UTILIZATION OF FLY ASH IN AGRICULTURE FOR IMPROVING SOIL PROPERTIES AND CROP PRODUCTIVITY

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Received-05.03.2015, Revised-24.03.2015

Abstract: Fly ash constitutes the major portion of the total quantity of residues produced in coal fired thermal power plant. The large amount of fly ash that is generated each year calls for a great deal of research to determine its feasibility or various potential uses. Disposal of high amount of fly-ash from thermal power plants absorbs huge amount of water, energy and land area by ash ponds. In order to meet the growing energy demand, various environmental, economic and social problems associated with the disposal of fly-ash would continue to increase. Therefore, fly-ash management would remain a great concern of the century. Fly-ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance. While compare to soil, fly-ash consists all the elements except organic carbon and nitrogen. The high concentration of elements (K, Na, Zn, Ca, Mg and Fe) in fly-ash increases the yield of many agricultural crops. But compared to other sectors, the use of fly-ash in agriculture is limited. Flyash addition to soil in different doses improves various physical and chemical properties of soil or improves soil quality and thereby is also beneficial for plant growth. Hence through the present review we can conclude that though fly ash is a waste of concern but now has become a boon for sustainable agriculture.

Keywords: Fly-ash, Agriculture, Soil health, Crop yield

INTRODUCTION

Fly-ash is the end residue from combustion of pulverized bituminous or sub-bituminous coal (lignite) in the furnace of thermal power plants and consists of mineral constituents of coal which is not fully burnt (Basu et.al. 2009). Globally, coal fly ash (CFA) generated in huge quantities from coal fired power plants, is a problematic solid waste. Clearly the huge quantity of CFA produced annually not only poses serious environmental concerns but also requires large areas of land for its storage and disposal. Thus, appropriate measures for its safe disposal and means of utilization are necessary for sustainable management of this waste (Singh et al., 2010). So far, two distinct alternatives FA disposal options have been used i.e. its utilization in construction materials and land application as a soil amendment. Fly-ash, having both the soil amending and nutrient-enriching properties, is helpful in improving crop growth and yield in low fertility soils. It has been shown that FA based soil conditioner not only improves the crop productivity and soil fertility but also mobilizes macro- and micronutrients in the soil (Buddhe, et.al.2014).

Many researchers (Yadava, et.al, 2012) have demon-started that fly-ash increased the crop yield of various crops and improved the physical and chemical characteristics of the soil. The FA contains essential macronutrients including P, K, and Ca, Mg and S and micronutrients Fe, Mn, Zn, Cu, Co, B and Mo. Some FA are rich in heavy metals such as Cd and Ni (Adriano et al., 1980).Fly ash used at different doses and may probably change the chemical as well as physicochemical soil properties which intern may determine the biological properties irrespective of the crop. Fly ash, the fine residue captured from flue exhausts when coal is burnt in power stations, may be used as an amendment to enhance water and nutrient retention in sandy soils (Pathan et al., 2003).

Many experiments and studies on the effect and potentiality of fly-ash as an amendment in agricultural applications have been conducted by various agencies, research institutes at dispersed locations all over the world. In this paper, utilization of fly-ash as a value-added product of agriculture is reviewed with the aim of helping opening up the usage of fly-ash and reducing the environmental and economic impacts of disposal.

RESULT AND DESCUSION

Physical properties of fly ash

The physical properties of fly-ash vary widely depending on the coal type, boiler type, ash content in coal, combustion method and collector setup. Coal fly ash is comprised of very fine particles, with an average diameter <10 mm, aggregated into spherical particles of 0.01-100 mm sizes which are hollow spheres (cenospheres) filled with smaller amorphous particles or crystals (pelospheres) (Jala and Goyal, 2006). The colour of FA ranges from water-white to yellow-orange to deep red or brown to opaque, depending mainly on the Fe_2O_3 and carbon contents. The un-burnt coal content, corresponding to loss on

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ignition, ranging from 0.5 to 12% is responsible for the black or grey appearance of FA. Fly ash addition changes the physical properties of soil such as texture, bulk density, WHC, hydraulic conductivity and particle size distribution (Sharma, et.al. 2006). Fly ash is used to improve the soil texture, water holding capacity, density, pH, bulk density, porosity etc. by using in different ratio with soil (Pathan, et.al.2003).

