

**EFFECT OF FLY ASH ON PHYSICO-CHEMICAL PROPERTIES OF
SOIL**

by

Mr. Khelbade Bharat Manikrao
(Reg. No. 016/083)

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MAHATMA PHULE KRISHI VIDYAPEETH
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Approved by

Dr. N. J. Ranshur
(Chairman and Research Guide)

Dr. B. D. Bhakare
(Committee Member)

Dr. R. B. Nazirkar
(Committee Member)

Dr. C. A. Nimbalkar
(Committee Member)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
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1. INTRODUCTION

Fly ash is a coal combustion residue of thermal power plants. It has been regarded as one of the problematic solid waste all over the world. Every year Indian thermal power plants generates more than 100 million tones of fly ash, which is expected to reach 175 million tones in near future. Every year 112 million tons per year of fly ash is produced and only 38 per cent utilized. As per the estimates, fly ash generation is expected to increase to about 225 million tons per year by 2017 (Dhadse *et al.*, 2008). It is estimated that 2 tones of fly ash is produced every minute at a modern 200 MW capacity generating unit.

The disposal of fly ash is a major problem all over the world due to limited use and possible toxic outcomes. In the absence of utilization of the byproduct of thermal plant, it has been getting accumulated and for storing large area of arable land will be required in future. So finding immediate use of fly ash for different purposes is very important, therefore attempt has been made to assess use of this ash in agriculture. Fly ash being an inert material containing mineral nutrients attracted the agriculture scientists for its utilization to improve crop and soil productivity. Initially, it was regarded as problematic solid waste all over the world but with time many beneficial applications of fly ash are being evaluated to minimize waste, decrease cost of disposal and provide value-added products. Fly ash addition alters the physical properties of soil such as texture, bulk density, water holding capacity and particle size distribution considered as useful ameliorant which improve physical, biological and chemical properties of problematic soils and enhance the available macro and micro nutrients for plants (Jala and Goyal, 2006). Since fly ash increase the nutrient content of the soil which is beneficial for the plant growth. It also increases the availability of certain micro-elements which is required in trace amount for the plant.

The disposal of fly ash by conventional methods leads to degradation of arable land and contamination of groundwater. Therefore development of proper technologies for disposal of this solid waste in an eco-friendly manner becomes essential to derive maximum benefit from its heterogeneous nature, since it is a storehouse of readily available plant macro and micronutrients. In conjunction with organic manure,

microbial inoculants or fertilizers with fly ash can be used to design a soil benefaction strategy, which can help in improving soil properties and enriching its nutrient status. The presence of almost all essential plant nutrients in ionic form and the ameliorating effect on the physical, chemical and microbial nature of soil makes fly ash an important input for biomass production, especially on variously degraded soils and wastelands.

The use of fly ash in agriculture provides a feasible alternative for its safe disposal to improve the soil environment and enhance the crop productivity. It has a great potentiality in agriculture due to its efficacy in modification of soil health and performance. Bakri *et al.* (2012) observed that in fly ash contains about 0.85 per cent K_2O . Arivazhagan *et al.* (2011) studied the effect of coal fly ash on agricultural crops. They stated that use of coal fly ash in agriculture is one way of disposal of fly ash and at the same time it improves the yield of variety of agricultural crops and physico-chemical properties of soil, they revealed that application of coal ash increase the yield of cereal crops to 15-20 per cent, sugarcane to 20-30 per cent, maize to 40 per cent, red gram to 50 per cent, potato to 25 per cent, plantation crops to 30 per cent, mustard and vegetable to 10 per cent. Besides increasing the yields of crops it also improved nutrient uptake in plants and physical and chemical properties of soil especially water holding capacity and fertility status of soil. They also revealed that the application of fly ash @ 50 t ha⁻¹ have increased the yield of wheat by 5-10 per cent.

In India and most country major source of electrical energy is coal based thermal power plants, which produce 175 million tones, which would require about 40,000 hectares of land for the construction of ash ponds (Lal *et al.*, 2012). The ash production in India is expected to reach about 225 million tones per annum by 2017. The Ministry of Power and Planning Commission estimates that the coal requirement and generation of fly ash during the year 2031-32 would be around 1800 million tones and 600 million tones respectively (Kanungo, 2013). The fly ash utilization in the country is estimated to be about 59 per cent only (Kanungo, 2013).

Fly ash an amorphous ferro-alumino silicate, physically fly ash occurs as fine particles (60-70 %) which has a size below 0.075 mm is a by-product of pulverized coal fired thermal power station and has low to medium bulk density, high surface area and very light texture with pH varying from 4.5 to 12 depending upon S content in the

coal (Lal *et al.*, 2012). Being a vegetative fossil fly ash consist of mineral matter which plant have up taken from the soil. It can act as a secondary source of fertilizer nutrients like P ,K, Ca, Mg, S, Cu, Fe, Zn, Mn, Mo etc. (Totawat *et al.*, 2002).

Lack of satisfactory disposal it creates a problem leading to environmental degradation. It is produced in huge amount and its problem of disposal can be well appreciated from the fact that for dumping one tones of fly ash about 0.35-3 m of space is required, finding an immediate use of fly ash for some fruitful purposes is an important proposition otherwise may lead to environmental degradation in time to come (Totawat *et al.*, 2002).

Application of fly ash increased the yield in various crops with improvement in the soil physical, chemical and biological properties and observed beneficial for soil and crop (Kohli *et al.*, 2010).

The other uses of fly ash i.e. brick making, road construction, cement industry are very limited, posing a problem of its disposal (Totawat *et al.*, 2002).

The presence of several natural elements in fly ash reflected on number of important physico-chemical properties of soil from the point of view of crop production. It can be possibly used as an amendment for clay soil, therefore important to evaluate the effect of fly ash on physical properties of soil by using column study experiment. Utilization of fly ash in agriculture would open a new avenues to improves soil productivity debarring the environmental from its degradation. Keeping in view the above facts, it is needed to carry out an investigation entitled “Effect of Fly Ash on Physico-Chemical Properties of Soil” with following objectives:

- i. To study the effect of fly ash on physical properties of soil.
- ii. To assess the effect of fly ash on chemical properties of soil.
- iii. To find out effect of fly ash on soil leachates composition.

2. REVIEW OF LITERATURE

The review pertaining to fly ash and its effect on physical, chemical and leacheate properties of soil are reviewed under different subheads.

2.1 Characterization of fly ash.

2.2 Effect of fly ash on physico-chemical properties of the soil.

Fly ash is the waste product of burning of coal in power plants and other industries. Formation of ash is the natural outcome of the combustion of coal in the furnace of the boiler at temperatures in the range of 1300-1450°C in presence of nearly 20 per cent excess air. The present investigation was under taken to study the effect of fly ash on physico-chemical properties of soil. There were several reports published on this research work. Keeping in view, efforts were being made to present the pertinent literature on the various aspects of present investigation as follow.

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. Fine minute particles of ash are carried away with flue gases in electrostatic precipitators or cyclone separators and are collected by wet (slurry form) or dry scrubbing method, which has some physico-chemical properties.

2.1 Characterization of fly ash

Adrino *et al.* (1980) observed that physical and chemical properties of coal ashes were dependent on the coal's geological origin, weathering and combustion before final disposal. Fly ash was basically an amorphous Ferro-alumino silicate, high in Ca, Na and K and contained virtually all natural elements in coal ash in trace amount.

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 per cent and clay size particles (below 0.002 mm) 10 par cent of the fly ash weight. The bulk density of fly ash was 1.02 g cm⁻³.

Kene *et al.* (1991) studied the properties of fly ash concluded that it had lower bulk density (1.39M g cm⁻³), water solubility (0.25 %) and electrical conductivity (0.35 dSm⁻¹). It was poor in NPK contents, but contains 350 ppm Mo, 75 ppm Cu and

100 ppm Zn at pH 7.5. It can also be used as a carrier for micronutrients to correct their deficiencies in soil.

Warambhe *et al.* (1993) collected fly ash from The Koradi Thermal Power Station and observed that it contained negligible amount of soluble salts and organic carbon and adequate content of total K, CaO, MgO, Zn and Mn. However, because of its high B content (345 ppm) it is potentially toxic to plants.

Dubey *et al.* (1999) characterized fly ash for its physical, chemical and nutrient capacity. The particle size distribution showed wide variation in the <0.25 mm size fraction. Bulk density lies between 0.85-1.16 g cm⁻³. The available water holding capacity ranges between 40.1 to 55.6 per cent. The organic carbon content lies between 1.9 to 4.5 kg⁻¹. The fly ash is slightly alkaline in reaction. Cation exchange capacity was 2.8-4.1 cmol (p+) kg⁻¹. The presence of various elements was in the order of Si > Al > Fe > Ca, Ti > Mg > K. The DTPA extractable micronutrients were in the order of Fe > Mn > Zn > Cu where as available N, P, K show the trend as N > K > P. Application of fly ash in soil, deficient in Fe, Zn, Cu and Mn could increase their availability.

Daniels *et al.* (2002) observed that fly ash characteristics vary depending on the type of coal burned, boiler type, and collector setup. Fly ash generally has a silt loam texture with 65-90 per cent of the particles having diameters of less than 0.010 mm. The fly ash has low bulk density varying (1.01-1.43 g cm⁻³), and specific gravity (1.6-3.1 g cm⁻³).

Kumar *et al.* (2005) observed that 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. It is by virtue of this and the ability of fly ash to modify the physical properties of soils, it works as a soil conditioner enhancing the yield of the crops.

Yeledhalli *et al.* (2008) Analyzed of fly ash and pond ash collected from Raichur Super Thermal Power Station, Shakhinagar, Karnataka has revealed that the both the ashes contained higher proportion of silt sized particles (40.1 to 50.2 %). The maximum water holding capacity of ash ranged from 48.1 to 68.1, pH from 7.9 to 10.5 and EC from 0.34 to 1.00 dSm⁻¹. Pond ash had higher WHC than fly ash. However, the pH and EC of pond ash were less as compared to fly ash.

Yeledhalli *et al.* (2008) analyzed fly ash and pond ash observed that both contained had 40 to 50.2 per cent higher proportion of silt sized particles. The maximum water holding capacity of ash ranged from 48.1 to 68.1, pH from 7.9 to 10.5 and EC from 0.34 to 1.00 dSm⁻¹. Pond ash had higher WHC than fly ash. However, the pH and EC of pond ash were less as compared to fly ash. The available amount of DTPA extractable Fe, Mn, Cu and Zn varied from 8.7 to 12.5, 10.3 to 13.1, 0.3 to 0.6 and 1.0 to 1.5 ppm, respectively.

Basu *et al.* (2009) stated 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. They also stated that fly ash is also useful for stabilizing erosion prone soils. Phyto-remediation can prevent cycling of toxicants from fly ash and growing of multipurpose tree species on problem soils.

Prem Kishor *et al.* (2009) mentioned that fly Ash a coal combustion residue of thermal power plants was a problematic solid waste all over the world and several studies proposed that fly ash can be used as soils ameliorant that may improve physical, chemical and biological properties of the degraded soils and is a source of readily available plant micro-and macro nutrients.

Rai *et al.* (2010) analyzed the physico-chemical properties of fly ash collected from Tata Iron and Steel Company (TISCO) power plant, at Jamadoba. The bulk density was 0.96 g cm⁻³, porosity 36.25 per cent, water holding capacity 74.55 per cent and cation exchange capacity 2.65 meq 100 g⁻¹.

Ram *et al.* (2011) observed that fly ash had low bulk density, high water holding capacity and porosity, rich in silt-sized particles, alkaline in nature and contains reasonable plant nutrients. The major content of fly ash was SiO₂ considerable amounts of oxides of Ca, Mg, K, P, and S, micronutrients (Cu, Zn, Mn, Fe, etc.) and low in N content.

Singh (2012) observed that fly ash occurs as very fine spherical particles, with diameter ranged from few μ to 100 μ , low to medium in bulk density, high surface area. Chemically, fly ash is amorphous ferro-alumino silicate mineral with major matrix elements like, Si, Al, Fe together with significant amount of Ca, Mg, K, P and S. The

concentration of total and available trace and heavy metals and radio nuclides in fly ash samples is in traces and their availability/leachability is negligible. The pH of fly ash has been varied from 4.5 to 12.0.

Murugan and Murugaiyan (2013) observed 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 $\mu\text{S cm}^{-1}$. Most of the fly ash has the bulk density (BD) values less than 1 g cm^{-3} and water holding capacity 43-66 per cent.

2.2 Effect of fly ash on physico-chemical properties of soil

Deshmukh *et al.* (2000) observed 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.

Sharma *et al.* (2002) evaluated fly ash addition effect on soil environment and yield of wheat crop. Fly ash application levels were up to 50 t ha^{-1} . Application of fly ash @10 t ha^{-1} 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.

Sharma *et al.* (2002) conducted experiment in villages around National Capital Power Project (NCPP), Dadri Uttar Pradesh and Indian Agricultural Research Institute (IARI) farm, New Delhi during 1995-96 to evaluated effect of fly ash addition on soil physical properties and observed that fly ash treated plots @ 50 t ha^{-1} tended to have lower bulk density of surface soil (0 to 30 cm).

Totawat *et al.* (2002) studied the effect of fly ash incorporation on physico-chemical properties of the soil. The treatments comprised of four levels of fly ash (0, 5, 10 and 15 t ha^{-1}), two levels of FYM (0 and 10 t ha^{-1}) and the two texturally different soils (sandy loam and clay loam). The incorporation of FYM and fly ash applied @ 10 t ha^{-1} improved CEC, organic carbon content, available nutrients status and decreased the soil pH.

Garg *et al.* (2005) studied the use of fly ash and biogas slurry for improving wheat yield and physical properties of soil. They revealed that leaf area index, root length density and grain yield of wheat were higher in plots amended with fly ash or biogas slurry compared to unamended plots. They also revealed that both types of amendments reduced bulk density, and increased saturated hydraulic conductivity and moisture retention capacity of soil.

Lee *et al.* (2006) studied the fly ash effect on improving soil properties and rice productivity in Korean paddy soils. They revealed that fly ash increased the soil pH and available Si and P contents of silt loam and loamy sand. They concluded that fly ash could be a good supplement to other inorganic soil amendments to improve the nutrient balance in paddy soils.

Sharma and Kalra (2006) reviewed the effect of fly ash incorporation on soil properties and productivity of crops. They stated that fly ash can be used for reclaiming the problematic soil and enhance the crop productivity depending upon the nature of soil and fly ash. It may improve physical, chemical and biological properties of problem soils and enhance the available macro and micronutrients for plants.

Sharma and Kalra (2006) observed that fly ash application improved the physical, chemical and biological properties of problem soils and enhance the available macro and micronutrients for plants. The high concentration of elements (K, Na, Zn, Ca, Mg, and Fe) in fly ash increase yield of agriculture crops. However, application of fly ash particularly unweathered ones show a tendency of accumulating element like B, Mo, Se, and Al. The accumulation of this toxic level is responsible for reduction in the crop yields and consequently influences animal and human health.

Sharma *et al.* (2006) studied the effect of fly ash incorporation on soil physical properties and observed that addition of fly ash to soil decreased the bulk density, improve soil porosity and enhance water retention capacity of soil.

Yeledhalli *et al.* (2007) conducted a experiment to study the effect of levels of fly ash (0, 25, 50, 75 and 100 t ha⁻¹) on physicochemical properties of alfisols with two levels of fertilizers (control and recommended dose of NPK fertilizers). Application of graded levels of coal fly ash with or without recommended dose of NPK fertilizers increased the organic carbon, N, K, Ca, Mg, P, Zn, Fe, Mn and Cu in soil.

Khan *et al.* (2008) studied the effect of integrated use of boiler ash as organic fertilizer on chemical properties of calcareous soil. The boiler ash was applied @ 3, 12, 25, 50, 125 and 250 t ha⁻¹ in pots having 20 kg soil and field with basal dose of NPK for Wheat crop. The available P, S and K, Fe, Mn, Zn and Cu content in soil, increased with the levels of boiler ash application.

Aggarwal *et al.* (2009) observed that the bulk density of fly ash was 1.01 M gm⁻³. Organic carbon content in the ash was 0.36 per cent. Water holding capacity of fly ash was 56.9 per cent. pH and electrical conductivity values were 6.98 and 0.65 dSm⁻¹ respectively.

Aggarwal *et al.* (2009) observed that the effect of fly ash on varying levels of fly ash (0, 5, 10, 20 t ha⁻¹) and nitrogen (0, 10, 20, 40 kg ha⁻¹) on physical properties of soil. The bulk density of soil was measured at harvest of wheat crop after two years of experimentation (2004-05 and 2005-06) at Agricultural Research Farm, Muzaffarnagar. Bulk density values were reduced by 5.9 per cent with the application of 20 t ha⁻¹ fly ash over control.

Aggarwal *et al.* (2009) studied that the effect on varying levels of fly ash applied @ 0, 5, 10 and 20 t ha⁻¹) and nitrogen @ 0, 10, 20 and 40 kg ha⁻¹ on chemical properties of soil and observed that the soil pH value decreased, whereas electrical conductivity (EC) increased, in accordance with the amounts of ash added in the soil. Organic carbon increased with fly ash.

Basu *et al.* (2009) studied the impact of fly ash utilization on soil physical properties and revealed that soil fly-ash mixture tend to have lower bulk density, higher water-holding capacity and lower hydraulic conductivity of soil.

Kumari (2009) estimated that the physico-chemical properties of fly ash from thermal power station Parichha (U.P.). Fly ash was dominated by coarse particles and constituted of 65.9, 1.0 and 10.5 per cent of the particles equal to diameters of sand, silt and clay fractions respectively. The level of organic carbon in fly ash was observed to be less than 1 per cent and bulk density less than 1 g cm⁻³.

Gupta *et al.* (2009) attempted to study the effect of fly ash (FA) on the physic-chemical characteristics *viz.* pH, electrical conductivity and trace element concentration. The treatment applied to soil was soil + NPK, 90 per cent soil + 10 per

cent FA + NPK, 80 per cent soil + 20 per cent FA + NPK, 70 per cent soil + 30 per cent FA + NPK, 60 per cent soil + 40 per cent FA+NPK and 50 per cent soil+50 per cent FA+NPK. The increasing proportion of fly ash in soil considerably increase the value pH, EC and trace element concentration.

Kishor *et al.* (2010) observed that application of fly ash at 0, 5, 10 and 15 per cent by weight in clay soil significantly reduced the bulk density and improve the soil structure, porosity, root penetration and moisture retention capacity of soil.

Kohli *et al.* (2010) studied mixed the fly ash with a slightly alkaline soil on w/w basis for use as a potting mixture for growing poplar nursery and investigated its influence on some physical properties of soil. Water holding capacity of fly ash amended soil increased and bulk density decreased as result of fly ash addition as compared to unamended soil.

Saini *et al.* (2010) observed 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

Pandey and Singh (2010) studied impact of fly ash incorporation in soil systems. They revealed that fly ash can be used as potential nutrient supplement for degraded soils thereby solving the solid waste disposal problem to some extent. They also revealed that fly ash could be effectively used in the barren or sterile soil for improving quality and enhancing fertility.

Reddy *et al.* (2010) studied the effect of varying level of fly ash (@ 0, 5, 10, and 15 t ha⁻¹) and FYM (0 and 10 t ha⁻¹) 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 FA 10 FYM 10 (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.

