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Prospects of Fly Ash Application in Agriculture: A Global Review

Harender Singh Dahiya* and Yogendra Kumar Budania

State Agriculture Department, Government of Haryana, India

**Corresponding author*

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A B S T R A C T

Among the various non-renewable resources, coal is one of the important and is considered as the core raw material for generation of energy and plays a key role in meeting the over increasing fossil fuels demands in India and across the world. However, advances in technological sector are leading to exert a great pressure on our valued natural resources such coal etc. Though in preceding few decades various alternate energy sources have come into the limelight, the use of coal as primary source of energy cannot be counter balanced. Despite of the increased efforts to prevent, reduce, reuse and recycle, the appropriate management of fly ash remains a major issue and it is hard truth that to meet the growing energy demand will continue to create various problems that may be environmental, economic and social. These problems are associated with generation of large amount of fly ash and therefore, lack of its judicious use and proper disposal is in question. It has been proved to be a useful supplement for agricultural application in addition to use in cement, bricks and blocks, road embankments, low lying area filling, mine applications, etc. Fly ash, being a good soil ameliorant and source of major and plant nutrients can significantly improve the physio-chemical properties. Incorporation of fly ash in agricultural soils is best alternate use or way to dispose it and studies around the world confirmed that fly ash application in agricultural soils have shown promising results with respect to crop production due its high mineral contents and unique physicochemical properties. This paper explores the possibilities of using fly ash in agriculture while providing safe environment by its safe consumption in agriculture.

Introduction

India has one of the largest reserves of coal in the world. Out of many byproducts of coal combustion, fly ash is one of the major by product which can be utilized potentially in agriculture. Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from combustion of coal at a temperature of 400-1500 ^{0}C. Fly ash is composed predominantly of small, glassy, hollow particles with low to medium bulk density ranging from 2.1 to 2.6 g cm^{-3} (Adriano *et al.*, 1980) with an average diameter of <10 µm, high surface area and light texture which are aggregated into micron and sub-micron spherical particles of sizes ranging from 0.01 to 100 mm (Davison *et al.*, 1974), with smaller particles entrapped within large spheres (Fischer *et al.*, 1976). At present scenario, around 200 million-tons of fly-ash is produced which is nearly twice over the last decade and the quality of ash varies from plant to plant and from coke to coke depending on source of supply and type combustion. In India about 80% power is produced by pulverized coal fired boilers (Fly Ash-Wikipedia, 2011) and thermal power plants are utilizing bituminous and sub-bituminous high ash containing (30–50%) coal, in addition to several captive power plants, contributes to indiscriminate disposal of this industrial waste every year (Jamwal, 2003; Garg *et al.*, 2005). In India, flyash utilization has increased from 3% in the 1990s [5] to 38% in 2005 [3].

The reason of low fly-ash utilization in India is the unavailability of appropriate cost-effective technologies. Many research experiments and studies all around the world is going on to study the effect and potential of fly-ash as an amendment in agricultural or other applications by various agencies, research institutes. Here in this paper we focused on utilization of fly-ash as a value-added product of agriculture and reducing the environmental and economic impacts of disposal.

Types of fly ash

The quality of coal depends upon its rank and grade. The coal rank arranged in an ascending order of carbon contents is: Peat << Lignite << sub-bituminous coal << bituminous coal << anthracite.

Indian coal is of mostly sub bituminous rank followed by bituminous and lignite (brown coal). The ash content in Indian coal ranges from 35 % to 50 % and the methods of fly ash transfer i.e. dry, wet and/or both are presented in figure 1.

There are generally three categories of coal ashes available from thermal power stations and are mentioned below:

Dry fly ash

Collected from different rows of electrostatic precipitator in dry form.

The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine grained,

Powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag-houses, or mechanical collection devices such as cyclones.

Bottom ash

Collected at the bottom of the boiler furnace and is characterized by better geotechnical properties.

Pond ash

Fly ash and bottom ashes are mixed together with water to form slurry which is pumped to the ash pond area. In the ash pond the, ash gets settled and excess water is decanted. This deposited ash is pond ash.

Characterization of fly ash

According to IS 3812-1981, there are two grades of Fly Ash

Grade I fly ash, which are derived from bituminous coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 70 %.

