ROLE OF FLY ASH ON SOIL HEALTH AND CROP PRODUCTION

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Abstract: Fly ash is a residue of burning of coal and lignite, the organic sources of energy. The micro and macro nutrients present in coal get generally concentrated in the ash. However, several studies proposed that fly ash can be used to improve physical, chemical and biological properties of the degraded soils and is a source of easily available and cheaper nutrients for crops. Fly ash can be used for reclaiming the problem soil and enhance the crop productivity depend upon the nature of soil and fly ash. Characterization of fly ash has widely shown about its usefulness in improving soil properties and crop growth, as its disposal needs large area of land. The use of fly ash in agriculture indicates that main constituents of fly ash are silicates of iron and aluminum. It contains fairly high available major nutrients like P, K and S and micronutrients such as In, Cu, Fe, Mn and B with high bio-available heavy metals. Depending up on its source of availability, it may be acidic or alkaline in reaction and therefore, it can be used as ameliorant to reclaim acidic and alkaline soils. Hence an attempt has been made to summarize the work done in recent past on the use of fly ash in crop production in this review article.

Keywords: Fly ash, Soil texture, Soil structure, Soil aggregation, Nutrient availability, Soil physical environment

INTRODUCTION

Fly ash is produced in thermal electrical power plant. Fly Ash (FA), a coal combustion residue (CCR), is a major type of solid waste. Elemental composition of FA (both nutrient and toxic elements) varies due to types and sources of used coal (Comberato et al., 1997). Increased urbanization and industrialization worldwide has resulted in increased releases of solid waste and enhanced environmental pollution around the globe. There are several categories of solid waste and these include sewage sludge and municipal solid wastes (Singh et al., 2011). According to the data provided by Govt. of India 110 million tonnes of this kind of waste is produced in India during 2005 - 06. Nearly 50 - 60 % of the fly ash is being stored at plant dump sites and other sites intended for this purpose. (Yeledhalli et al., 2007). In agriculture, FA is primarily utilized as a soil amendment to buffer the soil pH (Phung et al. 1978 ). Such amendment improves soil texture (Fail and Wochok 1977; Chang et al., 1977) and soil nutrient status (Raturaray et al., 2003). Fly ash may either have a positive and negative effect on plant growth and yielding if not used in optimum doses. The effect is determined primarily by chemical composition and the ash dose applied. In a study by Kalara et al., 2003. The commercialization of FA as a fertilizer in agricultural sector for crop production is uncommon in the most countries, because fly ashes may contain non-essential elements (e.g. As, B, Cd, Se) that adversely affect crop and soil and poor in both nitrogen (N is absent because it is oxidized into gaseous constituents during the combustion) and P (excessive Fe and Al convert soluble P to insoluble P compounds, which are not readily available to plants; Adriano et al., 1980). Although, the lower levels of FA in the soil caused enhancements of both growth and yield, however, the adverse effects at higher levels were observed for crops (Pandey et al., 2009a). Increased microbial activity was reported for ash amended soils containing sewage sludge (Pitchel 1990, Pitchel and Hayes 1990). To maintain high response of crops to applied fertilizer, equal importance has to be given to soil health management practices and efforts have to be made to create awareness of soil health among the farmers community, so that soils (natural resource) in good condition could be transferred to the next generation. For this purpose fertility restorer inputs like available Fly ash, Gypsum, formulated compost, FYM, city waste and other agro-industrial waste, have to be recycled in soil through integrated nutrient management approach (Gu et al., 2013).

Physico-chemical and Mineralogical properties of Fly Ash

Physical properties of Fly Ash
The physico-chemical properties of FA primarily depend on the nature of the parent coal composition from which it comes and secondly on the conditions under which the coal is combusted (Karapanagogi and Atalay 2001; Pandey and Singh 2010). The mineralogical, physical and chemical properties of fly ash (Adriano et al., 1980) depend on the nature of parent coal, conditions of combustion, type of emission control devices and storage and handling methods. Therefore, ash produced by burning of anthracite, bituminous and lignite coal has different composition. Fly ash has unusually high surface area and light texture due to the presence of large, porous and carbonaceous particles (Kishor et al., 2010).
Physically, FA is comprised of very fine glass-like particles that are 0.01–100 mm in size (Davison et al., 1974; Jala and Goyal 2006). The pH ranges from 4.5 to 12.0 and depends on the S content of the parent coal (Plank and Martens 1974). The bulk density (BD) of the FA was found to be lower than that of normal cultivable soil (Sikka and Kansal, 1994). FA constitutes a varied combination of amorphous and crystalline phases (usually considered as ferro aluminosilicate) (Lim and Choi 2014) and has a matrix similar to soil. It also contains about 69% of a finedearthed fraction (i.e., clay silt) that derives from coal. These FA particles have specific gravities of 2.1–2.6 g m⁻³ (Bern 1976), low to medium bulk density, a large surface area and very light texture. Hodgson and Townsend (1973) reported that samples of fly-ash-particle fractions contained from 45 to 70% silt and 1 to 4% clay.