Arivazhagan *et al.* (2011) studied the effect of coal fly ash on agricultural crops. They stated that use of coal fly ash in agriculture is one way of disposal of fly ash and at the same time it improves the yield of variety of agricultural crops and physico-

chemical properties of soil. They revealed that application of coal ash increase the yield of cereal crops to 15-20 per cent, sugarcane to 20-30 per cent, maize to 40 per cent, red gram to 50 per cent, potato to 25 per cent plantation crops to 30 per cent mustard and vegetable to 10 per cent. Besides increasing the yields of crops it also improved nutrient uptake in plants and physical properties of soil especially water holding capacity and fertility status of soil. They also revealed that the application of fly ash @ 50 t ha⁻¹ have increased the yield of wheat by 5-10 per cent.

Bakri *et al.* (2012) studied properties of fly ash and observed 0.85 per cent K₂O content in fly ash. They also observed use of fly ash is more environment friendly due to reduced emission of CO₂.

Khajanchi *et al.* (2012) the effects of fly ash applied @ 0, 2.5, 5.0, 7.5 and 10.0 t ha⁻¹ on release and uptake of potassium and sodium reclaimed alkali soils. Fly ash did not influence K content but significantly increased Na content in rice. The residual effect of fly ash was non-significant on wheat yields and contents of K and Na in plant tissues. Fly ash had non significant effect on the release of exchangeable K but significantly reduced the exchangeable Na content. Fly ash had non significant effect on the release of exchangeable K but significantly reduced the exchangeable Na content increased correspondingly with increasing level of fly ash application.

Dey *et al.* (2012) studied fly ash properties and observed that it may improve physical, chemical and biological properties of degraded soil and it is also a source for macronutrient and some metals enriched in fly ash such as Cd, Cr, Ni, Pb, and Zn with some enriched intermediate metals like Al, Si, Mg, Fe and Mn.

Das *et al.* (2013) conducted a field experiments was in *kharif* season 2012 at Instructional Cum Research Farm of Assam Agricultural University, Jorhat on Inceptisols to study the effect of application of fly ash alone and in combination with recommended dose of fertilizers and farm yard manure on physicochemical properties and nutrient availability of the soil. The addition of fly ash resulted in significant increase in organic carbon, CEC and available nutrient in the post harvest soil. The treatment consisting of RDF 50 per cent + FYM 5 t ha⁻¹ + FA 5 t ha⁻¹ recorded significantly the higher available nitrogen, while available phosphorus and potassium increased with the doses of fly ash applied @ 5 t ha⁻¹, 10 t ha⁻¹ and 15 t ha⁻¹.

3. MATERIAL AND METHODS

A column study experiment was conducted to study the effect of fly ash on physico-chemical properties of soil at Micronutrient Research Farm, Department of Soil Science and Agriculture Chemistry, M.P.K.V., Rahuri. The research was carried out during April 2017 to June 2017. The details of the material used in the experimental techniques and analytical methods adopted during the investigation are presented in this chapter under the following heads.

3.1 Material

A column study experiment was conducted at Micronutrient Research Farm, Department of Soil Science and Agriculture Chemistry M. P. K. V., Rahuri. The soil was air dried, ground and passed through a 2mm sieve and used in column study. Fly ash was obtained from Thermal Power Plant, Eklahare (Nasik). Fourteen kg of soil was added to the PVC pipes of (70 cm height, 6 inch diameter) and fly ash added @ 0, 1, 5, 10, 15, 20, and 25 t ha⁻¹ respectively. The treatment T₁ was kept as control. The experiment was laid out in a complete randomized design and each treatment was replicated three times. The moisture in soil maintained at field capacity by adding deionized water regularly. The leachate collected from pot at 30 days and 60 days respectively.

3.1.1 Soils

The soils of the experiment at Post Graduate Institute farm of Department of Soil Science and Agriculture Chemistry is classified as *Inceptisol (Vertic Haplustep)* the colour of soils was medium deep black.

3.1.2 Fly ash

The fly ash was air dried and passed through the 4 mm sieve and used for the experiment.

3.1.3 PVC Pipes

The cut pipes of PVC pipes of 70 cm height and 15 cm diameter were used for the column study.

3.1.4 Deionized water

The daily requirement of deionized water fulfilled by using electrical deionizer from Department of Soil Science and Agricultural Chemistry.

3.1.5 Treatment Details

T₁ : Soil only + 0 t ha⁻¹ fly ash

T₂ : Soil + 1 t ha⁻¹ fly ash

T₃ : Soil + 5 t ha⁻¹ fly ash

T₄ : Soil + 10 t ha⁻¹ fly ash

T₅ : Soil + 15 t ha⁻¹ fly ash

T₆ : Soil + 20 t ha⁻¹ fly ash

T₇ : Soil + 25 t ha⁻¹ fly ash

3.2 Methods

3.2.1 Experimental details (Table 3.1)

1.	Location of Experiment	Department of Soil Science and Agricultural Chemistry, PGI, M P K V, Rahuri.
2.	Number of treatments	07
3.	Levels of fly ash	1. Absolute control (No fly ash) 2. 1 t ha ⁻¹ 3. 5 t ha ⁻¹ 4. 10 t ha ⁻¹ 5. 15 t ha ⁻¹ 6. 20 t ha ⁻¹ 7. 25 t ha ⁻¹
4.	No. of replications	03
5.	Design of Experiment	Completely Randomized Design
6.	Type of soil	Medium Deep Black (Inceptisol)
7.	Length of column	70 cm
8.	Length of soil column	60 cm
9.	Diameter of column	15 cm (6 inch)
10.	Quantity of soil filled	14 kg
11.	Water used	Deionized water
12.	Year of Experiment	2017
13.	Period of Experiment	15 June-15 September 2017
14.	Leachate collected	After 30 and 60 days of experiment

3.2.2 Soil sampling and analysis

Soil samples collected by cutting each PVC pipe at the depth of 0-15 cm, 15-30 cm, 30-45 cm and 30-60 cm after the completion of 2 months of the experiment. The collected soil samples were air dried under shade well and part of that soil samples were utilized for chemical analysis and determining the physical properties. For the chemical analysis, soil samples were gently ground with wooden mortar and pestle, well mixed and sieved through 2 mm mesh and utilized for laboratory analysis. The initial characteristics of soil with respect to physical and chemical properties were observed in Table 3.2.

Table 3.2 Initial properties of experimental soil (*Vertic Haplustept*)

Sr. No.	Parameters	Value
A.	Physical properties	
	a) Sand (%)	14.90
	i. Fine sand (%)	8.10
	ii. Coarse sand (%)	6.80
	b) Silt (%)	38.00
	c) Clay (%)	47.10
	Textural class	Clay
1	Bulk Density (Mg m^{-3})	1.35
2	Hydraulic conductivity (cm h^{-1})	0.96
3	Field capacity (%)	36.75
4	Aggregate stability (%)	61.11
5	Mean weight diameter (mm)	0.76
6	Permanent wilting point (%)	20.46
B.	Chemical properties	
1.	pH (1:2.5)	8.02
2.	EC (dSm^{-1})	0.17
3.	Organic carbon (%)	0.47
4.	CEC (cmol kg^{-1})	47.5
5.	Free CaCO_3 (%)	6.10

3.2.3 Characterization of fly ash

The characterization of fly ash done for the determination of content of fly ash. The detailed characteristics of fly ash given in Table 3.3.

Table 3.3 Characterization of fly ash

Sr. No.	Parameters	Fly ash
A)	Physical properties	
1	Colour	Ash white
2	Moisture content (%)	2.09
3	Hydraulic conductivity (cmh ⁻¹)	0.26
B)	Chemical properties	
1	pH (1:10)	9.42
2	EC (dSm ⁻¹)	0.47
3	Organic carbon (%)	0.01
4	Total N (%)	Trace
5	Total P (%)	0.06
6	Total CaO (%)	0.36
7	Total MgO (%)	0.37
8	Total Na (%)	0.07
9	Total K (K ₂ O) (%)	0.60

3.2.4 Saturation paste extract analysis of soil

The 200 gm soil samples used for the saturation paste extract of the soil. The extract collected from that samples analyzed for various properties as detailed in table 3.4

Table 3.4 Saturation paste extract analysis of soil

Parameters		Values
1.	pHs	7.8
2	EC _e (dSm ⁻¹)	0.45
3	Ca ²⁺ (me L ⁻¹)	3.8
4	Mg ²⁺ (me L ⁻¹)	0.6
5	K ⁺ (me L ⁻¹)	1.26
6	Na ⁺ (me L ⁻¹)	0.59
7	CO ₃ ⁻ (me L ⁻¹)	--
8	HCO ₃ ⁻ (me L ⁻¹)	4.2
9	Cl ⁻ (me L ⁻¹)	3.2
10	SO ₄ ²⁻ (me L ⁻¹)	2.32

3.2.5 Standard analytical methods

The initial and post experiment soil samples were analyzed by using standard analytical methods given in the table 3.5.

Table 3.5 Standard analytical methods

Sr. No.	Parameter	Method used	Reference
1.	Physical properties		
i.	Bulk density	Clod Method	Blake and Hartage (1986)
ii.	Aggregate stability	Yoder's apparatus	Yoder (1936)
iii.	Particle size distribution	International pipette method	Piper (1956)
iv.	Hydraulic conductivity	Constant Head method	Klute and Parkinson (1986)
v.	Field Capacity	Pressure Plate Apparatus	Richards <i>et al</i> (1956)
vi.	Permanent wilting Point	Pressure Membrane	Richards and Weaver (1943)
2.	Chemical Properties		
i.	pH (1:2.5)	Potentiometric	Jackson (1973)
ii.	EC (1:2.5) dSm ⁻¹	Conductometry	Jackson (1973)
iii.	Organic carbon (%)	Wet oxidation	Nelson and Sommer (1982)
iv.	Free CaCO ₃ (%)	Acid neutralization	Alison and Moodier (1965)
v.	CEC	Centifuge Method extraction with 0.4 N NaOAc, 0.1 MNaCl (pH 8.2)	Pivinski (1985)
3.	Saturation paste extract		
i.	pHs	Potentiometry	Richards (1968)
ii.	E _{Ce}	Conductivity bridge	Richards (1968)
iii.	Ca ²⁺ and Mg ²⁺	Versenate titration	Richards (1968)
iv.	K ⁺	Flame photometry	Richards (1968)
v.	CO ₃ ²⁻ , HCO ₃ ⁻ and Cl ⁻	Volumetric	Richards (1968)
4.	Leachate analysis		
a)	Cations		
1.	Ca ²⁺	Versenate titration	Richards (1968)
2.	Mg ²⁺	Versenate titration	Richards (1968)
3.	K ⁺	Flame photometry	Richards (1968)
4.	Na ⁺	Flame photometry	Richards (1968)
b)	Anions		
1.	CO ₃ ²⁻	Volumetric	Richards (1968)
2.	Cl ⁻	Volumetric	Richards (1968)
3.	HCO ₃ ⁻	Volumetric	Richards (1968)
4.	SO ₄ ²⁻	Tubidimetric	Chopra and Kanwar (1980)

3.2.6 Observations recorded:

1. Characterization of fly ash.
2. Soil analysis at initial, leachate analysis at 30 and 60 days and final samples analysis.
 - a. Physical: Bulk density, hydraulic conductivity, aggregate stability, field capacity and permanent wilting point.
 - b. Chemical : pH, EC, Organic carbon, CEC and CaCO_3 .
 - c. Leachate analysis : Anions: CO_3^{2-} , Cl^- , HCO_3^- and SO_4^{2-}
Cations: Ca^{2+} , Mg^{2+} , K^+ and Na^+

3.2.7 Physical properties

The physical properties were assessed from the soil samples by using standard methods of analysis Table 2.

3.2.8 Chemical properties

Chemical properties were analyzed from the soil samples by using standard methods of analysis Table 2.

3.2.9 Leachate analysis

The leachate collected after 30 days and 60 days were analyzed by using standard methods of analysis.

3.2.10 Statistical analysis

The experimental data on different parameters were tabulated and statistically analyzed by using completely randomized design as described by Panse and Sukhatme (1985) and obtained results are presented in table.

4. RESULTS AND DISCUSSION

The present investigation was undertaken under wire house condition in the column study. The effect of fly ash on physical and chemical properties of soil was studied under the present investigation. The data, thus collected on various aspects are observed in this chapter.

4.1 Effect of fly ash on physical properties of soil

4.1.1 Effect of fly ash application on bulk density of soil

Table 4.1 Bulk density and hydraulic conductivity of soil as influenced by application of fly ash

Tr. No.	Treatment details	Bulk density (Mgm ⁻³)				Hydraulic conductivity (cmh ⁻¹)			
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	1.40	1.41	1.40	1.43	0.98	1.02	1.05	1.07
T ₂	Soil + 1 t ha ⁻¹ fly ash	1.39	1.40	1.42	1.43	1.03	1.06	1.09	1.10
T ₃	Soil + 5 t ha ⁻¹ fly ash	1.37	1.39	1.41	1.4	1.05	1.07	1.1	1.10
T ₄	Soil + 10 t ha ⁻¹ fly ash	1.34	1.36	1.38	1.40	1.06	1.09	1.11	1.12
T ₅	Soil + 15 t ha ⁻¹ fly ash	1.32	1.35	1.38	1.40	1.08	1.12	1.13	1.14
T ₆	Soil + 20 t ha ⁻¹ fly ash	1.32	1.34	1.37	1.39	1.09	1.10	1.14	1.13
T ₇	Soil + 25 t ha ⁻¹ fly ash	1.28	1.30	1.32	1.36	1.11	1.12	1.15	1.15
	SE ±	0.011	0.008	0.008	0.011	0.023	0.018	0.018	0.01
	CD at 5 %	0.035	0.026	0.026	0.035	0.071	0.055	0.056	0.051
	Initial	1.40				0.98			

The research data revealed that the bulk density of soil in 0-15 cm depth ranges from 1.28 to 1.40 Mgm⁻³. The significantly lowest bulk density was observed in the treatment T₇ 1.28 (Mgm⁻³). However, the highest bulk density was observed in treatment T₁ 1.40 (Mgm⁻³) the treatments T₂ and T₃ were at par with the treatment T₁.

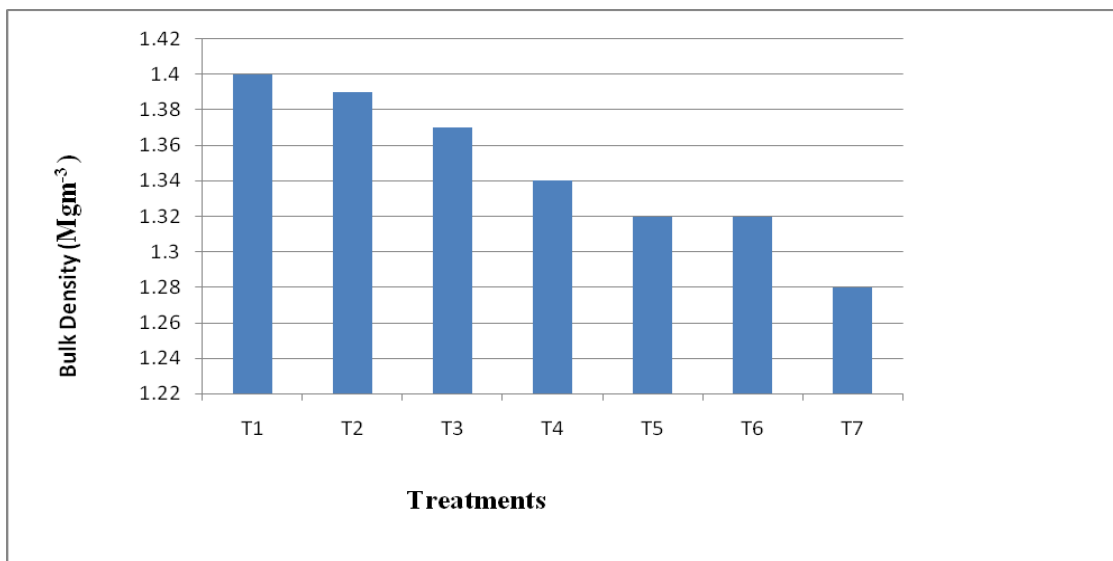


Fig.4.1.1 Effect of fly ash application on bulk density of soil (0-15 cm depth)

The data revealed that the bulk density of soil in 15-30 cm depth ranges from 1.41 to 1.30 Mgm⁻³. The lowest bulk density was observed in the treatment T₇ 1.30 (Mgm⁻³). However, the highest bulk density was observed in treatment T₁ 1.41 (Mgm⁻³) the treatments T₂ and T₃ were at par with the treatment T₁. (Table 4.2)

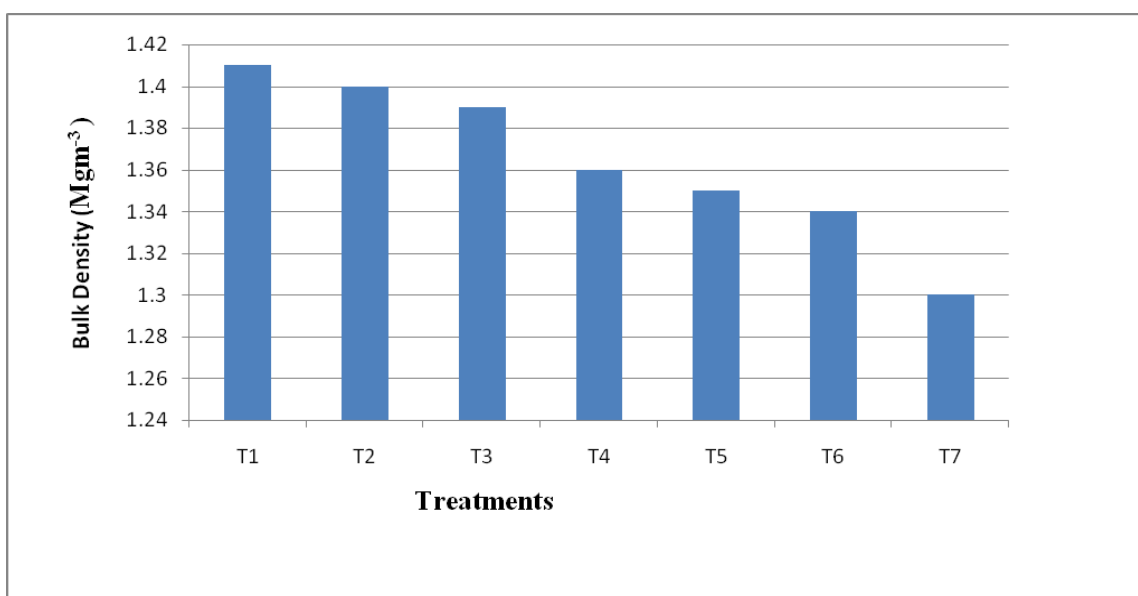


Fig.4.1.1 Effect of fly ash application on bulk density of soil (15-30 cm depth)

The data regarding the bulk density from column indicated that the bulk density of soil in 30-45 cm depth ranges from 1.40 to 1.32 Mgm^{-3} . The significantly lowest bulk density was observed in the treatment T₇ 1.32 (Mgm^{-3}). However, the highest bulk density was observed in treatment T₁ 1.40 (Mgm^{-3}) the treatments T₄ and T₅ were at par with the treatment T₁.

