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Potential Use of Fly Ash (FA) in Improving Soil and Crop Productivity on Arenosols

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Abstract: *Arenosols are least fertile mineral soils in the World. In Zimbabwe, 70% of soils are Arenosols characterized by poor structure and low crop productivity. Therefore, objective of this review was to determine soil conditioning potential of fly ash (FA) in Arenosols. Soil conditioners enhance soil productivity by modifying soil both physical and chemical properties. Application of organic manure (OM) is an excellent soil conditioner; however, scarce therefore alternative sources of conditioners are imperative. FA is a potential substitute to OM but in Zimbabwe large deposits are idle. Fly ash was observed to improve crop productivity in desert, lateral and saline soils. However, application rates under different soil types and effects on specific soil properties are still unclear. Fly ash is a potential soil conditioner, can improve soil productivity and its utilization reduces environmental pollution.*

Keywords: Marginalized, Physiochemical, Soil productivity, Soil structure, Soil texture

INTRODUCTION

About 70% of Zimbabwean soils are Arenosols, inherently infertile and prone to leaching (Mugwira and Murwira, 1998). The soils have poor structure, hence nutrient and water management is a challenge (Pathan, Aylmore and Colmer, 2001). Strategies to enhance the soil fertility and water holding capacity in Arenosols remains a major limitation to crop yield in Zimbabwe (Zingore, 2016). Arenosols soils are poorly aggregated, highly leached and acidic making many macronutrients unavailable and increase toxicity of many micronutrients thereby reducing crop productivity (Nyamangara, Mugwira and Mpofu, 2008). Addition of organic manure was observed to improve aggregation of the primary particles in Arenosols, however, the use of manure is still challenging as it is not readily availability among most communal farmer (Zingore et al., 2007). This calls for alternative soil conditioners in the Arenosols. Zimbabwe has large quantities of fly ash (FA) produced from coal mines and during electricity generation which is an environmental menace. The FA releases minerals or leachates that can contaminate the environment. Fly ash deposits in Zimbabwe are idle and if they continue to accumulate will be a serious environmental hazard. The fly ash is a potential soil conditioner as it enhances both physical and chemical soil properties. Addition of soil conditioners increases availability and solubility of plant nutrients thereby crop productivity. (Arivazhagan et al., 2011; Bhattacharya and Chatopadhaya, 2002; Kishor, Ghosh and Kumar, 2010) observed significant improvement on soil productivity when FA was applied at different rates that ranged from 5 to 650 t/ha on structurally degraded soils. In other studies, application of FA at different rates was observed to reduce soil bulk density, improved porosity, water holding capacity, better workability of soils, improved root penetration and neutralized pH in acid soils (Poykio, Nurmesniemi and Dahl, 2007; Aggarwal, Singh and Yadav, 2009; Alami and Akthar, 2011; Saraswat and Chaudrary, 2014). Application of FA in agricultural soils enriched crops with Ca, S, Na and Fe among other nutrients thereby improving crop quality in respect to protein and oil content which are good for human nutrition (Bhattacharya and Chatopadhaya, 2002; Sikka and Kansal, 1994). The application rates vary from region to region and source of fly ash. This suggest that soil type may play a major role in determining the quantity of FA to be applied, each soil type will have its own requirement.

Fly Ash (FA)