Grade II Fly ash, which are derived from lignite coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 50 %.

ASTM C618 specified two categories of fly ash, Class C and Class F depending on the type of coal and the resultant chemical analysis.

Class F fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime-mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to a Class F ash can form a geopolymer.

Class C fly ash

Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

Properties of flyash

Physical, chemical and other properties of fly ash play an important role in imparting it the pozzolanic reactivity and in its interaction with cement mortar and concrete. Ninety-five percent of the inorganic matter contained in coal is made up of clay or shale, pyrite and calcite minerals. Lignite coals contain the most calcite and bituminous the least. Sub-bituminous coals fall in between. The alkalies and trace minerals account for the rest of the minerals. Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from the combustion of ground or powdered coal at 400-1500 °C (Mattigod *et al.,* 1990). Physically, fly ash occurs as very fine particles having an average diameter of <10 µm and has low to medium bulk density, high surface area and light texture. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm. Most of the fly ash particles are glassy or amorphous. Yet, quartz, mullite, magnetite and calcium compounds including calcium sulfate may be present as crystalline compounds constituting about 15 per cent by weight of the fly ash.

Some of the important properties of fly ash are discussed below

Fineness of fly ash is most closely related to the operating condition of the coal crushers and the grindability of the coal itself. For fly ash use in concrete applications, fineness is defined as the percent by weight of the material retained on the 0.044 mm (No. 325) sieve. A coarser gradation can result in a less reactive ash and could contain higher carbon contents. Limits on fineness are addressed by ASTM and state transportation department specifications. Fly ash can be processed by screening or air classification to improve its fineness and reactivity (Anonymous, 2003). Fly ash particles of very small size are mostly made up of clear glass spheres. Spongy particles formed either by fusion of many fine particles or from ore minerallic particles are also common in most fly ashes. The particles in bituminous ash range from less than 1 pm to over 100 pm but average particle size in such ashes may vary from 7 pm to 12pm. The majorities of particles are finer than the average size and contribute to the high specific surface area as determined by Blaine air permeability method or by single point B.E.T. nitrogen sorption method. The surface area of the fly ash particles has been reported to vary from about 2000 cm*/g to over 10,000 cm*/g depending on the proportion of fine particles in the fly ash. The values of specific surface area are reported to range from 1800 to 5900 cm*/g. Murugan and Murugaiyan (2013) reported that fly ash is generally of silt loam texture with the particles diameter of less than 0.010 mm and had fly ashes have the pH value of 6-11, electrical conductivity (EC) 42-450 µS/cm. Most of the fly ash has the bulk density (BD) values less than 1 g/cm3 and water holding capacity 43-66% while Mishra and Shukla (1986) observed that the major portion of fly ash (60%) consisted of silt sized fraction (0.02 to 0.002 mm), whereas sand size particles (2 to 0.02 mm) represented 25% and clay size particles (below 0.002 mm) 10% of the fly ash weight. The bulk density of fly ash was 1.02 g cm^{-3}. Fly ash can be tan to dark gray, depending on its chemical and mineral constituents. Tan and light colors are typically associated with high lime content. A brownish color is typically associated with the iron content. A dark gray to black color is typically attributed to elevated unburned carbon content (Pandey and Singh, 2010). Fly ash color is usually very consistent for each power plant and coal source. Specific gravity is one of the important physical properties needed for the use of coal ashes for geotechnical and other applications. In general, the specific gravity of coal ashes varies around 2.0 but can vary to a large extent (1.6 to 3.1). Specific gravity is frequently required for finding out the degree of saturation, void ratio, unit weight of soil solids or moist soils. The unit weights "in turn are needed in pressure, settlement and stability problems in soil or geotechnical engineering. Therefore specific gravity is a very important physical-property of fly ash as a geo-material. In general, fly ash is characterised by low specific gravity. One explanation for this lower specific gravity is the feet that a high proportion of fly ash particles are cenospheres or hollow particles (Nyambura *et al.,* 2011). The specific gravity of minerallic fly ash particles is found to vary from less than 1 for hollow spherical particles called cenospheres to about 4.8 for spherical and rounded light brown to black particles that contain 50 to 95 percent of the total iron present in fly ash. Irregularly shaped black particles of unburned coal have a specific gravity of about 1.3. Specific gravity of fly ash depends on carbon and iron oxides contents. He found that a small increase in carbon content o f a fly ash results in a significant drop in specific gravity (Adriano *et al.,* 1980). Variation of specific gravity of coal ash is due to the combination of many factors such as gradation, particle shape and chemical composition, ashes with high iron contents have high specific gravity values (Pandian *et al.,* 1998). Thus, specific gravity of fly ash particles varies significantly depending upon the proportion of cenospheres, iron rich magnetite and unburned carbon particles. Grain size distribution indicates if a material is well graded, poorly graded, fine or coarse, etc. and also helps in classifying the coal ashes. Coal ashes are predominantly silt sized with some sand-size fraction.