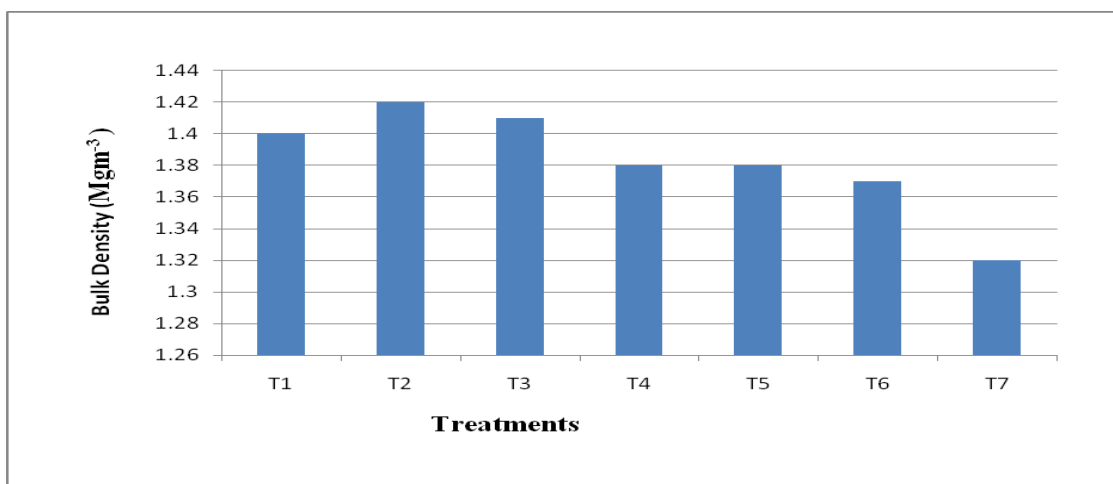


Fig.4.1.1 Effect of fly ash application on bulk density of soil (30-45 cm depth)

The samples collected from column observed that the bulk density of soil in 45-60 cm depth ranges from 1.43 to 1.36 Mgm^{-3} . The lowest bulk density was observed in the treatment T₇ 1.36 (Mgm^{-3}). However, the highest bulk density was observed in treatment T₁ 1.43 (Mgm^{-3}) the treatments T₄ and T₅ were at par with the treatments T₁ and T₂.

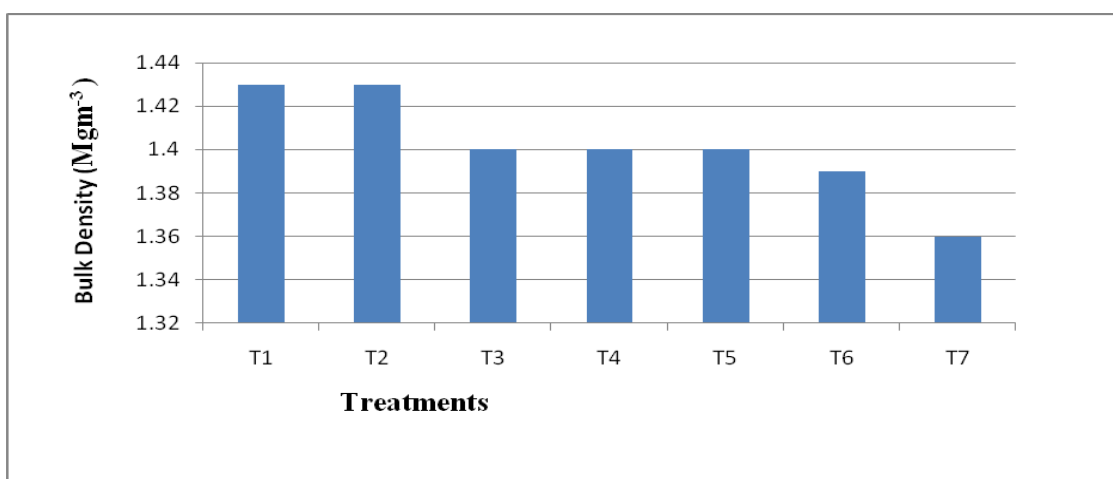


Fig.4.1.1 Effect of fly ash application on bulk density of soil (45-60 cm depth)

Decrease in bulk density from 1.43 to 1.28 Mgm^{-3} in clay soil was observed due to increasing proportion of fly ash added. Decrease might be due to increase in capillary pores at the expense of non-capillary pores.

Karmakar *et al.* (2010) observed that the reduction of bulk density in treated soil was due to lower bulk density of fly ash and FYM. The decrease in bulk density and improvement in soil porosity had positive affect on the water retention and moisture availability in the root zone. Similar results also confirmed by Khan *et al.* (2008), Yeledhalli *et al.* (2008) and Kohli *et al.* (2010).

4.1.2 Effect of fly ash application on hydraulic conductivity of soil

The research data from column reflected that the hydraulic conductivity of soil in 0-15 cm depth ranges from 0.98 to 1.11 cm h^{-1} . The lowest hydraulic conductivity was observed in the treatment T₁ 0.98 (cmh^{-1}) the treatments T₂ and T₃ were at par with the treatment T₁. However, the highest hydraulic conductivity was observed in treatment T₇ 1.11 (cm h^{-1}) the treatments T₂, T₃, T₄, T₅ and T₆ were at par with the treatment T₇.

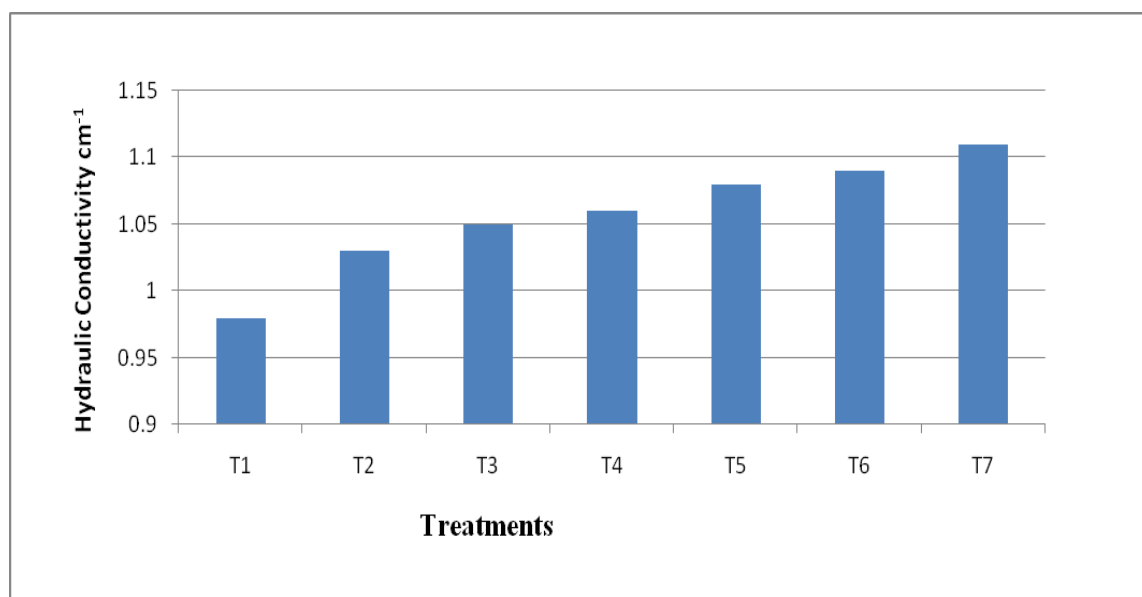


Fig.4.1.2 Effect of fly ash application on hydraulic conductivity of soil (0-15 cm depth)

The data from table 4.2 revealed that the hydraulic conductivity of soil in 15-30 cm depth ranges from 1.02 to 1.12 cmh^{-1} . The lowest hydraulic conductivity was observed in the treatment T₁ 1.02 (cmh^{-1}) the treatments T₂ and T₃ were at par with the

treatment T₁. However, the highest hydraulic conductivity was observed in treatment T₇ 1.12 (cmh⁻¹) the treatments T₃, T₄, T₅ and T₆ were at par with the treatment T₇

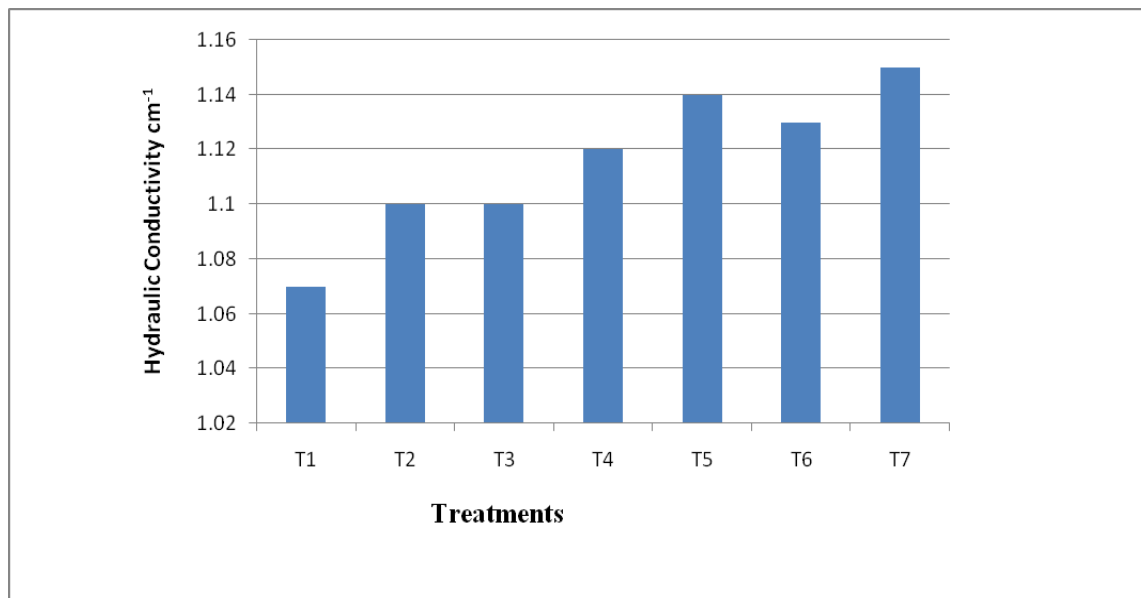


Fig.4.1.2 Effect of fly ash application on hydraulic conductivity of soil (15-30 cm depth)

The samples collected from column revealed that the hydraulic conductivity of soil in 30-45 cm depth ranges from 1.05 to 1.15 cmh⁻¹. The lowest hydraulic conductivity was observed in the treatment T₁ 1.05 (cmh⁻¹) the treatments T₂ and T₃ were at par with the treatment T₁. However, the highest hydraulic conductivity was observed in treatment T₇ 1.15 (cmh⁻¹) the treatments T₂, T₃, T₄, T₅ and T₆ were at par with the treatment T₇.

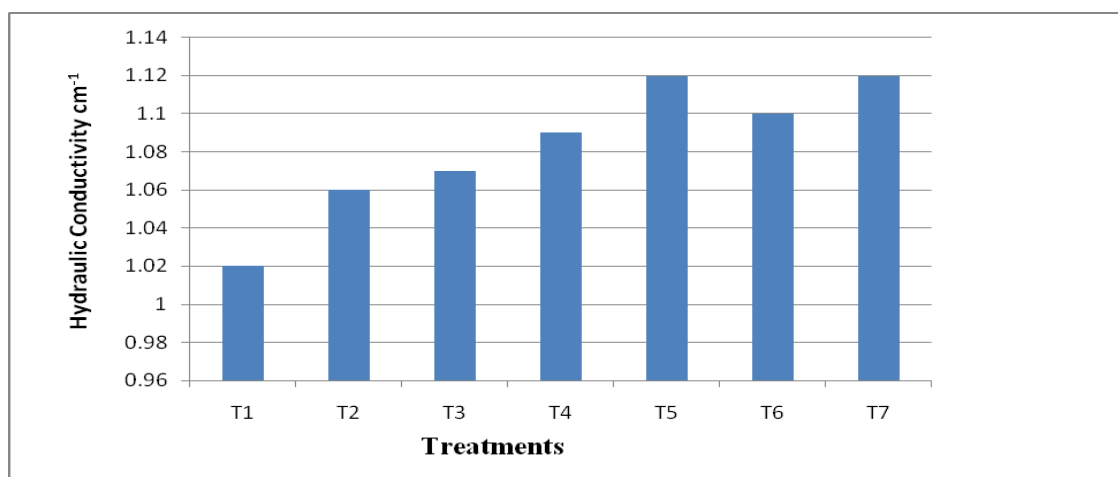


Fig.4.1.2 Effect of fly ash application on hydraulic conductivity of soil (30-45 cm depth)

The research data from column revealed that the hydraulic conductivity of soil in 45-60 cm depth ranges from 1.07 to 1.15 cmh^{-1} . The lowest hydraulic conductivity was observed in the treatment T_1 (1.07 cmh^{-1}) the treatments T_2 and T_3 were at par with the treatment T_1 . However, the highest hydraulic conductivity was observed in treatment T_7 (1.15 cmh^{-1}) the treatments T_2 , T_3 , T_4 , T_5 and T_6 were at par with the treatment T_7 .

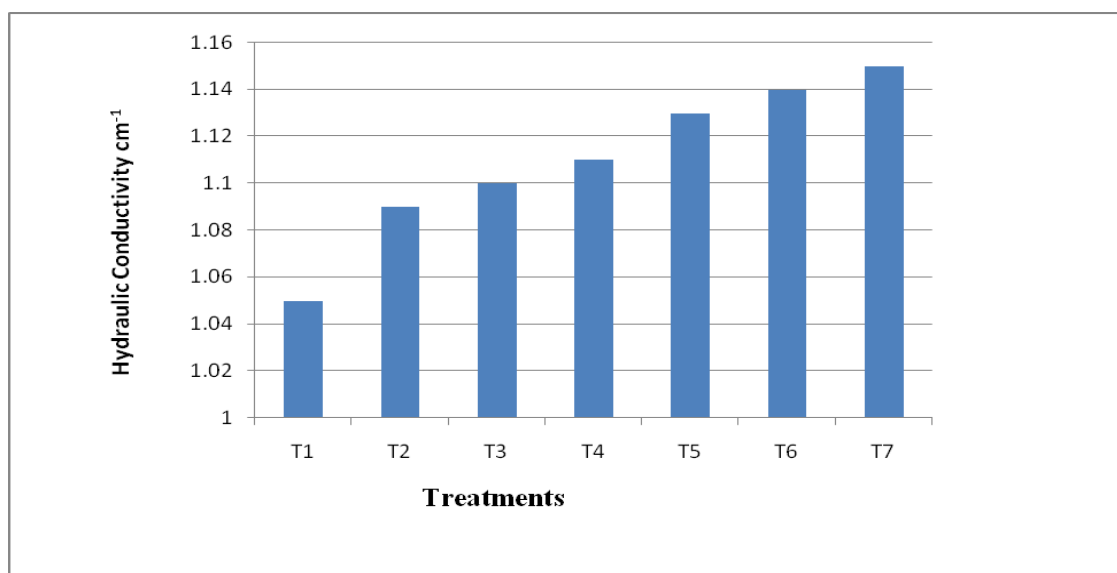


Fig.4.1.2 Effect of fly ash application on hydraulic conductivity of soil (45-60 cm depth)

Addition of fly ash, quite rich in fine sand and silt fraction to the highly clayey soil probably resulted in an increase in capillary pores which ultimately could be responsible for the increase in hydraulic conductivity. Similar results were observed by Chang et al. (1977) for clay soil. Campbell et al. (1983) observed that hydraulic conductivity of sand decreased with the fly ash addition.

4.1.3 Effect of fly ash application on aggregate stability of soil

The samples collected from column observed that the aggregate stability of soil in 0-15 cm depth ranges from 61.11 to 59.65 per cent. The lowest aggregate stability was showed in the treatment T_7 (59.65 %) the treatments T_5 and T_6 were at par with the treatment T_7 . However, the significantly highest aggregate stability was observed in treatment T_1 (61.11 %).

Table 4.2 Aggregate stability and mean weight diameter as influenced by application of fly ash

Tr. No.	Treatment details	Aggregate stability (%)				Mean weight diameter (mm)			
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	61.11	61.34	60.93	60.98	0.76	0.76	0.76	0.76
T ₂	Soil + 1 t ha ⁻¹ fly ash	60.58	61.12	60.72	60.75	0.76	0.76	0.77	0.76
T ₃	Soil + 5 t ha ⁻¹ fly ash	60.38	61.00	60.52	60.59	0.78	0.77	0.78	0.78
T ₄	Soil + 10 t ha ⁻¹ fly ash	60.29	60.76	60.27	60.58	0.78	0.78	0.78	0.78
T ₅	Soil + 15 t ha ⁻¹ fly ash	60.05	60.43	60.0	60.16	0.80	0.79	0.79	0.79
T ₆	Soil + 20 t ha ⁻¹ fly ash	59.82	60.29	59.76	60.05	0.80	0.80	0.80	0.80
T ₇	Soil + 25 t ha ⁻¹ fly ash	59.65	60.10	59.61	59.90	0.81	0.81	0.81	0.81
	SE ±	0.132	0.067	0.111	0.186	0.004	0.004	0.006	0.003
	CD at 5 %	0.401	0.206	0.338	0.566	0.012	0.013	0.018	0.009
	Initial	61.11				0.76			

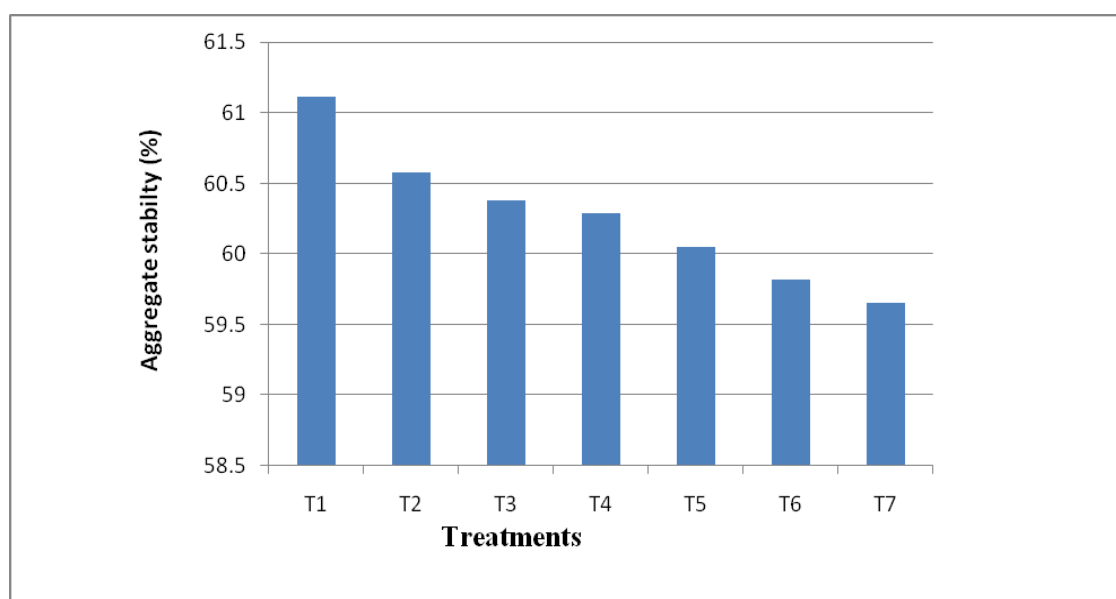


Fig.4.1.3 Effect of fly ash application on aggregate stability of soil (0-15 cm depth)

The data revealed that the aggregate stability of soil in 15-30 cm depth ranges from 61.34 to 60.10 per cent. The lowest aggregate stability was noticed in the treatment T₇ (60.10 %) the treatment T₆ was at par with the treatment T₇. However, the significantly highest aggregate stability was observed in treatment T₁ (61.34 %).