Fly ash are dust particles produced during electricity generation from coal (Kishor, Ghosh and Kumar, 2010). The FA accounts for about 70 % of the total wastes produced during coal combustion (Dwivedi and Jain, 2014). The physical structure of the fly ash is determined by the coal type, boiler type, ash content in coal, combustion method and collector set up (Basu et al., 2009). Fly ash has silt-loam texture with particles having dimensions of less than 0.010 mm (Aggarwal, Singh and Yadav, 2009). This particle size applied at sufficient rates can alter the soil's silt content and improve water holding capacity (Pathan, Aylmore and Colmer, 2001). Also this particle size characteristic has enabled FA to amend coarse textured or rocky soils to have better aggregation, infiltration and water holding capacity (Skousen et al., 2013). Fly ash has low to medium bulk density which varies from 1 to 1.8 gm^3 (Alami and Akthar, 2011). This bulk density is ideal for plant growth according to (Arshad, Lovery and Grossman, 1996) who elaborated that for sandy soils bulk density less than 1.60 g/cm^3, was ideal for plant growth for silt soils it had to be >1.40 g/cm^3 and clayey soils >1.10 g/cm^3 was proper. Hydraulic conductivity, and water holding capacity of 49 – 66 % on weight basis, specific gravity and high surface area (Bhattacharya and Chatopadhaya, 2002; Kishor, Ghosh and Kumar, 2010) are other important characteristics of fly ash. Chemically fly ash is amorphous ferro – alumino silicate mineral with elements like Si, Al, Fe, as major components and significant amounts of Ca, Mg, K, P, S as minor nutrients (Bhattacharya and Chatopadhaya, 2002). (Kumar, Mathur and Preeti, 2000) found that 95 – 99 % of FA consists of oxides of Si, Al, Fe, and Ca. The Fe oxide being responsible for the color of FA which ranges from water – white to yellow orange to deep red or brown to opaque (Kishor, Ghosh and Kumar, 2010). The silica and alumino ordinarily do not have the cementing capabilities but in the presence of moisture they react with calcium hydroxide to form compounds that have cementing properties (Wattimena, Antonni and Hardjito, 2017). This property has allowed FA utilization in the construction sector. FA from Zimbabwe has not been characterized, making it difficult to recommend specific uses for it, due to different chemical and physical properties as brought about by the FA origins, how it was produced as well as its storage.

Production of FA by country

Approximately 37% of the global population is dependent on coal for electricity generation, the proportion being higher (ranging from 65 to 80 %) in developing than developed countries (UNEP, 2017). In Zimbabwe about 35 to 40 % fly ash is produced annually which approximately corresponds to 1.16 million tons (UNEP, 2017). In electricity generation, the coal is subjected to combustion producing fly ash (Kishor, Ghosh and Kumar, 2010; Vom Berg, 1998). The solid wastes are known as coal combustion by-products (CCPs). Many approaches have been implemented in an attempt to reduce environmental hazard from the CCPs. Utilization can curb the problem of FA stock piling in many countries (Nawaz, 2013). The production of FA around the world is estimated to be over 800 million tons annually. India ranks the highest producer with an annual output of about 112 million tons (Table 1) that occupy at least 65000 acres of land as dumping sites (Nawaz, 2013; Chigondo et al., 2013). This production output was expected to have exceeded 225 million tons by the year 2017 (Nawaz, 2013). The ever increasing electricity generation from coal without alternative sources of power could result to unprecedented accumulation of fly ash if unchecked. Having large coal reserves in Zimbabwe suggest that FA will be future environmental hazard if nothing is done to reduce its accumulation. South Africa produces about 25 million tons of fly ash annually from coal production estimated to be around 109 million tons supplying 93 % of its electricity demand (Babajide et al., 2010), its fly ash utilization has remained subdued like most countries in the world.

Table 1: Fly ash production and utilization around the world (2005-6)

Country	FA Production (mt/ yr)	FA Utilization (%)
India	112.0	10
China	106.0	38
USA	75.0	45
Germany	46.0	65
United Kingdom	15.0	85
Australia	10.0	50
Canada	6.0	85
France	3.0	75
Denmark	2.0	100
Italy	2.0	100
Netherlands	2.0	100

Source: http:// www.tifac.org.in (Kishor, Ghosh and Kumar, 2010)

