toxic levels of trace elements detected are, as a rule, well within required standard levels.

Changes to Soil Structure for Controlled Chemical Retention and Release Properties

Fly ash amendment in soils has been shown to:

- Reduce leaching of nitrate and phosphate
- Improve nutrient management, and
- Hold and release phosphorous from fertilizer applications with more control within a soil.

Pathan et al. (10) demonstrated that in a sandy soil, fly ash amendment retarded nitrate and phosphate leaching, and improved nutrient management. Wood and Hird (11) found that fly ash absorbed phosphorous from fertilizer, and released it in a controlled manner as this element depleted within the soil mass over time.

The benefits of fly ash soil amendment should always be tested for particular applications prior to wide application. Research (12) showed that corn plant emergence, grain yield, percent moisture and harvest index were not significantly influenced by fly ash. The same study however showed that soybean yields treated with 50 mg/ha fly ash increased as much as 35%. In another study, grain and straw yield of rice were found to have increased by 21% and 18% respectively at the 20 mg/ha fly ash treatment (13).

FUTURE OPPORTUNITIES

The possibility of reducing the effects of hydrophobic compounds (waxes, alkenes, and long chained fatty acids) on soil particulates is another potential advantage of using fly ash for soil amendment. The accumulation of these organics in soils having less than 1% clay content poses a problem that stretches over substantial areas of South and Western Australia and Victoria. Consequences of their presence are water repellency by the topsoil mass and severe rainfall runoff. The problem at present is tackled by adding clay to the surface layers of soils, (14), but this procedure presents difficulties in timing, as if it rains before incorporation, the applied material tends to form a solid mass, shed water and restrict plant growth. Such problems are unlikely to affect fly ash material should it be demonstrated as ADAA – Page 4 of 4 either an effective clay replacement or addition to the process.

CONCLUSIONS

Fly ash used for soil amendment can add significant benefits. Amongst these are:-

- Improved water retention in soil,
- Possible reduced costs of materials forsoil amendment,
- Improved dispersion within the soil mass,
- Introduction of beneficial bulk and trace elements provided by the fly ash,
- Increased phosphorous content in soil to promote plant growth,
- Reduced leaching of nitrate and phosphate to make for more effective fertilizer applications,
- Improved nutrient management, and
- Improved hold and release of phosphorous from fertilizer applications with more control within a soil.

It is recommended that benefits for individual applications be tested prior to wide application as both soils and fly ashes from particular sources do vary in physical and chemical properties.

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