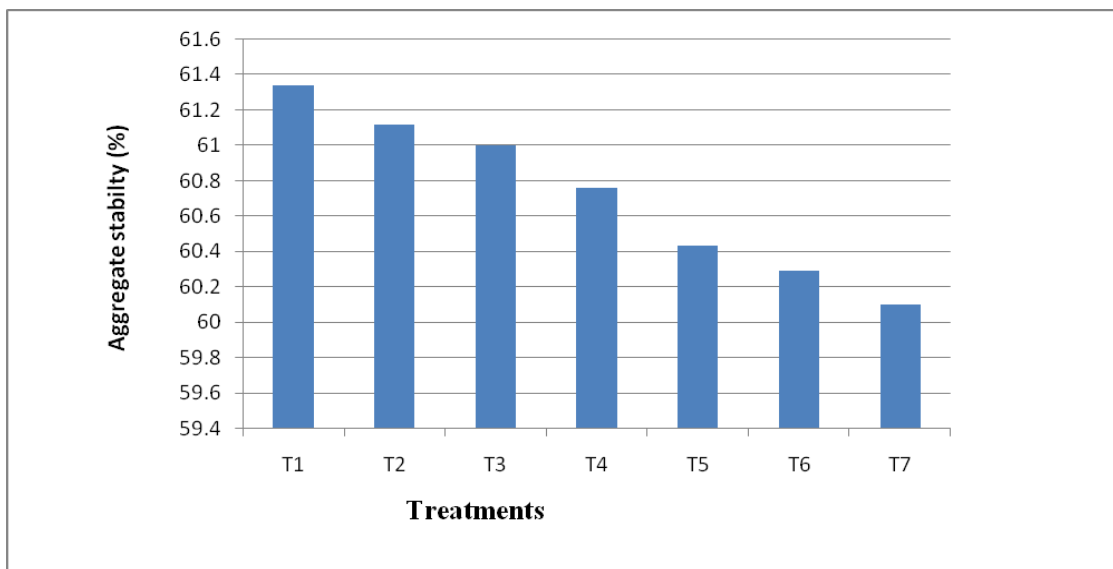


Fig.4.1.3 Effect of fly ash application on aggregate stability of soil (15-30 cm depth)

The samples collected from column observed that the aggregate stability of soil in 30-45 cm depth ranges from 60.93 to 59.61 per cent. The lowest aggregate stability was noticed in the treatment T₇ (59.61 %) the treatment T₆ was at par with the treatment T₇. However, the highest aggregate stability was observed in treatment T₁ (60.93 %) the treatment T₂ was at par with the treatment T₁.

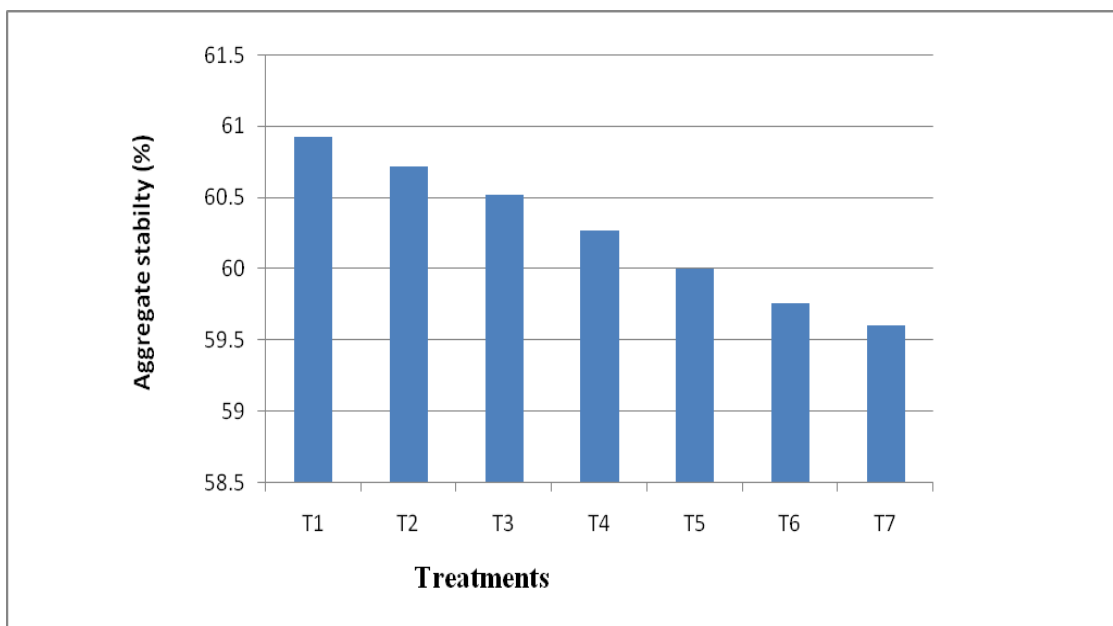


Fig.4.1.3 Effect of fly ash application on aggregate stability of soil (30-45 cm depth)

The research data from column observed that the aggregate stability of soil in 45-60 cm depth ranges from 60.98 to 59.90 per cent. The lowest aggregate stability was observed in the treatment T₇ (59.90 %) the treatments T₅ and T₆ were at par with the treatment T₇. However, the highest aggregate stability was observed in treatment T₁ (60.98 %) the treatments T₂, T₃ and T₄ were at par with the treatment T₁.

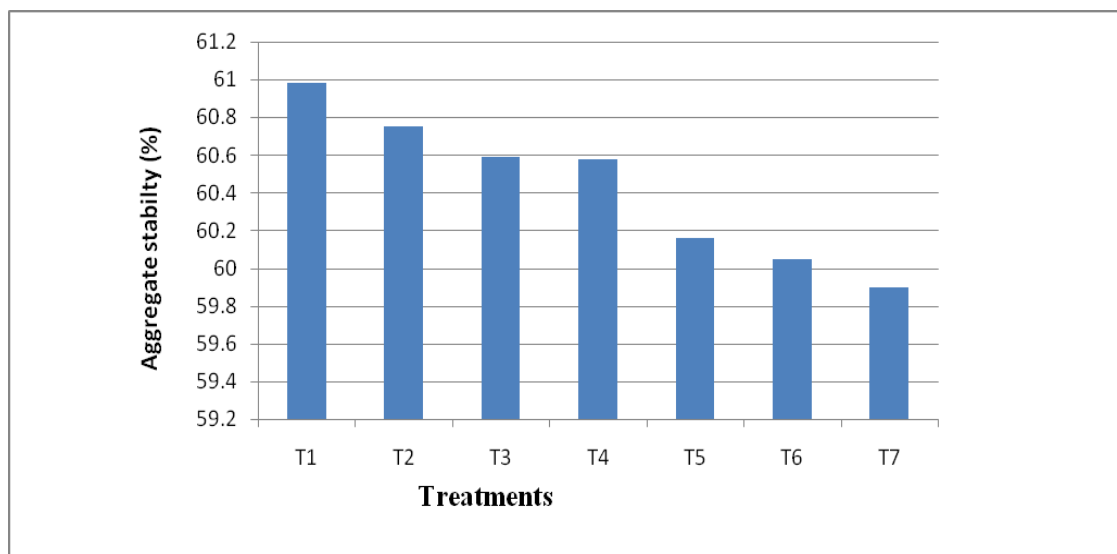


Fig.4.1.3 Effect of fly ash application on aggregate stability of soil (45-60 cm depth)

4.1.4 Effect of fly ash application on mean weight diameter of soil

The research data from column indicated that the mean weight diameter of soil in 0-15 cm depth ranges from 0.76 to 0.81 mm. The lowest mean weight diameter was observed in the treatment T₁ (0.76 mm) the treatment T₂, was at par with the treatment T₁. However the highest mean weight diameter was observed in treatment T₇ (0.81 mm) the treatments T₅ and T₆ were at par with the treatment T₇.

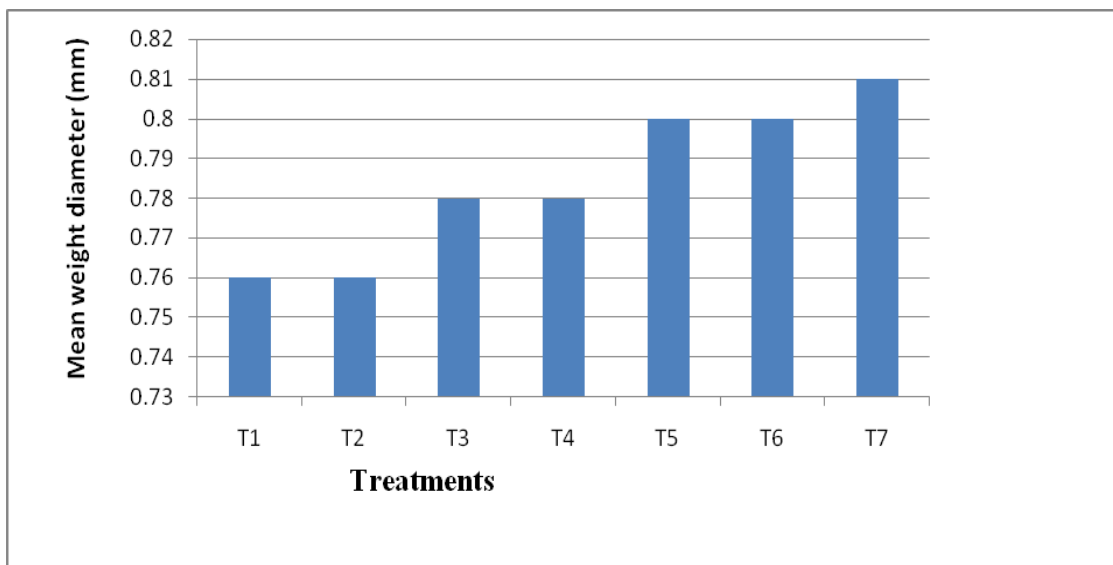


Fig.4.1.4 Effect of fly ash application on mean weight diameter of soil (0-15 cm depth)

The research data from column revealed that the mean weight diameter of soil in 15-30cm depth ranges from 0.76 to 0.81 mm. The lowest mean weight diameter was observed in the treatment T₁ (0.76 mm) the treatment T₂, was at par with the treatment T₁. However, the highest mean weight diameter was observed in treatment T₇ (0.81 mm) the treatments T₅ and T₆ were at par with the treatment T₇.

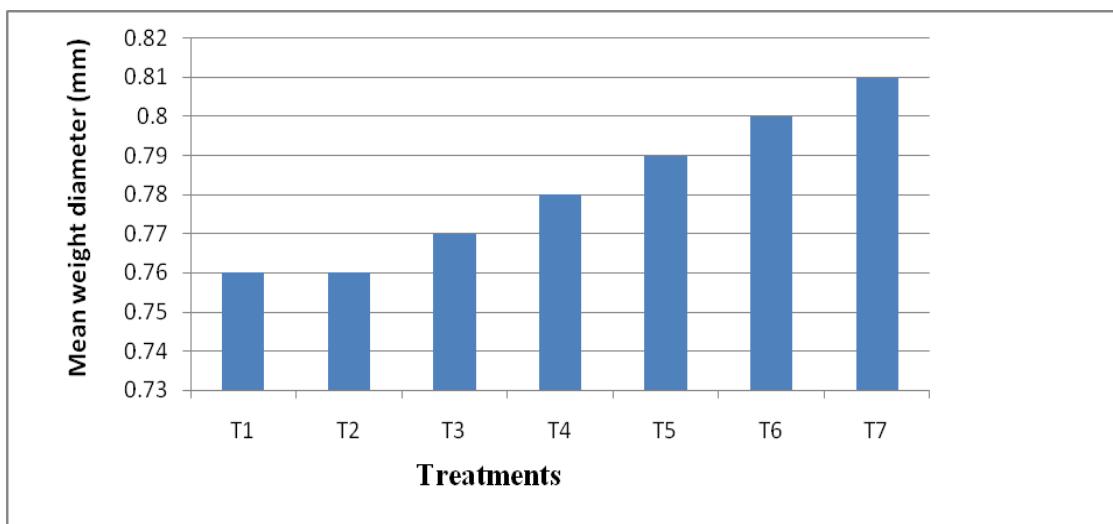


Fig.4.1.4 Effect of fly ash application on mean weight diameter of soil (15-30 cm depth)

The data from column reflected that the mean weight diameter of soil in 30-45 cm depth ranges from 0.76 to 0.81 mm. The lowest mean weight diameter was noticed in the treatment T₁ (0.76 mm) the treatment T₂, was at par with the treatment T₁. However, the highest mean weight diameter was observed in treatment T₇ (0.81 mm) the treatments T₅ and T₆ were at par with the treatment T₇ (Table 4.2).

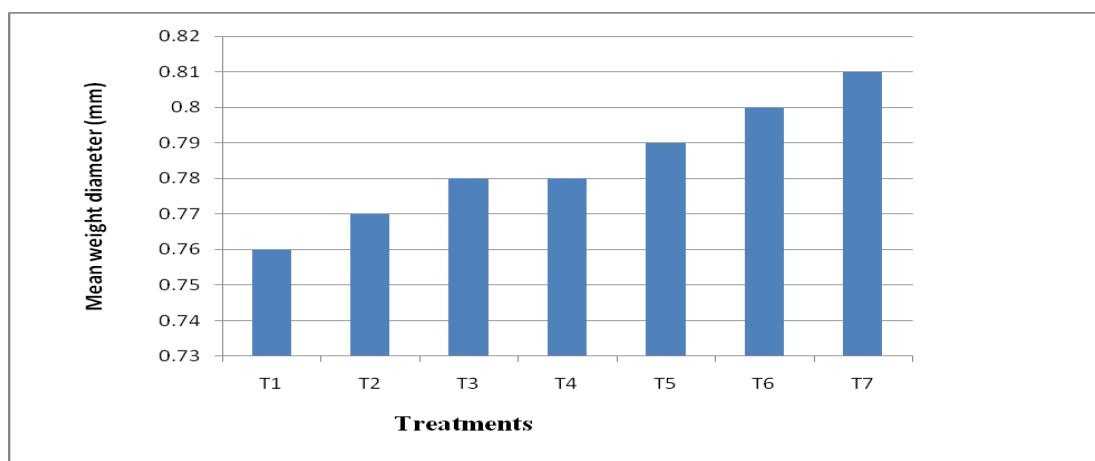


Fig.4.1.4 Effect of fly ash application on mean weight diameter of soil (30-45 cm depth)

The samples collected from column revealed that the mean weight diameter of soil in 45-60 cm depth ranges from 0.76 to 0.81 mm. The lowest mean weight diameter was observed in the treatment T₁ (0.76 mm) the treatment T₂, was at par with the treatment T₁. However, the highest mean weight diameter was observed in treatment T₇ (0.81 mm) the treatments T₅ and T₆ were at par with the treatment T₇.

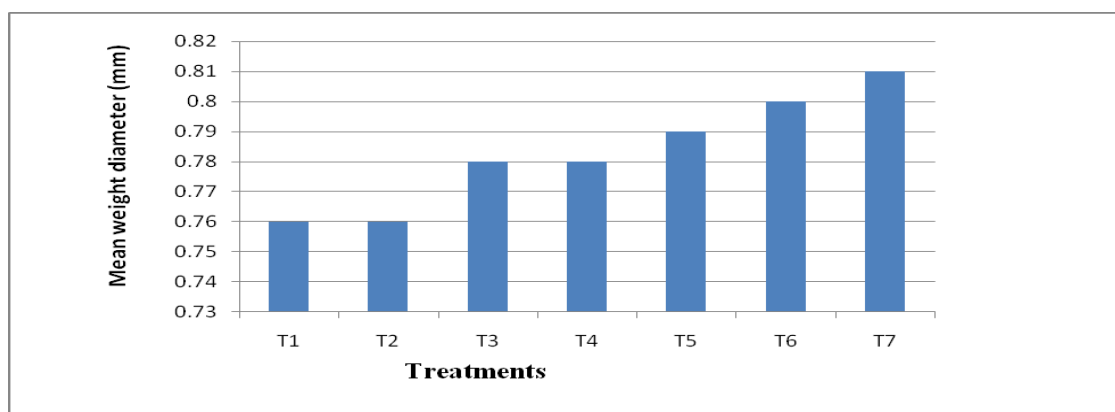


Fig.4.1.4 Effect of fly ash application on mean weight diameter of soil (45-60 cm depth)

In general per cent aggregates and MWD was not influenced by application of fly ash. Craini (1988) has observed that fly ash had significant effect on MWD. As it is well known that organic manures play role in soil aggregation, there by maintains favorable physicals conditions and supply polysaccharides which are vital for improvement of soil structure. Thus the FYM might have helped in improving the soil aggregate stability.

4.1.5 Effect of fly ash application on field capacity of soil

The research data from column reflected that the field capacity of soil in 0-15 cm depth ranges from 37.09 to 40.76 per cent. The lowest field capacity was observed in the treatment T₁ (37.09 %) the treatments T₂ and T₃ were at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (40.76 %) the treatments T₅ and T₆ were at par with the treatment T₇.

Table 4.3 Field capacity and permanent wilting point of soil as influenced by application of fly ash

Tr. No.	Treatment details	Field capacity (%)				Permanent wilting point (%)			
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	37.09	36.86	36.29	35.68	18.19	17.98	17.80	17.65
T ₂	Soil + 1 t ha ⁻¹ fly ash	37.60	36.57	36.15	35.58	18.40	18.19	18.00	17.86
T ₃	Soil + 5 t ha ⁻¹ fly ash	38.54	38.00	37.60	37.21	18.81	18.58	18.29	18.13
T ₄	Soil + 10 t ha ⁻¹ fly ash	38.75	38.50	37.69	37.26	19.08	18.84	18.63	18.54
T ₅	Soil + 15 t ha ⁻¹ fly ash	39.72	38.95	37.90	37.10	19.42	19.11	18.95	18.82
T ₆	Soil + 20 t ha ⁻¹ fly ash	40.33	38.67	38.63	37.75	19.83	19.46	19.31	19.17
T ₇	Soil + 25 t ha ⁻¹ fly ash	40.76	39.57	38.65	37.79	20.31	19.69	19.88	19.64
	SE ±	0.481	0.503	0.489	0.537	0.074	0.177	0.112	0.107
	CD at 5 %	1.460	1.526	1.484	1.629	0.225	0.537	0.342	0.325
	Initial	37.09				18.19			

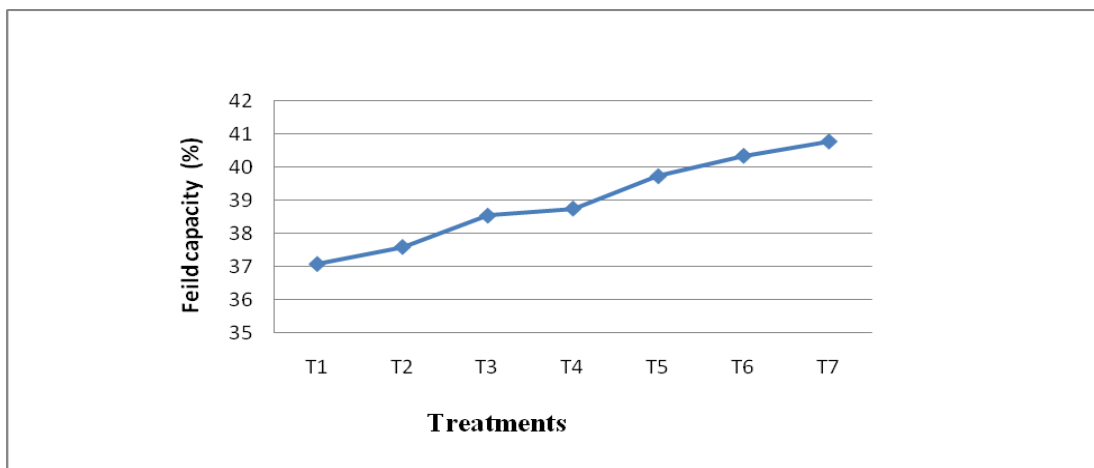


Fig.4.1.5 Effect of fly ash application on field capacity of soil (0-15 cm depth)

From column it observed that the field capacity of soil in 15-30 cm depth ranges from 36.86 to 39.57 per cent. The lowest field capacity was observed in the treatment T₁ (36.86 %). However, the highest field capacity was observed in treatment T₇ (39.57 %) the treatments T₄, T₅ and T₆ were at par with the treatment T₇.