Chemical composition suggests the possible applications for coal ash. The investigations carried out on Indian fly ashes show that all the fly ashes contain silica, alumina, iron oxide and calcium oxide. The silica content in fly ashes is between 38 and 63%, 37 and 75% in pond ashes, and 27 and 73% in bottom ashes. The alumina content ranged between 27 and 44% for fly ashes, 11 and 53% for pond ashes and 13 and 27% for bottom ashes. The calcium oxide is in the range of 0 to 8% for fly ashes, 0.2 to 0.6% for pond ashes and 0 to 0.8% for bottom ashes (Plank and Martens, 1974). There are mainly two types of ash, i.e: Class F (low lime) and Class C (high lime) based on total amounts of silica, alumina and iron oxide. Al in fly ash is mostly bound in insoluble aluminosilicate structures, which considerably limits its biological toxicity (Page *et al.,* 1979). It is substantially rich in trace elements like lanthanum, terbium, mercury, cobalt and chromium (Adriano *et al.,* 1980). Many trace elements in fly ash like As, B, Ca, Mo, S, Se and Sr are concentrated in the smaller ash particles (Page *et al.,* 1979). The authors opined that oxidation of C and N during combustion drastically reduces their quantities in ash. The pH of fly ash varies from 4.5-12.0 depending largely on the sulphur content of the parent coal and the type of coal used for combustion affects the sulphur content of fly ash (Page *et al.,* 1979). The solubility of fly ash depends directly on the physicochemical disintegration of the particles, for example indicating that a major portion of total K is localized in the interior glassy matrix while the external glass is enriched with Mg. When the solubility of alkaline fly ash was studied by selective dissolution in mineral acids, it was found that significant quantity of K occurred in the highly refractory magnetic Fe fraction and that the solubility of Mg in acids was much higher (Green and Manahan, 1978).

Fly ash and Agriculture

Effect of fly ash on physico-chemical properties of soil

Fly ash has immense potential as a soil-ameliorating agent in agriculture, forestry and wasteland reclamation because of its heterogenous nature. Previous work (Reynolds *et al.,* 1999) to determine the feasibility of converting waste disposal problem into a soil benefaction strategy has proven true. Fly ash has been studied as a useful soil-amending agent with agronomic and environmental benefits (Zhang *et al.,* 2004). Studies have been carried out to report the efficacy of fluidized bed combustion (FBC) and flue gas desulfurization (FGD) byproducts, when amended with dairy, swine and broiler litter manures, in reducing phosphorus (P) solubility and potential impact on water quality (Zhang *et al.,* 2004). A number of studies have shown that addition of alkaline ash can increase the pH of acidic soils (Plank *et al.,* 1975). Fly ash has been observed to have a positive effect on water holding capacity, hydraulic conductivity and pH apart from acting as source of nutrients and addition of unweathered fly ash up to 8% to calcareous or acidic soils resulted in higher crop yield due to increased availability of S from fly ash (Page *et al.,* 1979). Fly ash applied on acidic strip mine spoils at different places increased the yield of many crops which was attributed to increased availability of Al^{3+} and Mn^{2+} and other metallic ions at the resultant higher pH (Fail and Wochok, 1977). West and McBride (2005) observed that the available water capacity of the sand was increased by the addition of 30 per cent fly ash. They also found that although 100 per cent ash had the greatest available water holding capacity, yields on these treatments were not the highest because of limited aeration and the change in water content from 10 Kpa to near saturation.