Chemical properties of fly ash

The specific chemical composition of FA depends on the quality of and conditions under which the parent coal was combusted (Jala and Goyal 2006; Basu et al., 2009; Gupta et al., 2012). Chemical characteristics of coal include molecular weight, carbon aromaticity, normal aromatic and aliphatic structure and functional groups present. (Ahmaruzzaman, M. (2010) described FA as mainly being composed of Si, Al, and Fe, with a major proportion of Ca, K, Na, Ti, along with other trace elements. Coal FA consists of SiO₂ (49–67%), Al₂O₃ (16–29%), Fe₂O₃ (4–10%), CaO (1–4%), MgO (0.2–2%), and SO₃ (0.1–2%) (Singh et al., 2010). A listing of elements present in FA includes the following: Si, Ca, Mg, Na, K, Cd, Pb, Cu, Co, Fe, Mn, Mo, Ni, Zn, B, F and Al (Tripathi et al. 2004; Gupta and Sinha 2008).

Effect on soil health

Amending soils with FA affects all soil physical and chemical characteristics such as texture, bulk density, pH, water-holding capacity, electrical conductance (EC) (Chang et al., 1977; Pathan et al., 2003; Singh et al., 2012a). A gradual increase in the rate of fly-ash amendment (0% 10% 25%, up to 100% v/v) in normal field soils increased water-holding capacity, EC, and pH (Gupta and Sinha 2006, 2009). As expected, water holding capacity of the soil increased linearly with fly ash addition. Chemical properties of soil are also affected by adding fly ashes, since they are rich in heavy metal content (Singh et al., 2010, 2012a; Gupta and Sinha 2006, 2009). However, using excessive amounts of FA to neutralize soil acidity can result in excessive soil alkalinity, particularly with unweathered fly ashes (Sharma et al., 1989). FA amendment also increases the amounts of soluble major and minor inorganic constituents of soil, resulting in a higher EC value (Adriano et al., 1980; Jala and Goyal 2006; Basu et al., 2009). Fly ash addition to the soil also promotes soil aggregation (Sale et al., 1996). Bulk density decreased linearly with increasing fly ash addition (Chang et al., 1977, Chang et al., 1989) and leads to improved soil porosity, better workability, easier root penetration and increased moisture retention capacity of the soil (Page et al., 1979). Addition of fly ash decreases bulk density and improves water holding capacity due to dominance of silt-sized particles in fly ash (Campbell et al., 1983). Sale et al., (1996) have also reported that fly ash is composed predominantly of silt-sized particles and when added to a soil high in clay, the soil texture and other associated physical characteristics, such as bulk density, can be altered to be more desirable for plant growth. Due to the fine nature of fly ash, it improves the water holding capacity of sandy soils and removes the compaction of clay soils (Sharma and Kalra, 2006). For a fine textured soil such as clay, addition of fly ash will increase the soil bulk density whereas for a coarse textured soil such as the sandy loam soil addition of fly ash is expected to reduce the bulk density. FA in itself is not a source of soil microbes, its beneficial effect on the physicochemical properties of soils improves microbiological activity. An enhancement in the microbial activity after addition of FA upto 5% in soil–ash admixtures and inhibitory effects at higher dose of FA were inferred (Kalra et al., 1997).

Effect of fly ash on soil fertility

Fly Ash also reduce surface and enhance soil ventilation and the germination of plants. Acid clay soils treat even with a high dose (600 t/ha) of dry FA enhanced their physicochemical properties (Fulekar, 1993). FA has been used as a source of essential plant nutrients. Fly Ash application greatly increased the soil contents of P, K, B, Ca, Mg, Mn, Zn, carbonates, bicarbonates, and sulfates (Khan and Singh, 2001). A significant increase in the nutrient uptake of oil seed crops and improvement in the fertility status of soil after FA application were noticed. FA application improved the Si content of rice plants (Lee et al., 2006). FA applications have been observed to correct plant nutritional deficiencies of P and Mn, B, Mg, Mo, S and Zn. improvement in soil property, workability, WHC and permeability of different soil types after decrease in their BD on FA improvement are well recognized. FA helps to preserve soil moisture (Seneviratne et al., 2010). Nutrient enrichment of soil due to fly ash amendment up to a certain level would be expected to stimulate root growth and excretion of root exudates in the soil. (Kohli et al., 2010).

CONCLUSION

The volume of solid waste produced in the world is increasing annually and disposing of such wastes is a growing problem. Fly ash (FA) is a form of solid waste that is derived from the combustion of coal.
FA clearly shows that its application as an amendment to agricultural soils can significantly improve soil quality and produce higher soil fertility. A substantial amount of high-analysis chemical fertilizer may be saved through such utilization of fly ash under integrated plant nutrient system. The increased yield of crops with fly ash incorporation could be attributed to modification in soil properties. FA application method is best and what level of application is appropriate for any one biological responses of agricultural soils to fly-ash amendment soil depends on the following factors: type of soil treated, crop grown, the prevailing agro climatic condition and the character of the FA used. Although utilizing FA in agricultural soils may help address solid waste disposal problems and may enhance agricultural production, its use has potential adverse effects also. In particular, using it in agriculture may enhance amounts of radionuclides and heavy metals that reach soils and may therefore increase organism exposures in some instances. An ultimate goal would be to utilize FA in degraded/marginal soils to such an extent as to achieve enhanced fertility without affecting the soil quality and minimizing the accumulation of toxic metals in plants below critical levels for human health.

REFERENCES