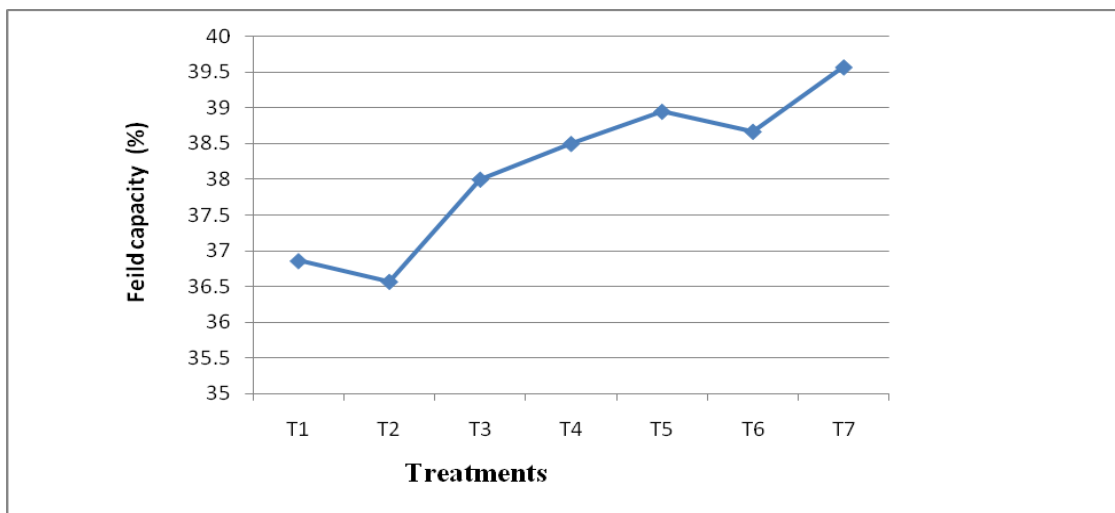


Fig.4.1.5 Effect of fly ash application on field capacity of soil (15-30 cm depth)

The samples collected from column revealed that the field capacity of soil in 30-45 cm depth ranges from 36.29 to 38.65 per cent. The lowest field capacity was noticed in the treatment T₁ (36.29 %) the treatments T₂, T₃ and T₄ were at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (38.65 %) the treatments T₅ and T₆ were at par with the treatment T₇.

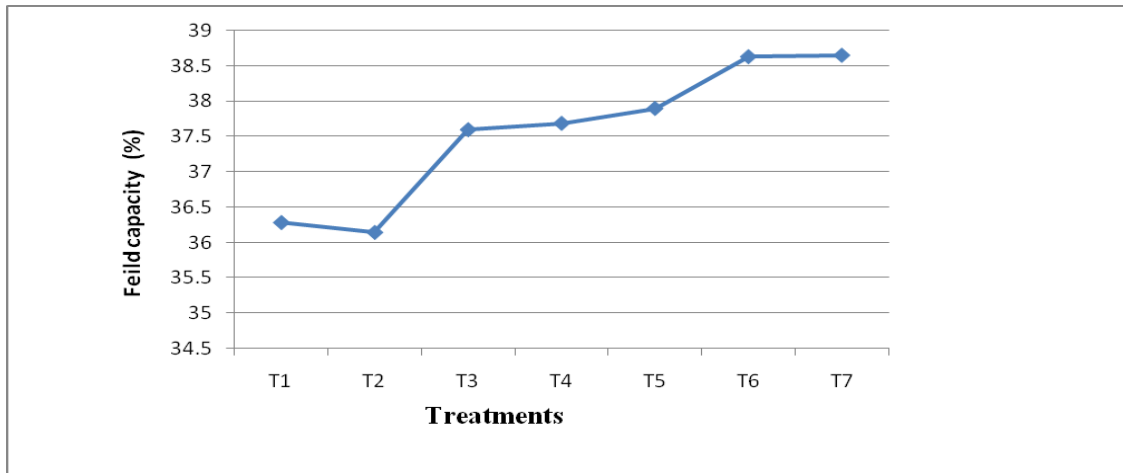


Fig.4.1.5 Effect of fly ash application on field capacity of soil (30-45 cm depth)

Samples collected from column revealed that the field capacity of soil in 45-60 cm depth ranges from 35.68 to 37.79 per cent. The lowest field capacity was showed in the treatment T₁ (35.68 %) the treatments T₂, T₃ and T₄ were at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (37.79 %) the treatments T₃, T₄, T₅ and T₆ were at par with the treatment T₇.

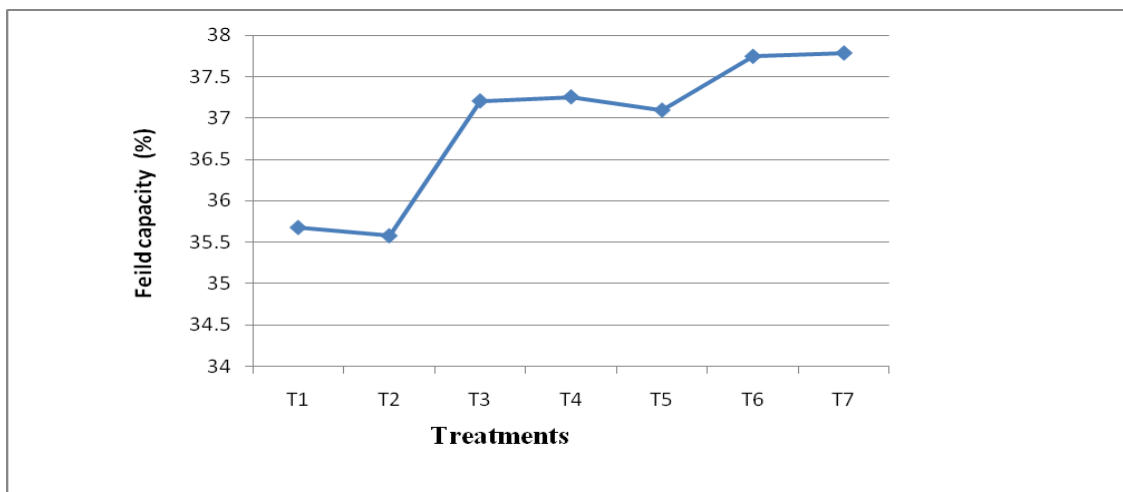


Fig.4.1.5 Effect of fly ash application on field capacity of soil (45-60 cm depth)

4.1.6 Effect of fly ash application on permanent wilting point of soil

From column it reflected that the permanent wilting point of soil in 0-15 cm depth ranges from 18.19 to 20.31 per cent. The lowest field capacity was noticed in the treatment T₁ (18.19 %) the treatment T₂ was at par with treatment T₁. However, the significantly highest field capacity was observed in treatment T₇ (20.31 %).

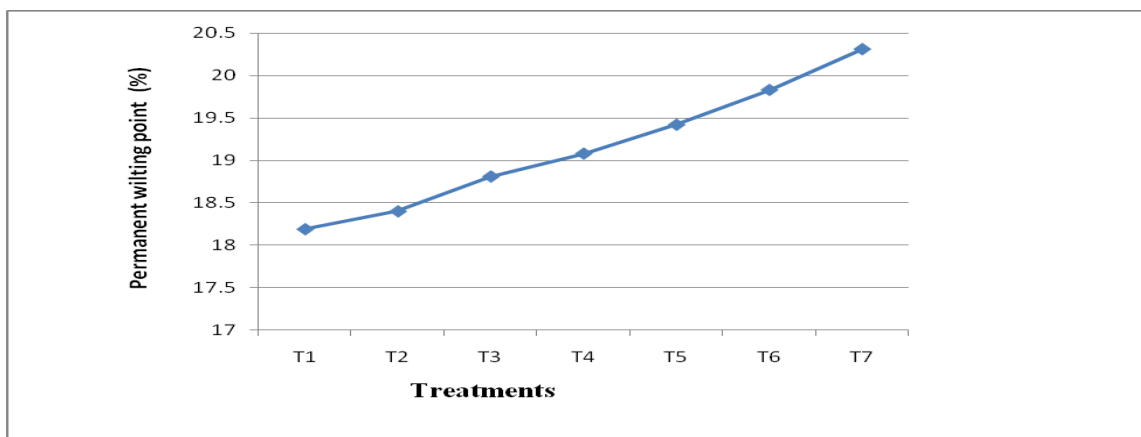


Fig.4.1.6 Effect of fly ash application on permanent wilting point of soil (0-15 cm depth)

The samples collected from column indicated that the permanent wilting point of soil in 15-30 cm depth ranges from 17.98 to 19.69 per cent. The lowest field capacity was observed in the treatment T₁ (17.98 %) the treatment T₂ was at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (19.69 %) the treatments T₆ was at par with the treatment T₇.

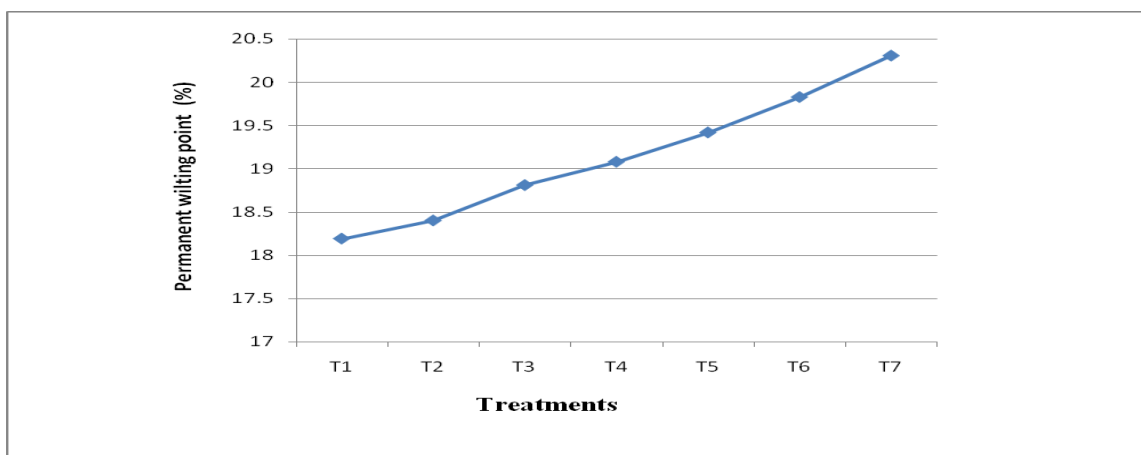


Fig.4.1.6 Effect of fly ash application on permanent wilting point of soil (15-30 cm depth)

The research data from column showed that the permanent wilting point of soil in 30-45 cm depth ranges from 17.80 to 19.88 per cent. The lowest field capacity was observed in the treatment T₁ (17.80 %) the treatment T₂ and T₃ were at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (19.88 %).

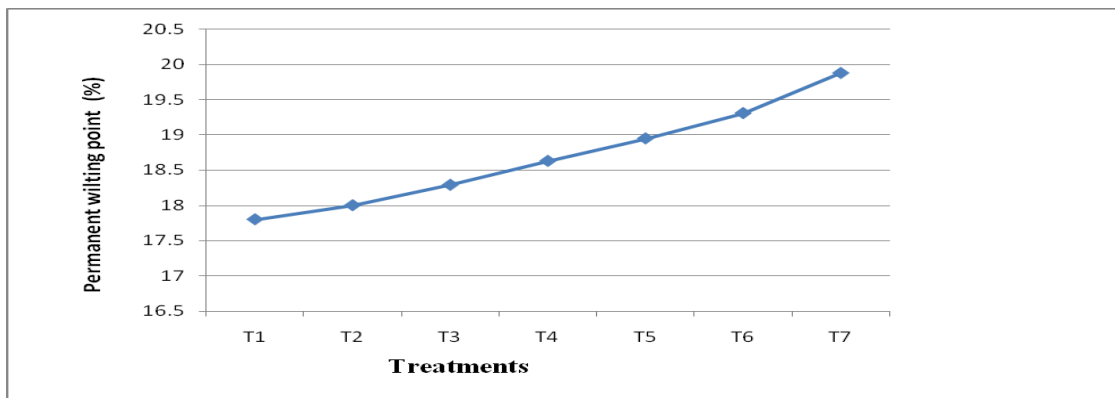


Fig.4.1.6 Effect of fly ash application on permanent wilting point of soil (30-45 cm depth)

The samples collected from column revealed that the permanent wilting point of soil in 45-60 cm depth ranges from 17.65 to 19.64 per cent. The lowest field capacity was observed in the treatment T₁ (17.65 %) the treatment T₂ was at par with the treatment T₁. However, the highest field capacity was observed in treatment T₇ (19.64 %).

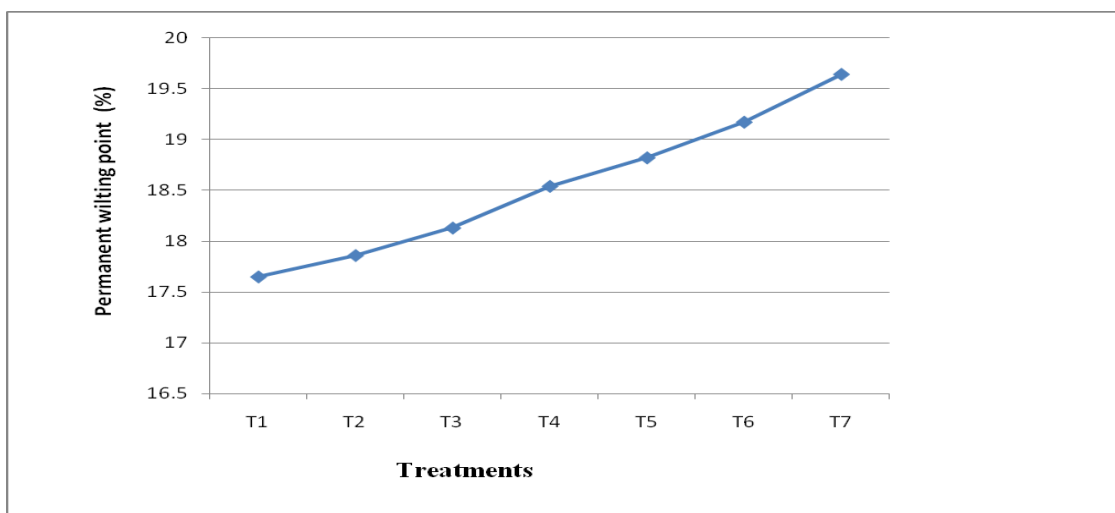


Fig.4.1.6 Effect of fly ash application on permanent wilting point of soil (45-60 cm depth)

4.2 Effect of fly ash on chemical properties of soil

4.2.1 Effect of fly ash application on soil pH (1:2.5)

The research data from column showed that the pH of soil in 0-15 cm depth ranges from 8.08 to 8.29. The significantly lowest pH was observed in the treatment T₁ (8.08). However, the significantly highest pH was observed in treatment T₇ (8.29).

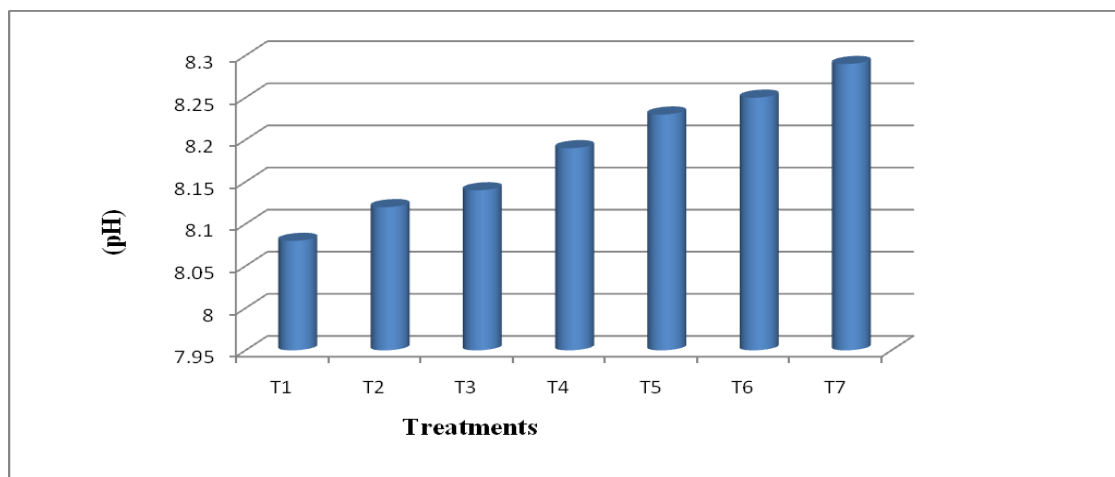


Fig.4.2.1 Effect of fly ash application on pH of soil (0-15 cm depth)

Samples collected from column revealed that the pH of soil in 15-30 cm depth ranges from 8.09 to 8.30. The significantly lowest pH was observed in the treatment T₁ (8.09). However, the significantly highest pH was observed in treatment T₇ (8.30).

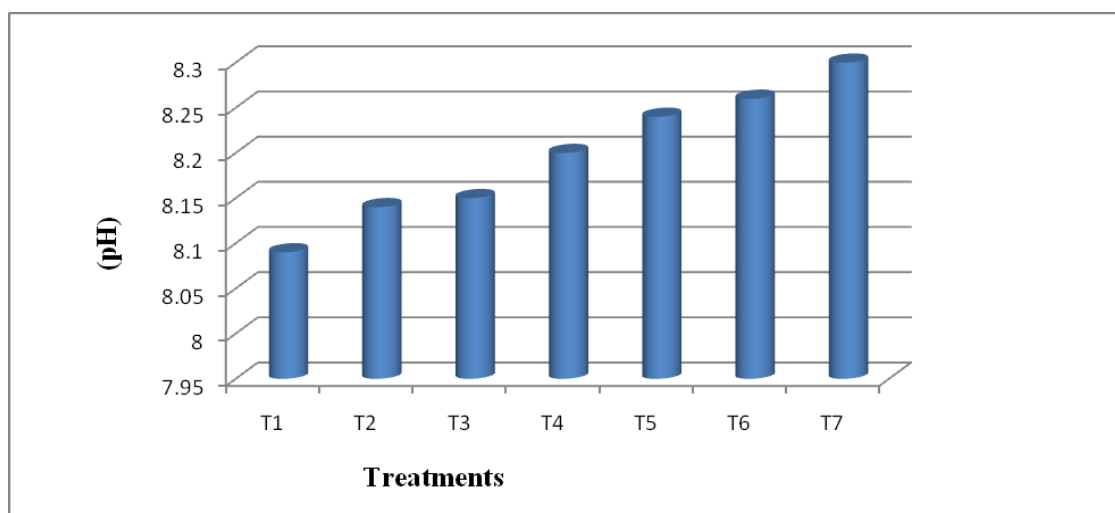


Fig.4.2.1 Effect of fly ash application on pH of soil (15-30 cm depth)

Data from column observed that the pH of soil in 30-45 cm depth ranges from 8.10 to 8.33. The significantly lowest pH was observed in the treatment T₁ (8.10). However, the significantly highest pH was observed in treatment T₇ (8.33).