Craini (1988) observed no significant effect on mechanical composition of soil, mean weight diameter, water holding capacity, pH, EC, CEC and available nutrients (N, P, K, Ca, Mg, S, Zn, Fe, Mn, Cu and B) but addition of fly ash to clay soils significantly reduced the bulk density of a clay soil and resulted in increased porosity and void ratio. Fly ash addition significantly reduced water holding capacity, bulk density, organic carbon, free $CaCO_3$, CEC and increased the content of sand which improved the soil texture (Kene *et al.,* 1991) while Maiti *et al.,* (1990) found that application of fly ash to light textured soil improved the soil texture, thereby increased their water holding capacity. Matte *et al.,* (1996) concluded from their study that fly ash alone or in combination with recommended dose of fertilizer had significant effect on water holding capacity and bulk density. Addition of 10 % of fly ash increased the available water capacity by 7.2 for the fine and 13.5 for coarse sand, respectively. Gourab and Joy (2011) reported that pH, EC, PO_4, Ca and Na of soil increased with fly ash dose and time, but OC, NO_3 and K decreased with increasing doses of fly ash. Application of fly ash significantly altered physic-chemical properties of soil which includes soil texture, decrease bulk density, increase water holding capacity, soil porosity, pH, electrical conductivity and organic carbon values of the soil.

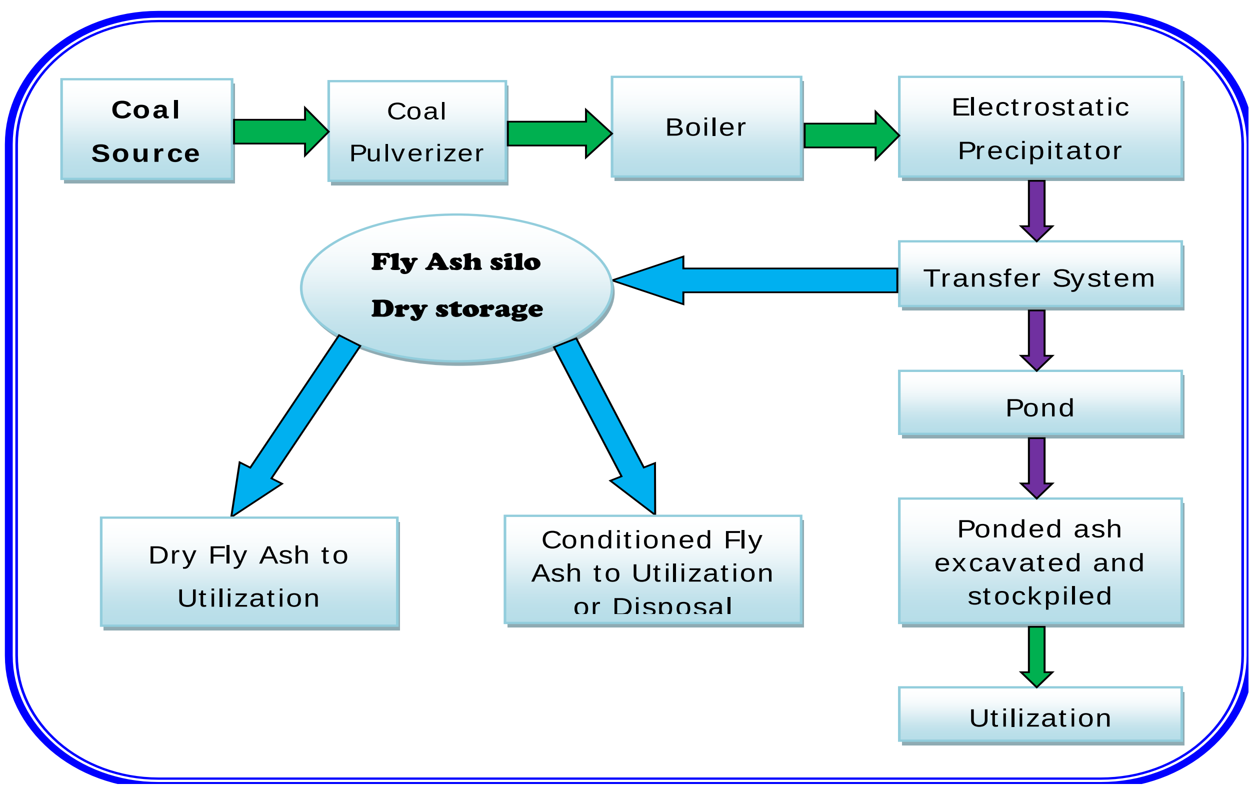
A marginal increase was also observed in the concentration of P, K, S, Fe, Zn, Mn, B, Ca and Mg elements in the fly ash amended soil (Khajanchi *et al.,* 2012). Singh *et al.,* (2011) studied that effect of different doses of fly ash and FYM on the nitrogen dynamics and paddy productivity. Fly ash and FYM treated plots had significantly higher organic carbon content, total N, total P, water holding capacity but lower bulk density as compared to control and positive relationship exist between gravimetric soil moisture content an N-mineralization and infiltration rate.