Fly ash utilization

Fly ash utilization is not only possible but has become a necessity, considering that it is produced in large quantities annually and cannot continue to lie in idle, at the same time the disposal ways have been unsustainable (Basu et al., 2009; Nawaz, 2013). There is need to employ economical and sustainable ways of disposing the FA (Bhattacharya and Chatopadhaya, 2002). In developed countries, more than 80 % of the produced FA is utilized in the construction industry e.g. by making bricks, cellular concrete blocks, road construction (Tiwari, Bajpai and Kumar, 2016). However at least 10 % of the FA produced in the developed countries is utilized in the agricultural sector, (Nawaz, 2013) leaving more room for improvement. The low utilization of FA in the developing countries is attributed to unavailability of appropriate and cost effective technologies that accompany its use be it in the agriculture or other sectors (Bhattacharjee and Kandpal, 2002). There is need for more research to be done in these developing countries that prove benefits of FA; there is little or no published work from FA utilization.

Potential challenges in FA utilization

Use of FA cannot be done without characterization to establish its pH levels, physical and chemical composition. There is FA that is acidic and the other that is alkaline depending on the sulfur content of the parent coal, its characterization may be costly where funding is limiting. So its application can only be done when addressing a known problem whether of acidity or alkalinity, or improving of soil water holding capacity, porosity, bulk density and other properties. Also depending on storage, weathered FA is different from un-weathered FA chemically hence the characterization which may be expensive to the farmers who are in the marginalized areas. There is FA that is rich in heavy metals such as Cd and Ni (Adriano et al., 1980; Bhattacharya and Chatopadhaya, 2002). This has brought about fear of these metals accumulating in food stuff when used in crop production. In their paper, (Bhattacharya and Chatopadhaya, 2002) showed results of soil and food crops produced at a rate of 200 t/ha that were tested for the presence of these metals. There was negligible trace of these elements in the soil as well as the food but there ought to be ceiling rates where application beyond, would be detrimental to the health of the soil, food and subsequently the health of humans.

Application of un-weathered fly ash may have a tendency of accumulating elements such as B, Mo, Se and Al which at toxic levels are responsible for reductions in crop yields and consequently influence animal and human health (Sharma and Kaira, 2006). Alkaline fly ash has been reported to act as a binding agent for fixation of heavy metals (Vinani, Carini and Silva, 1994; Lin and Hsin, 1996; Sharma and Uma-Singh, 2007). There is increased Selenium accumulation in plant tissues with increased fly ash application; this then need close examination and use of appropriately weathered fly ash (Furr et al., 1977; Straughan, Elseewi and Page, 1978). Not much work has been done on testing presence of heavy metals and radio nuclides that are said to be present in fly ash. According to (Bhattacharya and Chatopadhaya, 2002) the heavy metals are there in negligible amounts. It is not clear though up to what level they remain negligible. Application rates of 650 t/ha surely need confirmation of these metals in food stuff. Since sources of fly ash differ, it is believed there is fly ash that is rich in heavy metals such as Cd and Ni (Adriano et al., 1980; Bhattacharya and Chatopadhaya, 2002) that would translate to presence of these in food.