Chemical Properties of fly ash

The chemical characteristics of FA depend largely on geological factors related to the coal deposits and on different operating conditions/practices employed at the power plants. Thus, FA from every coal-fired plant has its own chemical characteristics. Coal fly ashes (CFAs) are usually grouped into two classes, i.e. Class F produced from anthracite, bituminous and sub-bituminous coals containing less than 7% CaO, and Class C produced from lignite coal containing more liming material, up to 30% (Wang and Wu, 2006). The main constituents of FA are silica, alumina and iron oxides, with varying amounts of carbon, calcium, magnesium, and sulphur. The pH of FA ranges between 4.5 and 13.25, depending largely on the sulphur and CaO contents of the parent coal (Riehl et al., 2010). According to Kumar et al. (2000), on an average 95–99% of fly-ash consists of oxides of Si, Al, Fe and Ca and about 0.5–3.5% consists of Na, P, K and S and the remainder of the ash is composed of trace elements. Depending on the source, fly-ash can be acidic or alkaline, which could be useful to buffer the soil pH .The hydroxide and carbonate salts give fly-ash one of its principal beneficial chemical characteristics, the ability to neutralize acidity in soils (Cetin and Pehlivan,2007).

Fly-ash as a source of plant nutrients

To solve the soil-shortage problem in subsided land of coal mines, the chemical properties of artificial soil comprising organic residue and inorganic fly ash were examined by Feng et al. (2006). Chemically, fly-ash contains elements like Ca, Fe, Mg, and K, essential to plant growth, but also other elements such as B, Se, and Mo, and metals that can be toxic to the plants (Kachroo, et.al, 2006). Fly-ash contains negligible amount of soluble salt and organic carbon and adequate quantity of K, CaO, MgO, Zn and Mo. However, it is potentially toxic to plants due to high B content (Warambhe, et. al., 1993). After application of fly-ash, the downward move of nutrients through soil column and the availability of nutrients for plant growth became limited to a depth of 80 cm from the soil surface (Menon, et.al., 1993). Coal fly ash through its influence on soil physical, chemical and biological properties and processes is likely to affect plants growth and development. Research has demonstrated positive benefits of CFA land application for improving soil properties and crop productivity (Skousen et al., 2013). The use of CFA in agriculture has been based on its liming potential and supply of nutrients such as Ca, Na, K, P, Mg, B, S and Mo, which promote plant growth and also alleviate the condition of nutrient deficiency in soils (Kumpiene et al., 2007). Many greenhouse and field studies indicate that many chemical constituents of CFA can improve the agronomic and fertility properties of the soil (Singh et al., 1997). Overall it seems the use of CFA can be a useful source of essential nutrients. Like other wastes (e.g. sewage sludge), its land application in excessive amounts or uncontrolled disposal is likely to present a significant risk of entry into the food chain.

Fly-ash for improving soil properties

Land application of FA can improve soils with poor physical properties, including texture, bulk density and water holding capacity. Coarse-textured soils can be amended with FA to increase the silt- and sand-sized fractions, which help in aggregation, infiltration and soil water-storage. However, the extent of changes in soil physical conditions would depend on the amount applied and physical properties of the soil and CFA.

Soil texture

Alteration of the soil texture is possible through the addition of appropriate quantities of fly-ash due to its textural manipulation through fly-ash mixing. Shenggao and Lei (2004) studied that fly ash was mixed in two acid clay loams (typic plithudult and typic hapludults) at the rates of 0, 5, 10, 20, 30 and 50 % by weight on application of 50% fly ash, there was significant increase in percentage of silt particles and decrease in clay content. Effect of fly ash (30 and 50%) to another soil caused a significant change in micro aggregate size disruption of soil, while non significant differences were observed in the rates of 5, 10 and 20 % fly ash. Application of high rates of fly-ash can change the surface texture of soils, usually by increasing the silt content (Garg, et. al., 2003). Fly ash is comprised primarily of silt and clay sized particles. Addition of fly-ash at 200 t acre $^{-1}$ improved the physical and chemical properties of soil and shifted the USDA textural class of the refuge from sandy loam to silt loam (Buck, et.al.,1990).

Soil pH

Coal fly ash can change soil pH in both directions i.e. decrease or increase, depending on the FA characteristics and the degree of weathering. Fly ashes produced from coal containing high amounts of sulphur are acidic in reaction; land application of such ashes is likely to decrease soil pH, particularly in soils with neutral to alkaline reactions (Pathan et al., 2003). Land application of weathered alkaline FA is likely to increase soil pH. Alkaline FA can be used to neutralize acidity and raise pH of acidic soils (Skousen et al., 2013). Most of the fly-ash produced in India is alkaline in nature; hence, its application to agricultural soils could increase the soil pH and thereby neutralize acidic soils. Considering the potential environmental impacts, fly ash can be used as a liming agent in acid soils by increasing pH and electrical conductivity may improve soil properties and increase crop yield (Matsi and Keramidas, 1999). An appreciable change in the soil physicochemical properties, an increase in pH and increased rice crop yield were obtained by mixed application of fly-ash, paper factory sludge and farmyard manure (Molliner and Street, 1982). Appropriately selected FA (alkaline for acidic soils and acidic for alkaline soils) can thus be used for soil pH correction purposes.