Reddy *et al.,* (2010) studied the effect of varying level of fly ash and FYM on physico-chemical properties and yield of rice grown on Inceptisol. Application of fly ash @ 15 t ha^{-1} + FYM 10 t ha^{-1} recorded the highest available N, P, K, S, Fe and Zn content of soil. The available Mn content was highest in FA10 FYM10 (6.69 mg kg^{-1}) and available Cu content was not influenced by fly ash levels; however, it was significantly higher in FYM treated plots. Saini *et al.,* (2010) reported impact of fly ash and FYM incorporation in soil on yield and nutrient availability to rice. The effect of fly ash on concentration of macro and micronutrients in rice showed considerable increase when grown in fly ash incorporated soil with and without FYM application. The uptake of macro and micronutrient by rice grain also increased correspondingly with increasing level of fly ash application.

Shenggao and Lei (2004) studied that effect of fly ash on physical properties of Ultisols. 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. Fly ash application not only increased water content but also increased plant available water. Sharma *et al.,* (2002) evaluated fly ash addition effect on soil environment and yield of wheat crop. Fly ash application levels were up to 50t/ha. Application of fly ash@10 t/ha in soil showed reduced hydraulic conductivity and improved moisture retention at field capacity and permanent wilting point. The pH value of soil decreased, whereas electrical conductivity, organic carbon and sodium increased in accordance with fly ash addition in soil. Deshmukh *et al.,* (2000) reported that increasing addition of fly ash decreased bulk density and maximum water holding capacity of soil, while no marked effects on pH, EC, cation exchange capacity and lime content was observed. The available NPK and Cu, Fe, Zn, and Mn and exchangeable Ca and Mg increased with fly ash application.

Incorporation of 'slash' in soil had positive effect on soil pH and Ca, Mg and P content and reduction in the translocation of Ni and Cd (Rethman *et al.,* 2001) and enhanced growth of corn, potatoes and beans in pot trials. The mine spoils could be revegetated by enhancing the activities of various enzymes such as dehydrogenase, phosphatase and nitrogenase upon inoculation with arbuscular mycorrhizal fungi *Glomus mosseae* (Rao and Tak, 2001). Very little is known regarding the effect of fly ash amendment on soil biological properties (Schutter and Fuhrmann, 2001). Fly ash was mixed with organic matter in the form of cow dung at 1:3, 1:1 and 3:1 ratio and incubated with and without epigeic earthworm (*Eisenia fetida*) for 50 days which resulted in a significant increase in the population of phosphate-solubilizing bacteria and increased bioavailability of phosphorus and nutrients by vermicomposting (Bhattacharya and Chattopadhyay, 2002). Application of fly ash at 40 t/ ha in conjunction with phosphate solubilizer, *Pseudomonas striata* improved the bean yield and phosphorus uptake by grain and fly ash did not exert any detrimental effect on the population of *P. striata* in soil (Gaind and Gaur, 2002). Amendment of Class F bituminous fly ash to soil at a rate of 505 Mg/ha did not show any detrimental effect on soil microbial communities. Analysis of community fatty acids indicated elevated populations of fungi, including arbuscular mycorrhizal fungi and Gram-negative bacteria (Schutter and Fuhrmann, 2001). Thus a clear cut beneficial effect of fly ash application on improvement of soil health in respect of physico-chemical parameters was observed from above cited references.