Soil physical properties

Effects of FA on Soil pH and Cation Exchange Capacity

Optimum pH for crop production ranges between 6.5–7.5 and soil fertility is impaired at pH below 5.5 which allows solubility of toxic elements like manganese and aluminum which then hinder root growth (Belachew and Abera, 2010; Saraswat and Chaudrary, 2014). Addition of organic matter to the soil buffers plants against acidity such that plant production can be possible in soils with lower pH (Saraswat and Chaudrary, 2014). The pH of FA depends on its source which can be acidic or alkaline, (Basu et al., 2009) it varies from 4.5 to 12.0 depending on the nature of the parent coal (Kishor, Ghosh and Kumar, 2010). (Kishor, Ghosh and Kumar, 2010) noted two types of FA i.e., Class F (low lime) and Class C (high lime) depending on silica, aluminia and iron oxide content, which makes the ash either acidic or alkaline. Fly ash is generally acidic due to high S, while the one with lignites has high Ca and is alkaline. (Das, Choudhury and Das, 2013) Saw an increase in the pH from 5.38 to 6.01 in post-harvest soils due to addition of fly ash. The hydroxide and carbonate salts confer the ability of fly ash to neutralize acidity in soils (Matsi and Keramidas, 1999). The CaO in the fly ash reacts with water in the presence of CO_2 to produce hydroxyl and other ionic forms and the carbonates as precipitates. These reactions and presence of Na give the high pH values (Selvakumari et al., 2000). On the other hand (Baskar and Selvakumari, 2005) and (Sikka and Kansal, 1995) found that addition of fly ash did not change the post-harvest soil pH. This suggests that use of fly ash to change pH should be done upon characterization of the fly ash and soil to be sure of what is to be corrected. (Ram et al., 2006) Reported an increase in pH of mine spoil after fly ash amendments. (Gangloff et al., 2000) Saw a slight reduction in soil pH while electrical conductivity of the soil decreased significantly with fly ash application. (Tiwari et al., 1992) Got a reduced pH from 10.0 to 8.5 after application of fly ash. The amelioration of soil pH by fly ash has had great results in vast types of soils including marginalized lands, mine spoils for agriculture and forestry. (Taylor and Schumann, 1988) Found that fly ash could act as a liming material and improving availability of plant nutrients. Use of FA instead of agricultural lime would benefit as a way of mitigating against global warming. All the CO_2 in Agric lime is released into the atmosphere which is contributing strongly to global warming (Basuet al., 2009). With more than 70 % of soils in countries like Zimbabwe being sandy and having a low pH (acidic) use of fly ash in amending them would be a dignified idea at the same time working against global warming by limiting CO_2emission, reclamation of these soils requires sustainable ways that will not create more problems than we already have. The effectiveness thereof of FA has to be evaluated in comparison to the already in use agriculture lime such that the lime can be substituted for FA.

On cation exchange capacity (CEC), (Nabantoglu, 2014) found that CEC of expansive soils decreased with increased fly ash content. (Tchuldjian et al., 1994) Confirmed the decrease in CEC after application of fly ash on sandy clay (SC) and low plasticity clay (CL) the decrease was significantly different from the lime application. These results are not desirable in crop production; there is expectation of an increase in CEC so that nutrients are not leached. It is also difficult to alter the CEC of a soil since this is a function of soil characteristics. (Pathan, Aylmore and Colmer, 2001) Found that Karrakatta sands in India had lower CEC than fly ash and upon application of fly ash it was expected that there be an increase in the CEC of the soil and increase in nutrient retention as well as cationic plant nutrients. There is still need for further investigation to establish how the fly ash influences that CEC of any soil type.

Effects of fly ash on water holding capacity (WHC)

Fly ash particles are silt sized in nature and that is a characteristic that allows it to be able to alter the soil silt content. Addition of FA was observed to increase micro porosity from 43 % to 53 % and water holding capacity improved from 39 % to 55 % of soils (Ghodratti, Sims and Vasilas, 1995; Singh and Siddiqui, 2003). (Khan and Khan, 1996) reported that a gradual increase of fly ash concentration in the field from 0, 10, 20, 100 % v/v, increased porosity and water holding capacity. (Pathan, Aylmore and Colmer, 2001) Observed significant increases in soil moisture content in situ in the top 10 cm after FA application. (Pathan, Aylmore and Colmer, 2001) Went on to discover that fly ash reduced infiltration rate owing to the high silt content it has, which translates to a need to have an optimum rate of fly ash application to avoid creating water logging conditions in the fields. (Taylor and Schumann, 1988) Also noted an increase in water holding capacity of sandy soils due to fly ash application. (Sakker and Rano, 2007) Tested different fly ash from different thermal power plants and discovered that particle size of fly ash had different effect on the soil water holding capacity where bigger particle sizes had highest holding capacity. The improvement in soil water holding capacity is beneficial to crop production under rain fed (Basu et al., 2009) especially in areas where the season is short with poorly distributed rainfall, use of fly ash may lengthen the growing season. With all these confirmed results of improved water holding capacity in sandy soils, FA use remains subdued in some cases in developing countries which continue to struggle with big marginalized lands.