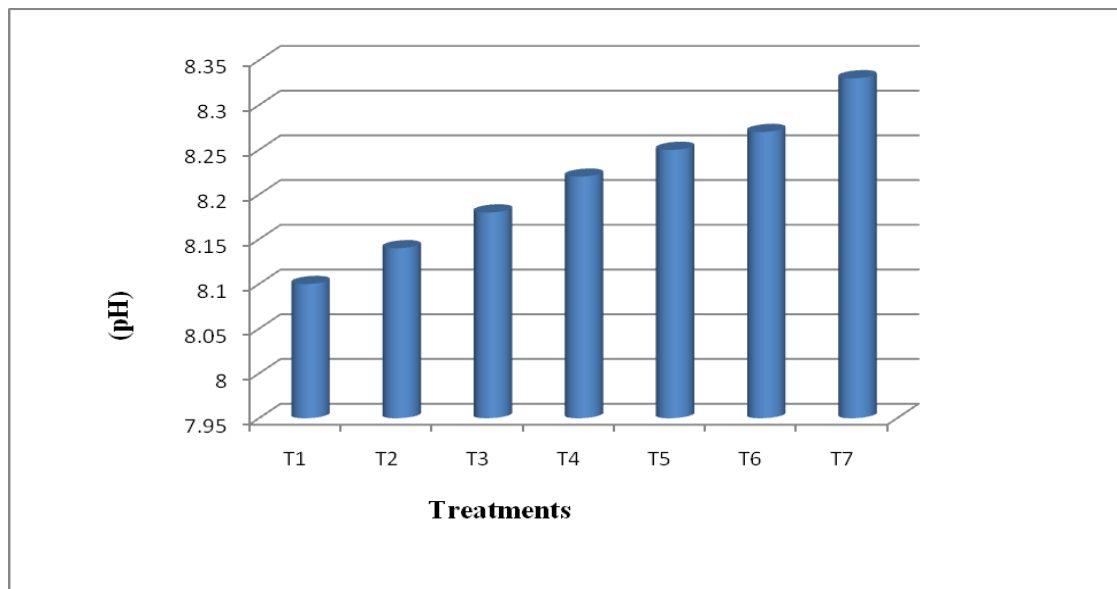


Fig. 4.2.1 Effect of fly ash application on pH of soil (30-45 cm depth)

The samples collected from column revealed that the pH of soil in 45-60 cm depth ranges from 8.14 to 8.36. The significantly lowest pH was noticed in the treatment T₁ (8.14). However, the significantly highest pH was observed in treatment T₇ (8.36).

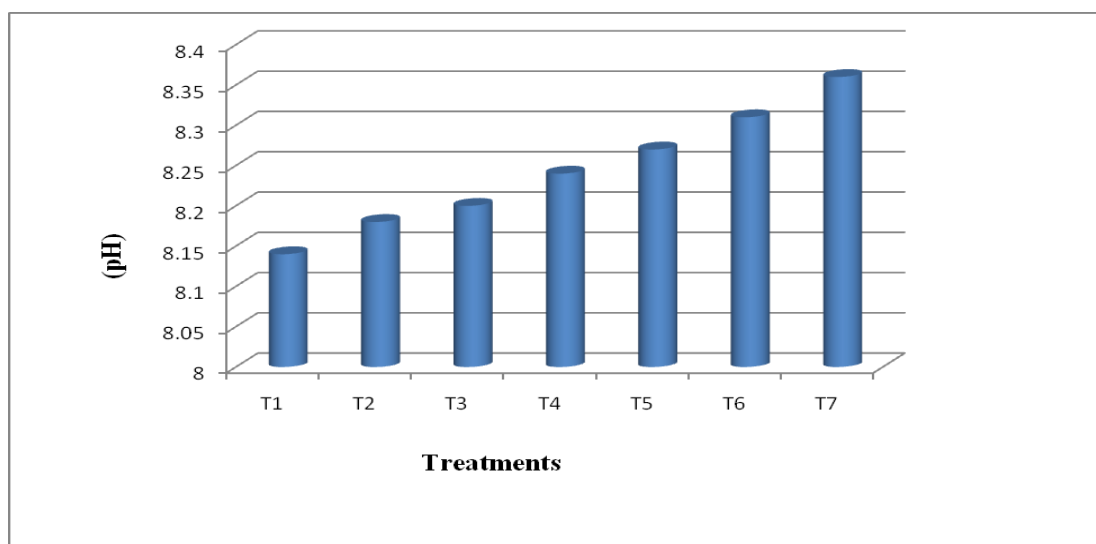


Fig. 4.2.1 Effect of fly ash application on pH of soil (45-60 cm depth)

Slightly increased in soil pH might be due to presence of secondary and small quantities of micronutrients with oxides forms in fly ash.

The fly ash although had pH of 8.2 did not influence the pH of soil which might be of high buffering capacity of Inceptisol and similar effect of fly ash on soil pH was observed by Kao *et al.* (1991) and Pande *et al.* (1985)

The effect of different treatment combinations on soil pH is presented in the table. The application of different fly ash doses either with or without FYM had no significant influence on soil reaction. The Khan *et al.* (2008) also observed non significant effect of fly ash on soil reaction, similar results were also concluded by Yadav (2006) and Jala (2005).

4.2.2 Effect of fly ash application on electrical conductivity of soil

The samples collected from column revealed that the electrical conductivity of soil in 0-15 cm depth ranges from 0.19 to 0.36 (dSm^{-1}). The significantly lowest electrical conductivity was noticed in the treatment T₁ 0.19 (dSm^{-1}). However, the significantly highest electrical conductivity was observed in treatment T₇ 0.36 (dSm^{-1}).

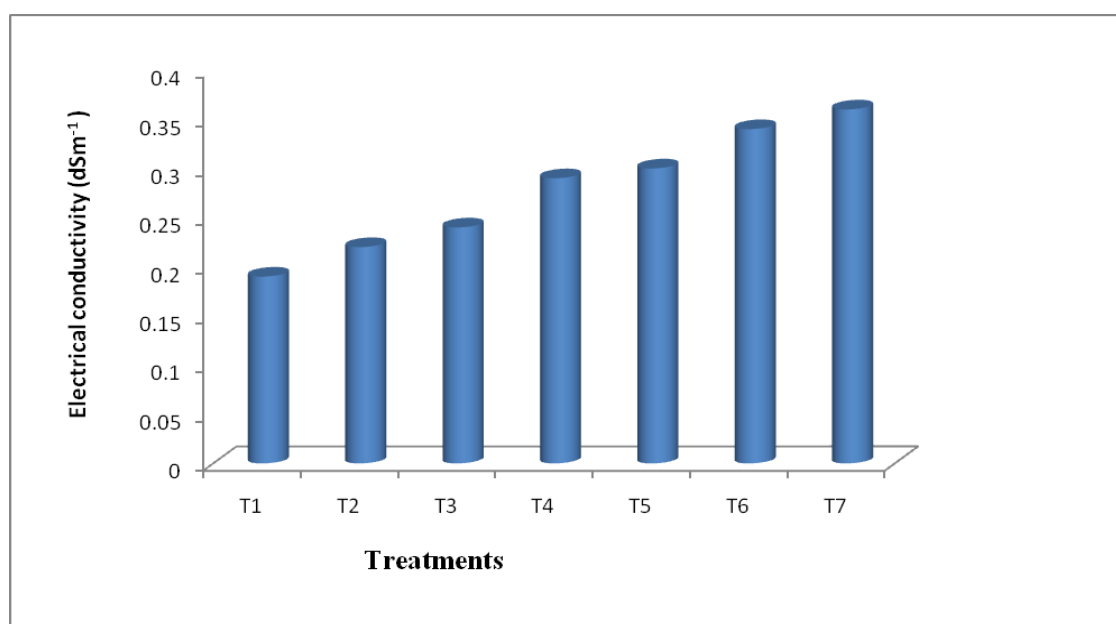


Fig 4.2.2 Effect of fly ash application on electrical conductivity of soil (0-15 cm depth)

From column observed that the electrical conductivity of soil in 15-30 cm depth ranges from 0.22 0.39 (dSm^{-1}). The significantly lowest electrical conductivity was

observed in the treatment T₁ 0.22 (dSm⁻¹). However, the significantly highest electrical conductivity was observed in treatment T₇ 0.39 (dSm⁻¹).

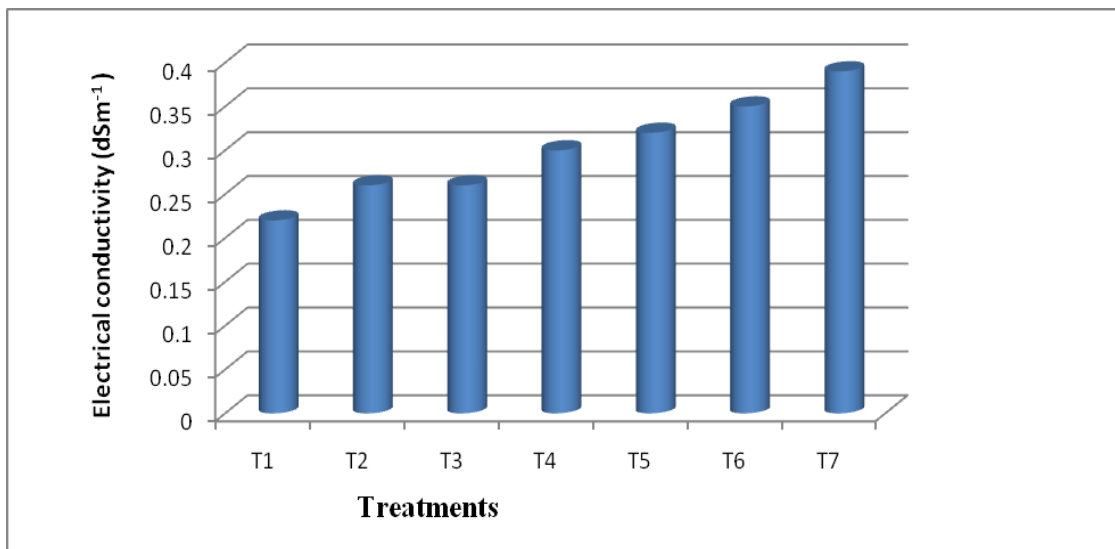


Fig. 4.2.2 Effect of fly ash application on electrical conductivity of soil (15-30 cm depth)

The samples collected from column showed that the electrical conductivity of soil in 30-45 cm depth ranged from 0.27 to 0.34 (dSm⁻¹). The significantly lowest electrical conductivity was observed in the treatment T₁ 0.27 (dSm⁻¹). However, the significantly highest electrical conductivity was observed in treatment T₇ 0.34 (dSm⁻¹).

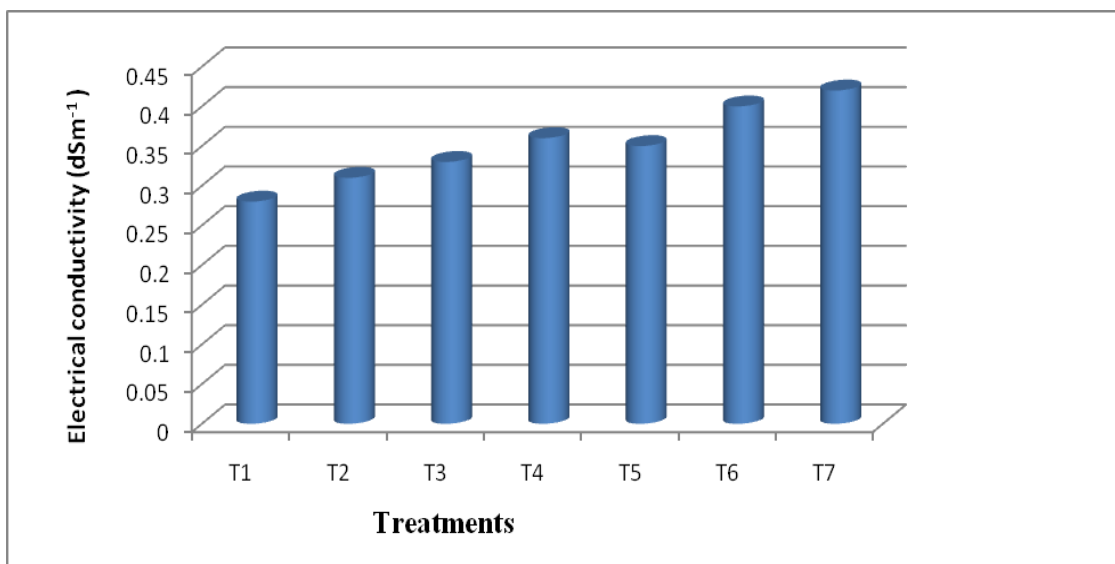


Fig. 4.2.2 Effect of fly ash application on electrical conductivity of soil (30-45 cm depth)

The research data from column revealed that the electrical conductivity of soil in 45-60 cm depth ranges from 0.28 to 0.42 (dSm^{-1}). The lowest electrical conductivity was observed in the treatment T_1 0.28 (dSm^{-1}). However, the highest electrical conductivity was observed in treatment T_7 0.42 (dSm^{-1}).

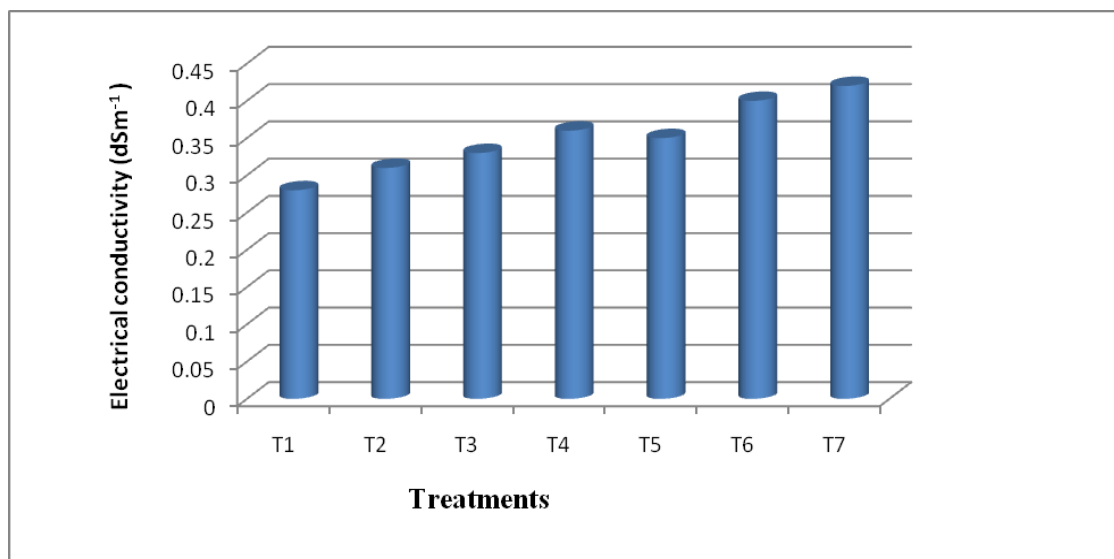


Fig. 4.2.2 Effect of fly ash application on electrical conductivity of soil (45-60 cm depth)

The electrical conductivity of soil did not differ significantly in all the treatment combinations applied. Khan *et al.* (2008) and Yadav (2006) also observed that no effect of fly ash application on electrical conductivity of soil.

Table 4.4 pH and electrical conductivity of soil as influenced by application of fly ash

Tr. No.	Treatment details	pH (1:2.5)				Electrical Conductivity (dSm^{-1})			
		0-15 cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	8.08	8.09	8.10	8.14	0.19	0.22	0.27	0.28
T ₂	Soil + 1 t ha ⁻¹ fly ash	8.12	8.14	8.14	8.18	0.22	0.26	0.28	0.31
T ₃	Soil + 5 t ha ⁻¹ fly ash	8.14	8.15	8.18	8.20	0.24	0.26	0.29	0.33
T ₄	Soil + 10 t ha ⁻¹ fly ash	8.19	8.20	8.22	8.24	0.29	0.30	0.32	0.36
T ₅	Soil + 15 t ha ⁻¹ fly ash	8.23	8.24	8.25	8.27	0.30	0.32	0.34	0.35
T ₆	Soil + 20 t ha ⁻¹ fly ash	8.25	8.26	8.27	8.31	0.34	0.35	0.37	0.40
T ₇	Soil + 25 t ha ⁻¹ fly ash	8.29	8.3	8.33	8.36	0.36	0.39	0.34	0.42
	SE ±	0.011	0.009	0.008	0.013	0.009	0.010	0.015	0.016
	CD at 5 %	0.033	0.027	0.025	0.040	0.028	0.035	0.045	0.049
	Initial	8.08				0.19			

4.2.3 Effect of fly ash application on organic carbon soil

The research data from column revealed that the organic carbon of soil in 0-15 cm depth ranges from 0.47 to 0.50 per cent. The significantly lowest organic carbon was noticed in the treatment T₁ (0.47 %). However, the significantly highest organic carbon was observed in treatment T₇ (0.50 %).

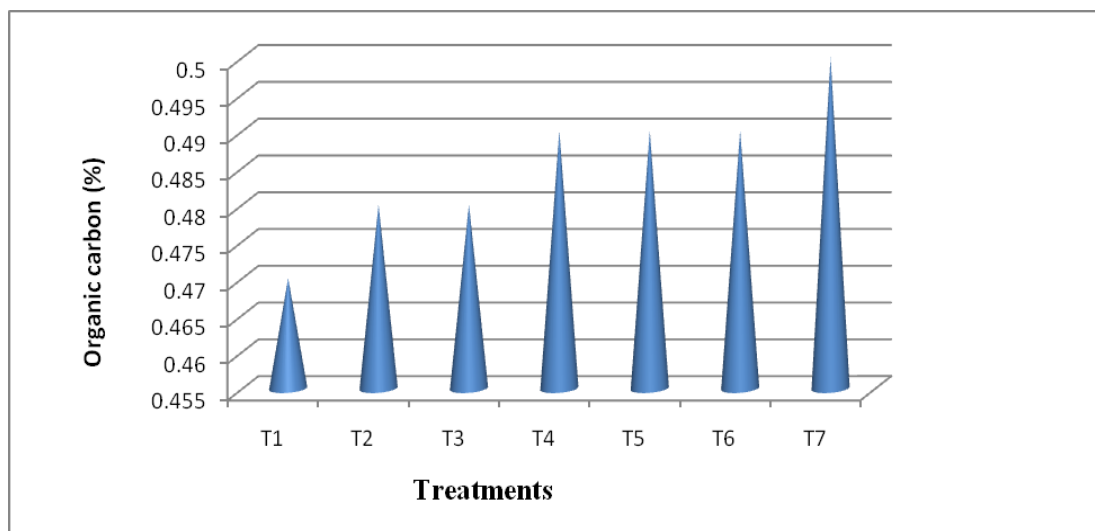


Fig. 4.2.3 Effect of fly ash application on organic carbon soil (0-15 cm depth)

The data pertaining to the organic carbon of soil noticed that in 15-30 cm depth ranges from 0.47 to 0.48 per cent. The significantly lowest organic carbon was observed in the treatment T₁ (0.47 %). However, the significantly highest organic carbon was observed in treatment T₇ (0.48 %).