Fig.1 Methods of fly ash transfer- dry, wet and/or both



Effect of fly ash on production of agricultural crops

Agricultural utilization of fly ash has been proposed because of its considerable content of K, Ca, Mg, S and P (Singh *et al.*, 1997). Fly ash is the inorganic solid component of the residue from the combustion of fuels and can be used in agriculture as a soil amendment or fertilizer and its addition generally results in consistently favourable impact on plant growth and nutrient uptake

(Aitken *et al.,* 1984). Adriano *et al.,* (1978) observed that application of 5, 10, 15 and 20 per cent fly ash by weight resulted in P deficiency symptoms in corn, while symptoms characteristic of 'B' toxicity occurred in beans. Analysis of tissues of both crops indicated that 'P' concentrations were at deficient levels, while Cu, Mn and Zn were deficient to marginal, Fe however, appeared to be in the normal range.

Furr *et al.,* (1979) observed that selenium concentration in the plant tissues consistently increased with fly ash treatment. This increase was shown to be roughly proportional to either rates of fly ash application or selenium content of fly ash. Application of 20 per cent fly ash significantly increased the content of N, P, K at all the growth stages of rice plant. Uptake of these nutrients by grain and straw also increased in plants grown with 20 per cent fly ash treatment. On the other hand application of fly ash at 30 per cent level decreased the content and uptake of these nutrients (Singh and Singh, 1986). Hussain (1993) observed that the uptake of N, P and K by groundnut crop increased significantly due to application of amendment of fly ash at different levels. Similar trends in the uptake of Zn, Fe and Mn by groundnut crop were observed. The increased uptake of nutrients by the crop was mainly due to increase in the availability of these nutrient elements in soil consequent to the application of amendments and fly ash levels. Mattee and Thakare (1994) recorded higher N and P uptake in groundnut where fly ash was applied @ 10 t/ha. Selvakumari *et al.,* (2000) conducted field experiment to study the effect of integration of fly ash with fertilizer and organic manures on yield and nutrient uptake of rice in Alfisols. The highest yield (69.00 q/ha) was recorded when fly ash applied was @ 40 t/ha in combination with fertilizer, compost and Azospirillum. Moreover, Rungsun *et al.,* (2004) also concluded that the application of coal ash mixture, either fly ash or clinker ash at 18.75-25 t/ha was the most effective in terms of plant yield. The use of coal ash mixture increased cation exchange capacity, base saturation percentage and Ca, Mg and S contents in the soil as well as plant uptake of nitrogen. The yield of wheat increased for 20t/ha fly ash while paddy and mustard were observed to survive well in soil amended with 10t/ha of fly ash, all three crop plants showed improved growth over control (Kalra *et al.,* 2003). The availability of B in fly ash to alfalfa was shown by Plank and Martens (1974) to be essentially equal to that of sodium borate-B. Application of 5-20 % fly ash on w/w basis in the plough layer (0-15 cm) increased both grain and straw yield of pearlmillet (*Sorghum vulgare*) followed by wheat (Grewal *et al.,* 2001).

Nilesh *et al.,* (2012) reported that the application of fly ash enhances the seed germination rate considerably, whereas in the absence of fly ash (control) rate of seed germination was very slow. The use of fly ash as an admixture in agriculture up to 60% for the wheat (*Triticum aestivum*), 10-20% for mung bean (*Vigna radiata*), and 20% for urad beans (*Vigna mungo*) is suitable for maximum growth and yield. Cd, Cu, Fe, Mn, Mg Ni, Pb, and Zn were accumulated in the plants under study, but at very low concentrations and below the permissible limits pro-vided for human consumption. Alkaline fly ash with pH higher than 8 from Illinois has been reported to be beneficial for growth of turfgrass (*Cynodon dactylon*) and (*Lycopersicon esculentum*) at 12.5% with the nutrient content within permissible limits in soil and plants (Chou *et al.,* 2005). Yeledhalli *et al.,* (2008) reported that ash application @ 30-40 t/ha (one time and repeat application) with recommended dose of NPK fertilizers alone or along with FYM @ 20 t/ha was used and the total yield of 35.7 q/ha was recorded in treatment receiving pond ash @ 40 t/ha along with FYM @ 20 t/ha followed by fly ash @ 30 t/ha.