Fly ash for improving soil structure

Changes in silt content of soil after application of fly ash is correlated to bulk density, porosity, hydraulic conductivity, void ratio and water holding capacity (Saraswat and Chaudrary, 2014). These directly impact on plant growth, nutrient retention and biological activities. (Buck, Honston and Beimbonn, 1990) Found that application rates of FA at 200 t/acre, improved physical and chemical characteristics of soil shifting the textural class from sandy loam to silt loam which contradicts with the known scientific notion that soil texture cannot be altered save for the soil structure. Application of 10 % fly ash amended to sand soil was ideal rooting media for *Leucaena leucacephala* (Pandey and Kumar, 2013). The hollow spheres of FA, replacing bigger soil particles, made it possible for the silt particles to accumulate in the voids and modified the soil structure from sandy loam to silt loam and the clay to loamy (Khan and Khan, 1996; Ram et al., 2006). (Yunusa et al., 2006) Observed that fly ash with high content of calcium and with appropriate particle size of 2–200μm improved the structural properties of soil; this confirms the known science that soil structure can be altered and not texture. (Gracia et al., 1995) Added a range of between 200 to 400 t/ha of fly ash to sandy loamy soils, there was a significant change in field water holding capacity, porosity, reduced bulk density which benefited crop production. There is need for scientists to agree as to what the FA does, as some are indicating that it alters the texture and some say structure. These findings to alter texture if confirmed will nullify the already held notion that soil texture is a function of the parent rock and that it cannot be changed.

Soil and Crop productivity

Soil productivity is the ability of a soil to support crop production determined by the entire spectrum of its physical, chemical and biological attributes. Soil fertility is only one aspect of soil productivity but it is a very important one. Soil fertility is the status or the inherent capacity of the soil to supply nutrients to plants in adequate amounts and in suitable proportions. Soil productivity is the capacity of the soil to produce crops with specific systems of management and is expressed in terms of yields. All productive soils are fertile, but all fertile soils need not be productive. It may be due to some problems like water logging, saline or alkaline condition, adverse climate etc. Under these conditions, crop growth is restricted though the soil has sufficient amounts of nutrients.

Crop productivity is the quantitative measure of crop yield in given measured area of field. The use of new crop varieties and the efficient application of agrochemicals, immensely contributed to increased plant productivity. Crop production is based largely on soils. Soils with a high clay or organic matter content tend to have a more stable soil structure than those containing mostly sand and or silt particles. Soil structure describes the arrangement of mineral particles and organic matter to form aggregates, as well as how pore spaces are arranged within and between aggregates. Soils with degraded structure can result in low crop yields and are difficult to manage due to a restricted range of soil wetness for tillage operations. A poor structure leads to problems with drainage due to the blocking of soil pores resulting in a decrease in the rate at which water can infiltrate the soil and drain through the soil. Soil structure affect soil fertility by affecting water movement through soil, root penetration and water logging. Erosion is an important physical process that decreases soil fertility. It is clear that under normal cases soil productivity and crop productivity are positively correlated, however whether such relationship exists after soil amendment with FA is still unclear.