Water-holding capacity

Fly-ash application to sandy soil could permanently alter soil texture, increase micro porosity and improve the water-holding capacity as it is mainly comprised of silt-sized particles. Fly-ash generally decreased the bulk density of soils leading to improved soil porosity, workability and enhanced water-retention capacity. A gradual increase in fly-ash concentration in the normal field soil (0, 10, and 20 up to 100% v/v) was reported to increase the porosity, water-holding capacity, conductivity and cation exchange capacity (Khan and Khan 1996). However, the FA application did increase the plant available water content and water holding capacity of the soil (Adriano and Weber, 2001). This was attributed to the large surface area of the spherical-shaped FA particles which increases soil micro porosity, thus, enhancing soil water holding capacity. It should however be noted that improvement in the water holding capacity and plant available water content became significant only at very high FA application rates (560 and 1120 t ha^{-1} respectively). Such large amounts of FA application are likely to induce undesirable changes in other soil properties.

Bulk Density

The particle size range of fly-ash is similar to silt and changes the bulk density of soil. Application of fly-ash at 0%, 5%, 10% and 15% by weight in clay soil significantly reduced the bulk density and improved the soil structure, which in turn improves porosity, workability, root penetration and moisture-retention capacity of the soil (Garg, et.al. 2005). Application of FA at 0, 5, 10 and 15% by weight in clay soil significantly reduced the BD and improved the soil structure, which in turn improves porosity, workability, root penetration and moisture-retention capacity of the soil (Kene, et. Al., 1991).The utilization of fly in agriculture is proven helpful it is physical properties of soil hence fertility and crop productivity to significant level. It reduce texture of soil such that it reduce the bulk density, increase porosity ,aeration and cation exchange capacity which increase water and nutrient holding capacity of soil(Rautary,et.al.,2003).

Fly-ash for improving crop growth and yield

Presence of majority of macro and micro nutrient in fly ash in sufficient amount in makes it an efficient material for agriculture.Coal fly ash through its influence on soil physical, chemical and biological properties and processes is likely to affect plants growth and development. Research has demonstrated positive benefits of FA land application for improving soil properties and crop productivity (Skousen et al., 2013). Yeledhalli, ey. al., 2012 studied the bulk application of fly ash application at 30-40 t/ha recommended dose of NPK fertilizers alone or along with FYM @ 20 t/ha was used for cultivation of sunflower maize crops. Fly ash applied to soil resulted in an increased seedling height, plant height, grith, leaf number, leaf area, spike length and dry weight of wheat at 5% rate of application (Tripathy, and Sahu, 1997). Dry biomass yield of ryegrass, tomato and growth of spinach significantly increased with fly ash application of acid soils (Malewar, et.al., 1999). Vimal Kumar, et.al. 2005 Shown the crops yield percentage with the application of fly ash in different soil crop combination and it is mentioned in Table 1.

Table 1. Crops Yield Increase on Amendment of fly ash

Crops	Yield increase in %
Banana	30
Paddy	31
Pearl Millet	32
Seed cotton,Sorghum, Gram,Soybean	10-46
Sunflower, Groundnut	10-26
Sugarcane	22
Wheat, Mustard, Rice, Maize,	6-18
Vegetables	15

Summary

To meet the growing energy demand and thereby increase power generating capacity, the dependency on coal for power generation and disposal of fly-ash will continue to increase along with various unavoidable problems. It could be stated that the potentiality of fly-ash for its use in agriculture is popularizing day by day due to the fact that it contains almost all the essential plant nutrients i.e., macronutrients including P, K, Ca, Mg and S and micronutrients like Fe, Mn, Zn, Cu, Co, B and Mo, except organic carbon and nitrogen.fly ash can used as liming materials for acid soils or acid mine soils or alkali soils for improving the pH of the soils depending upon the nature if the fly ash and soil. It is now well proved that though it can substitute lime, a costly amendment for acid soils, it cannot be a substitute for chemical fertilizers or organic manures. However, integrated application of all these can foreshorten the plant uptake of different heavy metals from fly-ash-amended soils as well as can reduce the use of chemical fertilizers and thereby reduces environment pollution. Simultaneously, in future, attention should be given on some important areas related to fly-ash utilization, like proper handling of dry ash in plants as well as in fields, ash pond management, and long term studies of impact of fly-ash on soil health, crop quality, and continuous monitoring on the characteristics of soil as well as fly-ash. All these situations need to be carefully assessed while recommending application of fly ash in agriculture.

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