Aggarwal *et al.,* (2009), worked on utilization of fly ash for crop production and effect on the growth of wheat and sorghum crops and soil properties. Soils from both experimental sites and fly ash used in the study were analysed for their physical and chemical characteristics. Surface soil samples (0-30 cm) of each location were collected, analysed and averaged for sites' characterization. Wheat cultivar, HD- 2285 was tested for four levels of fly ash, i.e., 0, 5, 10 and 20 t/ha and four levels of N, i.e., 0, 25, 50 and 100 kg/ha at Muthiani village. Grain and biomass yields increased continuously with combined application of fly ash and nitrogen levels and were 11.8 percent and 14.3 percent higher with 20 t/ha fly ash and 100 kg/ ha N level over control with its values of 2.85 t/ha and 9.70 t/ha, respectively. Growth characteristics of sorghum were influenced significantly by increasing levels of fly ash and nitrogen. Highest average plant heights of 162 cm were recorded with 40 kg N + 20 t/ ha fly ash. Test weight of grain was also increased significantly with increasing levels of fly ash. N and fly ash levels also increased the harvest index of sorghum ranging from 21.6 to 29.0 percent with mean value of 24.95 percent.

Lee *et al.,* (2008) applied fly ash at 0, 40, 80, and 120 Mg ha^{-1} in paddy soil to determine boron (B) uptake by rice and characteristics of accumulation in the soil. Results indicated that in all fly ash treatments, B content in rice leaves and available B in soil at all growing stages were higher than those of control but all were below toxicity levels. Boron occluded in amorphous iron and aluminium oxides was 20–39% of total B and was not influenced by fly ash application. Most of the B accumulated by fly ash application was residual B which is of plant unavailable form and comprised >60% of the total B in soil.

Srivastava and Kumar (2014) carried out to study the effect of different fly ash amendment levels on growth of green manure crop *Sesbania cannabina* (Dhaincha). Fly ash used in present study was obtained from IFFCO (Indian Farmers fertilizers Cooperative Limited), Phulpur. Fly ash was mixed with garden soil of Botany Department of University of Allahabad, in four different concentrations of fly ash i.e. 0% (control/garden soil), 25%, 50%, 75% and 100%. A portion of the soil-fly ash mixtures was separated for physio-chemical properties. Pre-soaked seeds of *Sesbania cannabina* were sown in their respective pots. Data for germination and survival percentages were taken after 15 and 30 days of sowing, respectively. Data for morphological parameters were taken after 45 days of sowing. Some morphological data were taken after maturity of plants. The control set of garden soil and 25% fly ash exhibited 100% germination and 100% survival. In case of 50% fly ash amended soil germination was 100% while survival was 93.33%. The overall estimation of germination percentages illustrated that it was not much affected by fly ash amendment while survival was greatly affected in case of 100% fly ash. The plants sown in 100% fly ash survived only about 2 months and were with very significantly reduced biomass. The result of present study indicates that the four different amendments tested the amendment level up to 75%, showed no adverse effect on *Sesbania* pea plant growth and this plant could be used in reclamation of fly ash deposited sites.

Srivastava *et al.,* (2016) reported that fly ash acts as an excellent soil modifier, conditioner and a source of essential nutrients for appreciably improving the texture and fertility with significant increase in crop yield over the control at a particular concentration only and is supportive to plant growth. Moreover, Sahu *et al.,* (2017) also concluded that fly-ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance. The high concentration of elements (K, Na, Zn, Ca, Mg and Fe) in fly-ash increases the yield of many agricultural crops. But the use of fly-ash in agriculture is limited compare to other sector.

The beneficial effect of fly ash on improvement of soil health in respect of physico-chemical parameters, nutritional status and thereby increasing plant productivity may be due to the cumulative effect of improvement in individual physico-chemical characteristics. Further, utilization of fly ash in agriculture may provide a feasible alternative for its safe disposal without serious deleterious effects. However, FA varied widely in its physical and chemical composition, therefore, the mode of use in agriculture is different and depends on the characteristics of soil or soil type. An ultimate goal would be to utilize fly ash in soils to such an extent so as to achieve enhanced fertility and increased crop productivity. Further, there is need to investigate the fate of trace/heavy metals in soil-water-plant system with fly ash applications.

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