Effect of FA on crop productivity

Fly ash is a potential soil conditioner that may increase the solubility and availability of plant nutrients therefore enhancing crop productivity in low fertility acid lateritic soils (Basu et al., 2009). (Singh and Siddiqui, 2003) Found that amending soil with fly ash at 40 % improved growth and yield of rice crop but there was a gradual decline in plant growth at 60 % to 100 % application rates. This adverse effect could be due to the higher levels of sulfate, chloride, carbonate and bicarbonate in fly ash amended soils. In a study with seven soils of varying texture with FA mixed at 0, 2, 4 and 8 % (w/w) levels, the moderate rates of 2 and 4 % (w/w) increase yield of rice dry matter where the 8 % (w/w) significantly depressed growth (Sikka, and Kansal, 1995). The application of fly ash increased N, S, Ca, Na and Fe but significant decreased P and Zn in rice grain (Sikka, and Kansal, 1995). (Patel, Singh and Tedia, 2018) Observed significantly high total tillers, effective tillers, panicle length and number of grains per panicle of rice when 75 % of an inorganic fertilizer GRD (100:60:40) + 20 t/ha fly ash and 5 t FYM were mixed with the soils. The same treatment combination gave significant higher paddy and straw yield. 40 and 60 t/ha fly ash gave similar result.

Application rates of 5, 10, 20 t/ha fly ash in combination with nitrogen rates of 25, 50, 100 kg/ha significantly increased grain and biomass yield of wheat (Aggarwal, Singh and Yadav, 2009). (Aggarwal, Singh and Yadav, 2009) Found that sorghum growth characteristics were influenced significantly in a treatment combination of 40 kg N/ ha and 20 t/ha fly ash. Harvest index of sorghum increased from 21.6 to 29 %. There was increased yield of sorghum with 20 t/ha fly ash application from 1.49 t/ha to 1.56 t/ha and interaction of fly ash and nitrogen at 20 t/ha and 40 kg N/ha respectively resulted to significantly highest yield of 1.87 t/ha (Aggarwal, Singh and Yadav, 2009). This implied that the 20 t/ha fly ash allowed significant changes on sorghum without deleterious effects on grain yield (Aggarwal, Singh and Yadav, 2009). (Mishra and Shukla, 1986) Found that foliar application of fly ash enhanced growth and metabolic rates and it increased photosynthetic pigments of maize and soybean. (Khan and Khan, 1996) Reported that application of 40 % of fly ash increased the yield of tomatoes by 81 %, while (Khan and Singh, 2001) noted that tomatoes grown on fly ash amended soils had higher tolerance to wilt fungus (Fusarium oxysporium) thereby increasing yields.

In various studies, Different crops were subjected to different rates of fly ash which ranged from 0 – 650 t/ha applied on to different types of soils (Arivazhagan et al., 2011). The crops included cereals, pulses, oil seeds, cotton, sugarcane, fodder crops, horticultural crops, ornamentals and medicinal plants. There was increased yield from 10 to 15 % on pulses, 20 to 25 % on oil seeds with other crops going up to 40 % (Kumar and Jha, 2014). Oil crops such as sunflower (*Helianthu* *s*sp), sesame (*Sesamum indicum*), turnip (*Brassica rapa*) and groundnuts (*Arachis hypogaea*) have had their performance improved after application of fly ash (Jala and Goyal, 2006; Thetwar, Sahu and Vaishnava, 2006; Inam, 2007; Basu et al., 2009; Sao, Gothalwal and Thetwari, 2007). (Thanunathan et al., 2001) Did an experiment studying the effect of fly ash on growth, yield and nutrient uptake of sesame. Fly ash was applied at 10, 20, 30 t/ha along with decomposed FYM of 12.5 t/ha and inorganic fertilizer of 35:23:23 kg/ha N.P.K. there was increase in growth characters (plant height, number of branches) and yield parameters (number of capsules, number of seed/ capsule, 1000 seed weight), grain yield and NPK uptake of sesame. This happened with maximum application of fly ash at 30 t/ ha. (Kuchanwar, Matte and Kene, 1997) applied 10 t/ha fly ash and 25:50:0 kg NPK/ ha and this combination gave better growth and yield attributes which led to the highest pod yield in groundnuts. (Arivazhagan et al., 2011) Revealed an increase in yield of various crops grown after application of fly ash at a rate of 50 MT/ ha (Table 2).