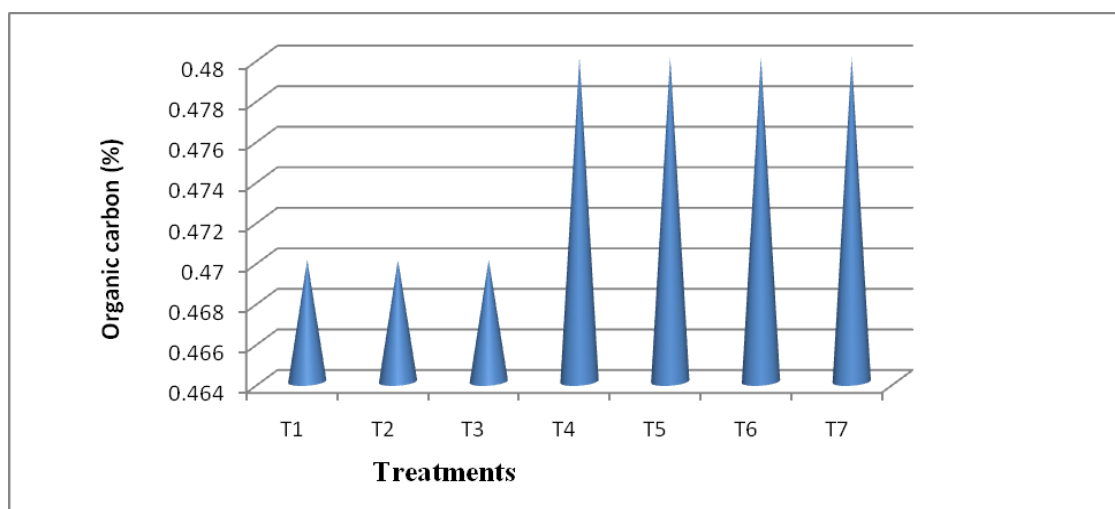


Fig. 4.2.3 Effect of fly ash application on organic carbon soil (15-30 cm depth)

The data of research revealed that the organic carbon of soil in 30-45 cm depth ranges from 0.47 to 0.50 per cent. The significantly lowest organic carbon was observed in the treatment T₁ (0.47 %). However, the significantly highest organic carbon was observed in treatment T₇ (0.50 %).

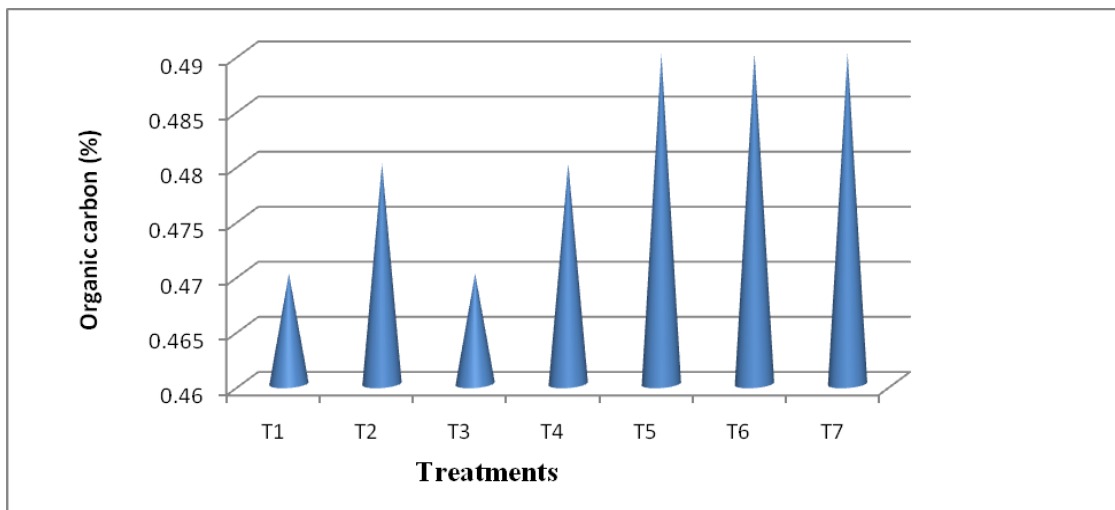


Fig. 4.2.3 Effect of fly ash application on organic carbon soil (30-45 cm depth)

From column revealed that the organic carbon of soil in 45-60 cm depth ranges from 0.47 to 0.49 per cent. The significantly lowest organic carbon was observed in the treatment T₁ (0.47 %). However, the significantly highest organic carbon was observed in treatment T₇ (0.49 %).

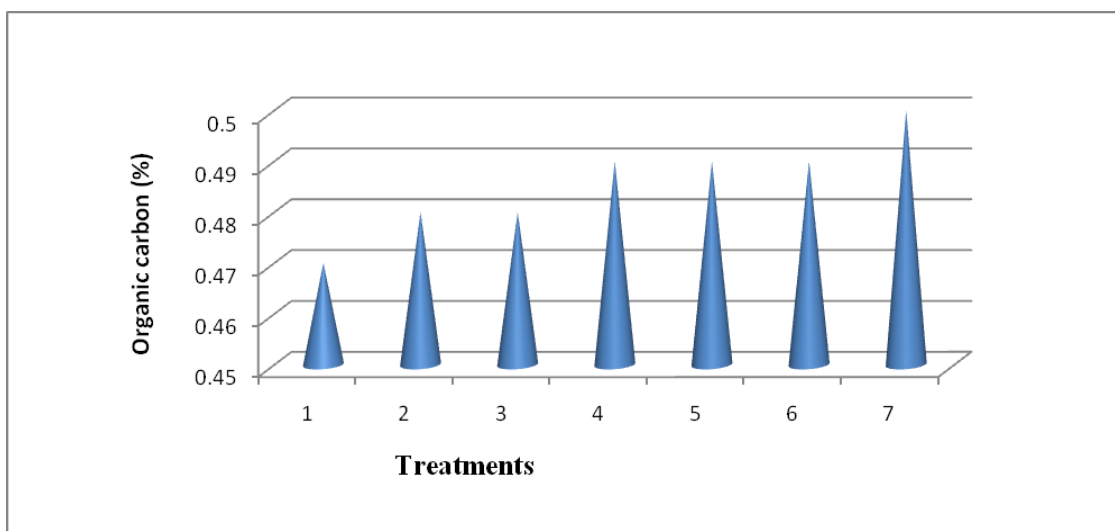


Fig. 4.2.3 Effect of fly ash application on organic carbon soil (45-60 cm depth)

The organic carbon content in soil as influenced by application of fly ash and showed non significant results. Similar observations were also observed by Lee *et al.* (2005) and Tejasvi *et al.* (2012).

4.2.4 Effect of fly ash application on cation exchange capacity of soil

The data of research indicated that the cation exchange capacity of soil in 0-15 cm depth ranges from 47.16 to 49.89 ($\text{cmol (p}^+) \text{ kg}^{-1}$). The lowest cation exchange capacity was noticed in the treatment T₁ (47.16 ($\text{cmol (p}^+) \text{ kg}^{-1}$)) the treatment T₂ was at par with T₁. However, the highest cation exchange capacity was observed in treatment T₇ (49.89 ($\text{cmol (p}^+) \text{ kg}^{-1}$)) the treatment T₄, T₅ and T₆ were at par with T₇.

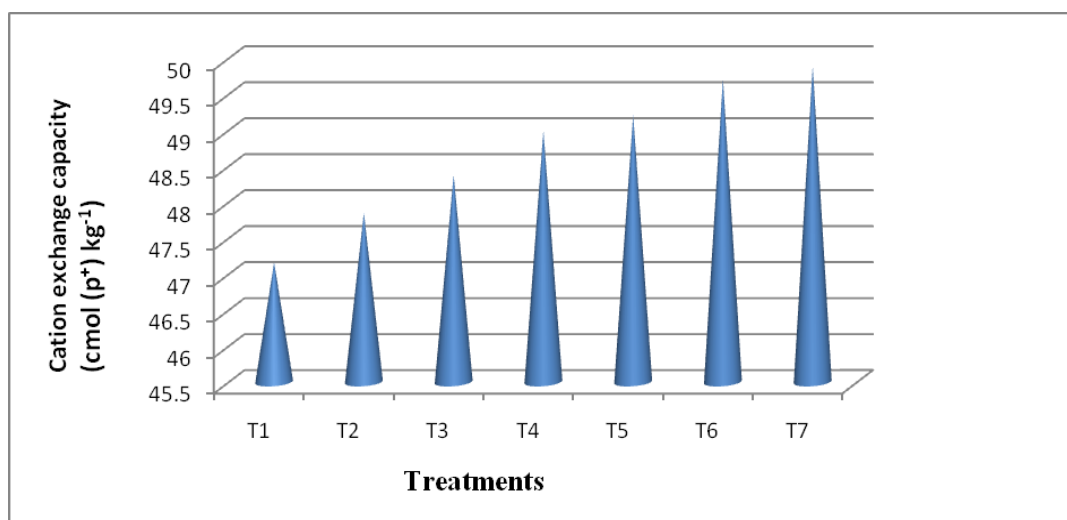


Fig. 4.2.4 Effect of fly ash application on cation exchange capacity of soil (0-15 cm depth)

The research data from column observed that the cation exchange capacity of soil in 15-30 cm depth ranges from 45.51 to 48.49 ($\text{cmol (p}^+) \text{ kg}^{-1}$). The significantly lowest cation exchange capacity was observed in the treatment T₁ (45.51 ($\text{cmol (p}^+) \text{ kg}^{-1}$)). However, the significantly highest cation exchange capacity was observed in treatment T₇ (48.49 ($\text{cmol (p}^+) \text{ kg}^{-1}$)).

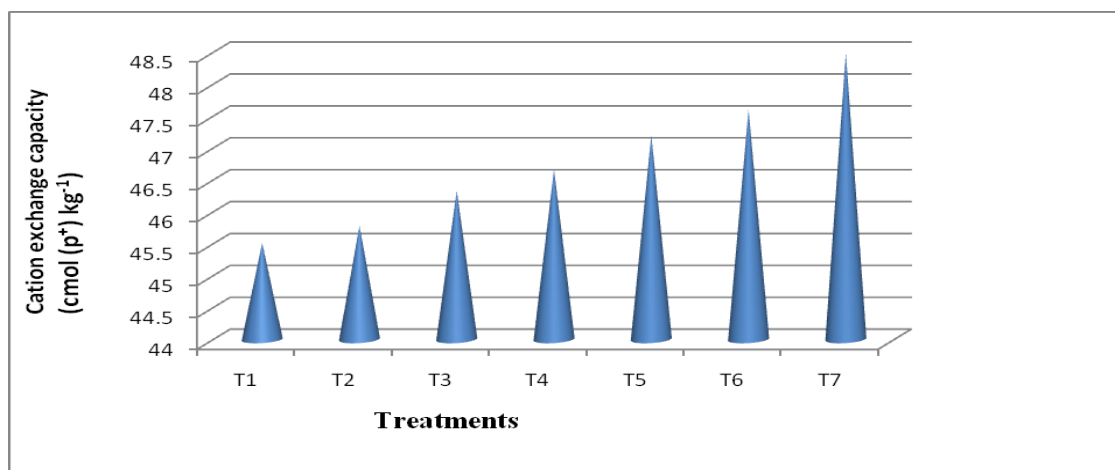


Fig. 4.2.4 Effect of fly ash application on cation exchange capacity of soil (15-30 cm depth)

From column revealed that the cation exchange capacity of soil in 30-45 cm depth ranges from 46.67 to 50.12 (cmol (p⁺) kg⁻¹). The significantly lowest cation exchange capacity was observed in the treatment T₁ (46.67 (cmol (p⁺) kg⁻¹)). However, the significantly highest cation exchange capacity was observed in treatment T₇ (50.12 (cmol (p⁺) kg⁻¹)).

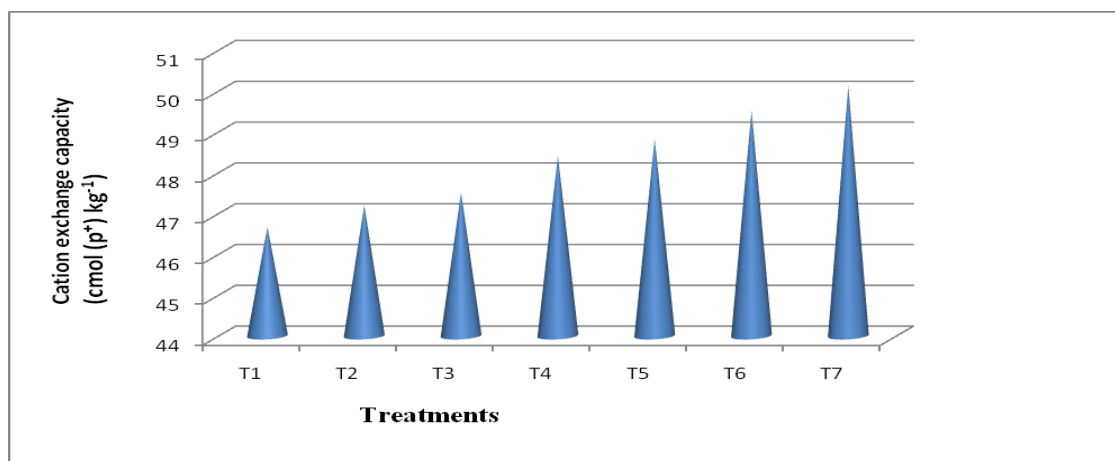


Fig. 4.2.4 Effect of fly ash application on cation exchange capacity of soil (30-45 cm depth)

The samples collected from column revealed that the cation exchange capacity of soil in 45-60 cm depth ranges from 45.51 to 48.49 (cmol (p⁺) kg⁻¹). The significantly lowest cation exchange capacity was observed in the treatment T₁ (45.51

($\text{cmol (p}^+) \text{ kg}^{-1}$). However, the significantly highest cation exchange capacity was observed in treatment T₇ (48.49 ($\text{cmol (p}^+) \text{ kg}^{-1}$)).

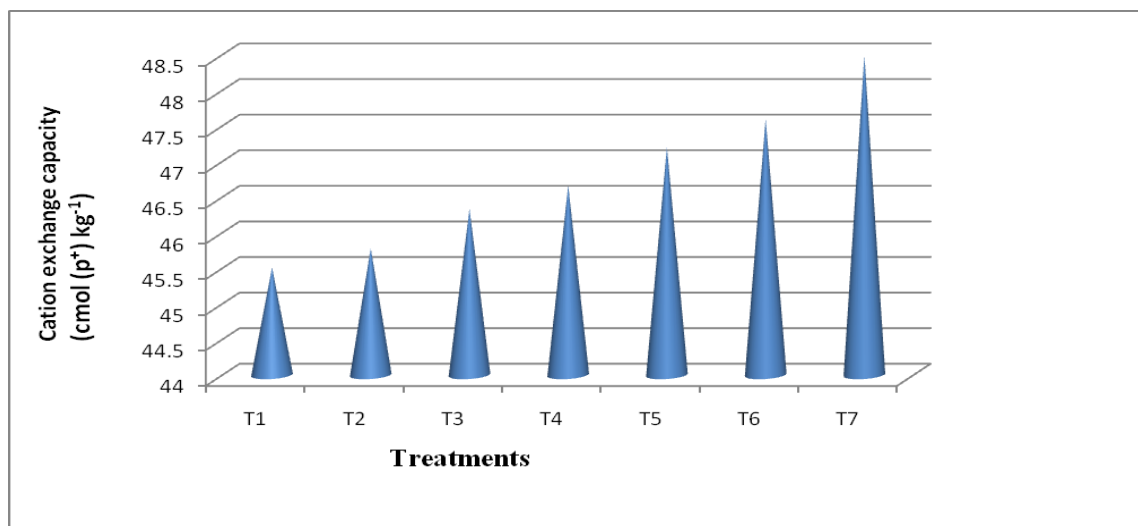


Fig. 4.2.4 Effect of fly ash application on cation exchange capacity of soil (45-60 cm depth)

The data pertaining to cation exchange capacity are presented in (Table 4.6). The application of fertilizer and fly ash with and without FYM not significantly increase the cation exchange capacity of soil. Similar results observed by Khan *et al.* (2008).

Table 4.5 Organic carbon and cations exchange capacity of soil as influenced by application of fly ash

Tr. No.	Treatment details	Organic carbon (%)				Cation exchange capacity ($\text{cmol (p}^+) \text{ kg}^{-1}$)			
		0-15 Cm	15-30 cm	30-45 cm	45-60 cm	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	0.47	0.47	0.47	0.47	47.16	45.51	46.67	45.51
T ₂	Soil + 1 t ha ⁻¹ fly ash	0.48	0.47	0.48	0.48	47.85	45.78	47.20	45.78
T ₃	Soil + 5 t ha ⁻¹ fly ash	0.48	0.47	0.48	0.47	48.38	46.33	47.51	46.33
T ₄	Soil + 10 t ha ⁻¹ fly ash	0.49	0.48	0.49	0.48	48.99	46.66	48.41	46.66
T ₅	Soil + 15 t ha ⁻¹ fly ash	0.49	0.48	0.49	0.49	49.21	47.20	48.82	47.20
T ₆	Soil + 20 t ha ⁻¹ fly ash	0.49	0.48	0.49	0.49	49.71	47.6	49.52	47.6
T ₇	Soil + 25 t ha ⁻¹ fly ash	0.50	0.48	0.50	0.49	49.89	48.49	50.12	48.49
	SE ±	0.006	0.002	0.006	0.004	0.320	0.052	0.132	0.052
	CD at 5 %	NS	NS	NS	NS	0.97	0.15	0.40	0.15
	Initial	0.47				47.16			

4.2.5 Effect of fly ash application on calcium carbonate of soil

Samples collected from column indicated that the calcium carbonate of soil in 0-15 cm depth ranges from 6.06 to 7.4 per cent. The significantly lowest calcium carbonate was observed in the treatment T₁ (6.06 %). However, the significantly highest calcium carbonate was observed in treatment T₇ (7.4 %).

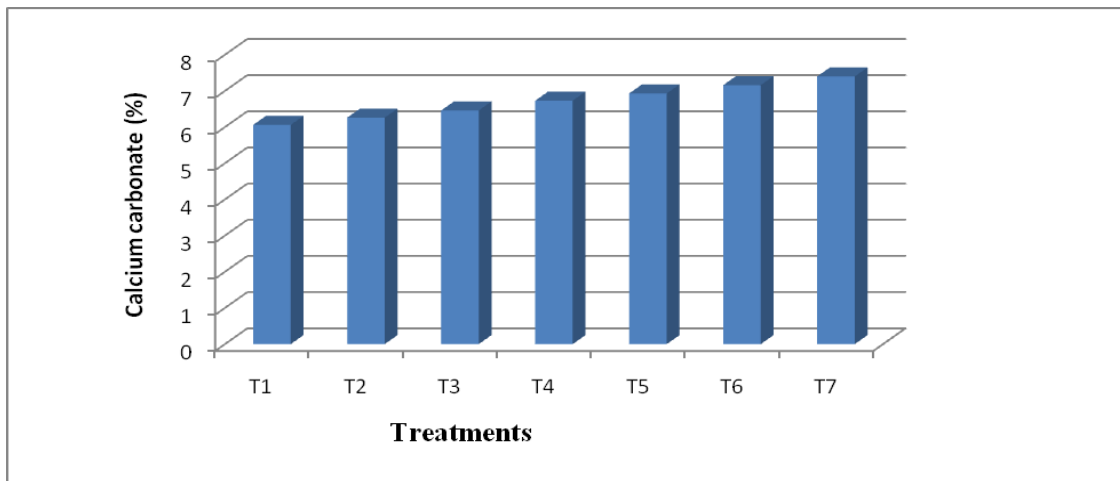


Fig. 4.2.5 Effect of fly ash application on calcium carbonate of soil (0-15 cm depth)

The samples collected from column revealed that the calcium carbonate of soil in 15-30 cm depth ranges from 6.03 to 7.26 per cent. The significantly lowest calcium carbonate was noticed in the treatment T₁ (6.03 %). However, the significantly highest calcium carbonate was observed in treatment T₇ (7.26 %).