Table 2: Yield increases of different crops after 50 MT/ha fly ash application

Crop	Yield increases
Rice grown on normal soils	4920 – 5625 kg/ha
Rice grown on alkali soils	2000 – 3550 kg/ha
Wheat	2400 – 3840 kg/ha
Banana	20 – 30 %
Tomato	15 – 20 %
Potato	92.50 – 122.50 q/ ha

Source: (Arivazhagan et al., 2011)

Influence of FA on soil productivity

(Patil et al., 1996) Observed that as levels of fly ash and FYM increased, there was a corresponding increase in the uptake of N P K. Nutrient uptake of groundnuts increased with application of fly ash. The interaction effect of fly ash and fertilizer was significant with highest uptake of N. P. K and Ca, Mg, S with 15 t/ha fly ash and 100 % recommended dose of fertilizer. This was attributed to presence of these nutrients in considerable quantities in fly ash (Sireesha and Prasuna Rani, 2014). Increase in N uptake by the addition of fly ash was facilitated by presents of Ca, Mg, S, B and Mo which enhance N_2 fixation which in turn facilitated more N uptake by the crop. (Selvakumari et al., 1999) Revealed that there is a possibility of decreasing recommended rate of P and K by about 25 % when fly ash and compost were added to groundnuts. In rice production an integrated application of fly ash, inorganic fertilizer and organic fertilizer increased uptake of N. P.K (Selvakumari et al., 1999). (Shinde, Koohan and Patil, 1995) Got results that revealed that application of fly ash increased the uptake of N, K, Ca and Mg by groundnuts crop. There is increased uptake of P with application of fly ash due to increase in pre release via bio activity to soil and plants benefit (Sireesha, and Prasuna Rani, 2014). Graded dose of fly ash increased significantly uptake of N by grain and straw in rice. Total N and organic carbon of fly ash are 0.08 and 0.01 % respectively. The N in fly ash is low but fly ash enhances microbial activity, by providing all the nutrients from it and thus mobilizing the available N (Nayak et al., 2015). (Baskar and Selvakumari, 2005) Found that there was P and K uptake in rice which might have been contributed from the fly ash itself. The P uptake of grain was from 2.3 to 4.3 kg/ha, K was from 1.71 to 3.51 kg/ ha. Fly ash applied at 20 and 40 t/ha registered an increase of Si uptake 11 and 26 kg/ha by grain and 28 and 61 kg/ha by straw respectively over the control (Baskar and Selvakumari, 2005). (Ramesh and Chhonkar, 2001) Confirmed the increase in nutrient uptake by rice due to fly ash application. (Das, Choudhury and Das, 2013) Observed that interaction of farm yard manure (FYM), inorganic fertilizer and fly ash gave statistically significant uptake of available nutrients in rice. The highest uptake of N. P.K and Fe, Mn, Zn, Cu was 119.22, 73.84, and 209.69 kg/ha and 3574.9, 1354.3, 180.2 and 104.9 g/ha respectively at treatment 50 % RDF (inorganic fertilizer) + FYM 5 t/ha and FA 15 t/ha. The lowest uptake was from the control being 49.01, 27.83 and 53.87 kg/ha and 546.0, 397.3, 53.1 and 23.1 g/ha.

Conclusion and recommendations

The fly ash can be used to reclaim problems of low water holding capacity, pH, CEC in Aerosols hence increasing crop productivity. However, the application of FA in agricultural soils is still limited due to its uncertainty effects on the soil properties and crop growth performances. The soil nutritional content in the FA has to be quantified before recommending specific application rates but most FAs have not been characterized to date. Current literature has showed that the application rates of FA varied from region to region and is influenced by the soil types hence cannot be generalized. Therefore, researches on use of FA should aim at their characterization by quantifying the plant nutrients available, possible negative effects of FA on the soil and determining appropriate application quantities in different soil types that enhances crop productivity.

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