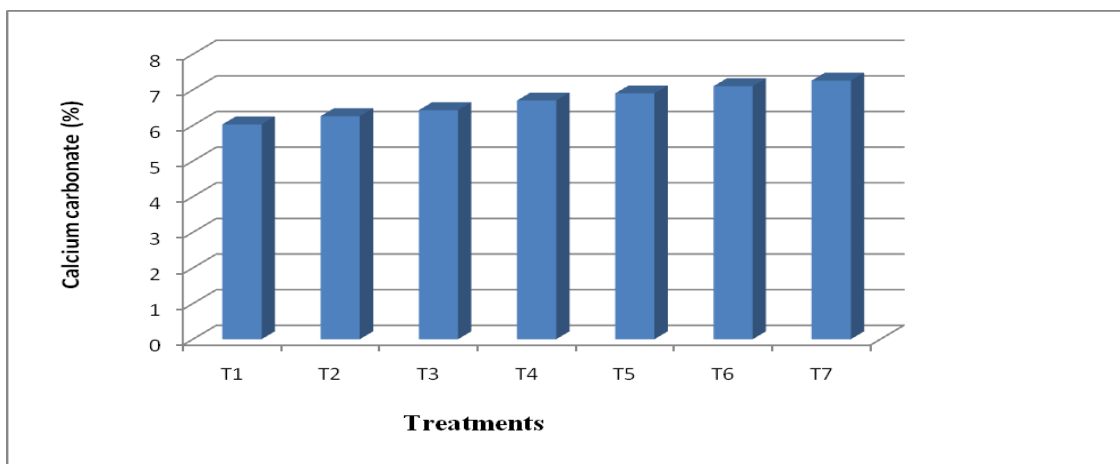


Fig. 4.2.5 Effect of fly ash application on calcium carbonate of soil (15-30 cm depth)

The research data from column reflected that the calcium carbonate of soil in 30-45 cm depth ranges from 6.03 to 7.26 per cent. The significantly lowest calcium carbonate was noticed in the treatment T₁ (6.03 %). However, the significantly highest calcium carbonate was observed in treatment T₇ (7.26 %).

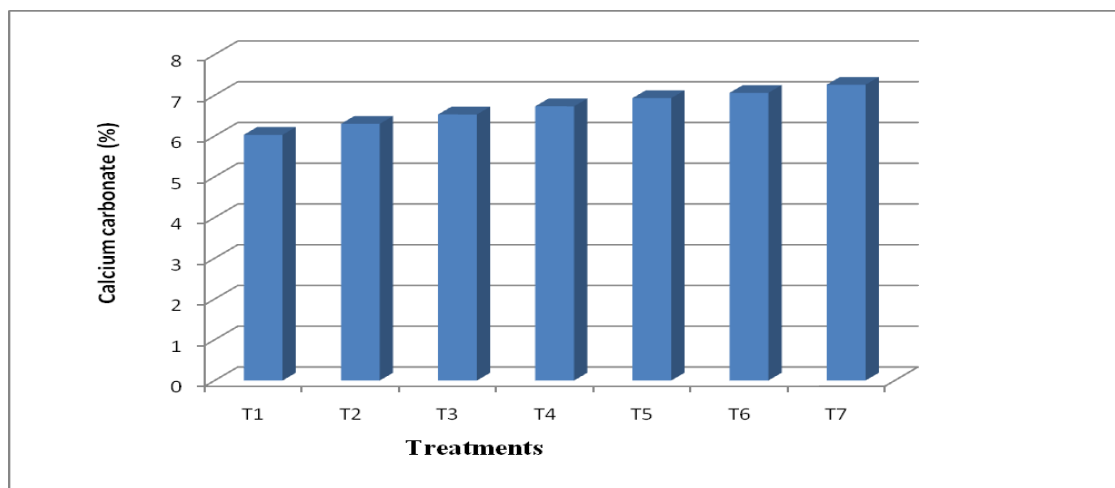


Fig. 4.2.5 Effect of fly ash application on calcium carbonate of soil (30-45 cm depth)

The data pertaining to calcium carbonate revealed that the calcium carbonate of soil in 45-60 cm depth ranges from 6.06 to 7.3 per cent. The significantly lowest calcium carbonate was showed in the treatment T₁ (6.06 %). However, the significantly highest calcium carbonate was observed in treatment T₇ (7.3 %).

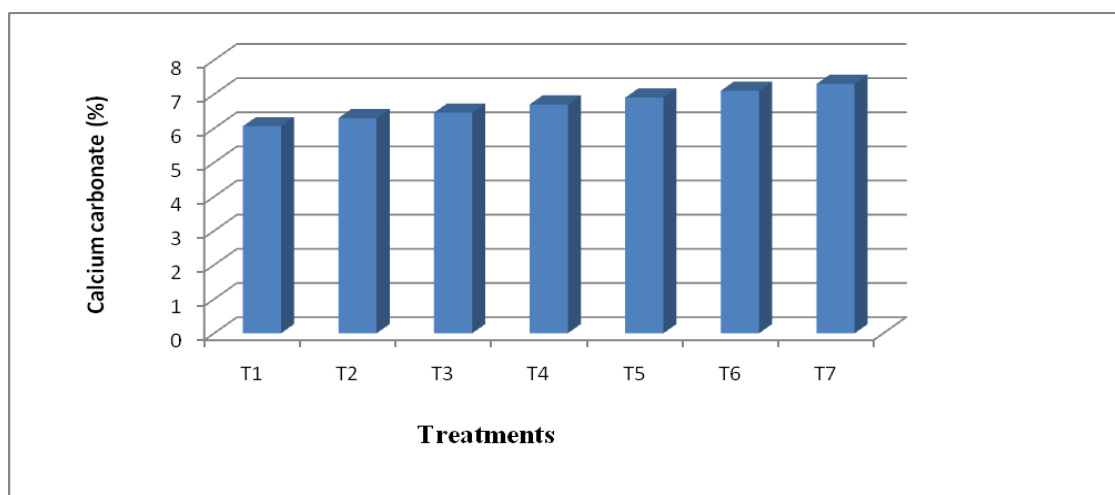


Fig. 4.2.5 Effect of fly ash application on calcium carbonate of soil (45-60 cm depth)

Table 4.6 Calcium carbonate of soil as influenced by application of fly ash

Tr. No.	Treatment details	Calcium carbonate (%)			
		0-15 cm	15-30 cm	30-45 cm	45-60 cm
T ₁	Soil only	6.06	6.03	6.03	6.06
T ₂	Soil + 1 t ha ⁻¹ fly ash	6.26	6.26	6.3	6.3
T ₃	Soil + 5 t ha ⁻¹ fly ash	6.46	6.43	6.53	6.46
T ₄	Soil + 10 t ha ⁻¹ fly ash	6.73	6.7	6.73	6.7
T ₅	Soil + 15 t ha ⁻¹ fly ash	6.93	6.9	6.93	6.9
T ₆	Soil + 20 t ha ⁻¹ fly ash	7.16	7.1	7.06	7.1
T ₇	Soil + 25 t ha ⁻¹ fly ash	7.4	7.26	7.26	7.3
	SE ±	0.065	0.033	0.037	0.035
	CD at 5 %	0.198	0.101	0.114	0.108
	Initial	6.06			

4.3 Effect of fly ash on leachate properties of soil

4.3.1 Effect of fly ash application on anions of soil after 30 days of leachate

The data on anions content of soil (after 60 days of leachate analysis) presented in table 4.7 revealed that the application of fly ash observed the anions in the soil.

Effect of fly ash application on bicarbonates of soil leachate

The research data collected from column after 30 days revealed that the bicarbonate in soil ranged from 6.33 to 7.1 me L⁻¹. The significantly lowest bicarbonate was observed in the treatment T₁ (6.33 me L⁻¹). However, the significantly highest bicarbonate was observed in treatment T₇ (7.71 me L⁻¹).

Effect of fly ash application on chlorides of soil leachate

The analysis of leachate at 30 days for chloride revealed that the chloride in soil ranged from 5.9 to 5.8 me L⁻¹. The significantly lowest chloride was observed in the treatment T₁ 5.9 (me L⁻¹). However, the significantly highest chloride was observed in treatment T₇ 5.8 (me L⁻¹).

Effect of fly ash application on sulphates of soil leachate

The samples collected from column after 30 days revealed that the sulphate in soil ranged from 2.31 to 2.33 me L⁻¹. The significantly lowest sulphate was noticed in the treatment T₁ 2.31 (me L⁻¹). However, the significantly highest sulphate was observed in treatment T₇ 2.33 (me L⁻¹).

4.3.3 Effect of fly ash application on cations of soil after 30 days of leacheate

The data on cations content of soil after 30 days of leacheate analysis presented in table 4.8 revealed that the application of fly ash observed the cations in the soil.

Effect of fly ash application on calcium of soil leacheate

Data collected from column after 30 days revealed that the calcium in soil ranged from 4.83 to 7.5 me L⁻¹. The significantly lowest cation was noticed in the treatment T₁ (4.83 me L⁻¹). However, the significantly highest cation was observed in treatment T₇ (7.5 me L⁻¹).

Effect of fly ash application on magnesium of soil leacheate

The analysis of leacheate at 30 days for magnesium revealed that the magnesium in soil ranged from 0.27 to 1.16 me L⁻¹. The lowest magnesium was observed in the treatment T₁ (0.27 me L⁻¹) the treatments T₂ and T₃ at par with the treatment T₁. However, the significantly highest cation was observed in treatment T₇ (1.16 me L⁻¹).

Effect of fly ash application on potassium of soil leacheate

The samples collected from column after 30 days revealed that the potassium in soil ranged from 1.32 to 2.96 me L⁻¹. The lowest potassium was noticed in the treatment T₁ (1.32 me L⁻¹) the treatment T₂ at par with the treatment T₁. However, the highest potassium was observed in treatment T₇ (2.96 me L⁻¹) the treatment T₆ at par with the treatment T₇.

Effect of fly ash application on sodium of soil leacheate

The samples collected from column after 30 days revealed that the sodium in soil ranged from 0.58-0.59 me L⁻¹. The lowest sodium was observed in the treatment T₁ (0.58 me L⁻¹). However, the highest sodium was observed in treatment T₇ (0.59 me L⁻¹).

4.3.4 Effect of fly ash application on cations of soil after 60 days of leacheate

The data on cations content of soil after 60 days of leacheate analysis presented in table 4.8 revealed that the application of fly ash observed the cations in the soil.

Effect of fly ash application on calcium of soil leacheate

The research data from column after 60 days revealed that the calcium in soil from 4.53 to 7.1 me L⁻¹. The lowest calcium was observed in the treatment T₁ (4.53

me L⁻¹) the treatment T₂ at par with the treatment T₁. However, the highest calcium was observed in treatment T₇ (7.1 me L⁻¹).

Effect of fly ash application on magnesium of soil leachate

Samples collected from column after 60 days revealed that the magnesium in soil from 0.7 to 0.73 me L⁻¹. The lowest magnesium was showed in the treatment T₁ (0.7 me L⁻¹) the treatment T₂ T₃ and T₄ at par with the treatment T₁. However, the highest magnesium was observed in treatment T₇ (0.73 me L⁻¹) that was at par with T₆.

Effect of fly ash application on potassium of soil leachate

The research data from column after 60 days observed that the potassium in soil from 1.23 to 2.89 me L⁻¹. The lowest potassium was observed in the treatment T₁ (1.23 me L⁻¹) the treatment T₂ at par with the treatment T₁. However, the highest potassium was observed in treatment T₇ (2.89 me L⁻¹) the treatment T₆ at par with the treatment T₇.

Effect of fly ash application on sodium of soil leachate

The analysis of leachate at 60 days for sodium revealed that the sodium in soil ranged from 1.23 to 2.89 me L⁻¹. The lowest sodium was noticed in the treatment T₁ (1.23 me L⁻¹) the treatment T₂, T₃ and T₄ at par with the treatment T₁. However, the highest sodium was observed in treatment T₇ (2.89 me L⁻¹) the treatment T₃, T₄, T₅ and T₆ at par with the treatment T₇.

Table 4.8 Effect of fly ash application on cations of soil after 30 and 60 days of interval

Tr. No.	Treatment details	Ca ²⁺ (me L ⁻¹)		Mg ²⁺ (me L ⁻¹)		K ⁺ (me L ⁻¹)		Na ⁺ (me L ⁻¹)	
		30 days	60 days	30 days	60 days	30 days	60 days	30 Days	60 days
T ₁	Soil only	4.83	4.53	0.27	0.7	1.32	1.23	0.58	0.58
T ₂	Soil + 1 t ha ⁻¹ fly ash	5.5	5.13	0.32	0.87	1.47	1.40	0.58	0.58
T ₃	Soil + 5 t ha ⁻¹ fly ash	6.03	5.73	0.43	0.77	1.67	1.81	0.58	0.58
T ₄	Soil + 10 t ha ⁻¹ fly ash	6.4	6.13	0.63	0.67	1.96	2.05	0.58	0.58
T ₅	Soil + 15 t ha ⁻¹ fly ash	6.73	5.63	0.80	1.27	2.36	1.99	0.58	0.59
T ₆	Soil + 20 t ha ⁻¹ fly ash	7.1	6.1	0.96	1.23	2.74	2.69	0.58	0.58
T ₇	Soil + 25 t ha ⁻¹ fly ash	7.5	7.1	1.16	0.73	2.96	2.89	0.59	0.59
	SE ±	0.12	0.21	0.06	0.10	0.05	0.14	0.006	0.005
	CD at 5 %	0.38	0.65	0.190	0.30	0.16	0.44	NS	NS

5. SUMMARY AND CONCLUSION

5.1 Summary

To evaluate agricultural utilization of fly ash, present investigation was undertaken with the fly ash obtained from thermal power station, Eklahare (Nasik). The fly ash was characterized for particle size distribution, pH, EC, bulk density, CEC, exchangeable cations, organic carbon, total elemental composition. The effect of different levels of fly ash (@ 0, 1, 5, 10, 15, 20 and 25 t ha⁻¹ on physico-chemical properties of soil. The important findings of this study are summarized below. The fly ash was observed to be equivalent to sandy loam in texture. The ash was slightly alkaline in reaction with a pH value of 8.2. EC of fly ash was low. It had low organic carbon. The fly ash addition at different rates significantly reduced the bulk density of a clay soil and resulted in increased porosity and void ratio. The saturated hydraulic conductivity of the clay soil was significantly improved by fly ash application. The magnitude of improvement was higher with the higher levels of fly ash i.e. 20 t ha⁻¹ and 25 t ha⁻¹. The pH, electrical conductivity and organic carbon of the soil were not affected by the fly ash application. The fly ash addition did not significantly affect the exchangeable cations *viz.*, Ca, Mg, Na, K of the soil under different treatments.

Effect of fly ash application on chemical properties under column study

pH

The result revealed that the different levels of fly ash application resulted notable increase in the pH values. The increased in the pH values ranged from 8.08 in treatment T₁ to 8.29 in treatment T₇ at 0-15 cm depth, 8.09 to 8.30 in T₇ at 15-30 cm depth, 8.10 to 8.33 at 30-45 cm depth and 8.14 to 8.36 at 45-60 cm depth. The lowest pH (8.08) was observed in treatment T₁ (depth 0-15 cm). The highest increased in pH (8.36) was observed in treatment T₇ (depth 45-60 cm) and significant over initial.

Electrical conductivity

With application of fly ash increased the electrical conductivity with treatment wise but depth wise there is slightly increase in the EC of soil. The increased in the EC values ranged from 0.19 to 0.36 dSm⁻¹ at 0-15 cm depth, 0.22 to 0.39 dSm⁻¹ in T₇ at 15-30 cm depth, 0.27 to 0.34 dSm⁻¹ at 30-45 cm depth and 0.28 to 0.42 dSm⁻¹ at 45-60 cm depth. The lowest EC (0.19 dSm⁻¹) was observed in treatment T₁ (depth 0-15 cm).

The highest increased in EC (0.42 dSm^{-1}) was observed in treatment T_7 (depth 45-60 cm) and significant over initial.

Organic carbon

There was no significant increase in organic carbon content by application of fly ash to the soil. The organic carbon ranged from 0.47 per cent in treatment T_1 to 0.50 per cent in treatment T_7 at 0-15 cm depth, 0.47 to 0.48 per cent in T_7 at 15-30 cm depth, 0.47 to 0.50 per cent at 30-45 cm depth and 0.47 to 0.49 per cent at 45-60 cm depth. In case of fly ash due to the nearly absent of organic carbon it does not effect on the change in organic carbon with the increasing level of fly ash.

Free Calcium carbonate

There was increased in free CaCO_3 as the treatment of fly ash increases. It was ranged from 6.06 per cent in treatment T_1 to 7.4 per cent in treatment T_7 at 0-15 cm depth, 6.03 to 7.26 per cent in T_7 at 15-30 cm depth, 6.03 to 7.26 per cent at 30-45 cm depth and 6.06 to 7.3 per cent at 45-60 cm depth. This increased per cent CaCO_3 content might be also due to addition of Ca^{2+} through fly ash and also replacement of native Ca^{2+} ions which may have been further precipitated as calcium carbonate.

Cation exchange capacity

The soil cation exchange capacity of soil was increased due to the fly ash application. It was ranged from $47.16 \text{ cmol (p}^+) \text{ kg}^{-1}$ in treatment T_1 to $49.89 \text{ cmol (p}^+) \text{ kg}^{-1}$ in treatment T_7 at 0-15 cm depth, $45.51 \text{ cmol (p}^+) \text{ kg}^{-1}$ to $48.49 \text{ v in } T_7$ at 15-30 cm depth, 46.67 to $50.12 \text{ cmol (p}^+) \text{ kg}^{-1}$ at 30-45 cm depth and $45.51 \text{ cmol (p}^+) \text{ kg}^{-1}$ to $48.49 \text{ cmol (p}^+) \text{ kg}^{-1}$ at 45-60 cm depth.

In experimental soil the significantly highest cation exchange capacity ($50.12 \text{ cmol (p}^+) \text{ kg}^{-1}$, depth of 30-45 cm) was observed in treatment T_7 , received fly ash @ 25 t ha^{-1} and the lowest cation exchange capacity of soil ($45.51 \text{ cmol(p}^+) \text{ kg}^{-1}$) observed in (T_1 , depth of 15-30 cm).

Effect of fly ash on physical properties of soil

Bulk density

The fly ash application to soil significantly reduced the bulk density from 1.40 to 1.28 Mg m^{-3} in treatment T_7 at 0-15 cm depth, 1.41 to 1.30 Mg m^{-3} in T_7 at 15-30 cm depth, 1.40 to 1.32 Mg m^{-3} at 30-45 cm depth and 1.43 to 1.36 Mg m^{-3} at 45-60 cm depth. However, the bulk density was observed slightly higher as the depth of soil

increases. The fly ash application effect more on surface soil (0-15 cm) as compared to the sub surface soil (45-60 cm).

The lowest bulk density (1.28 Mg m^{-3}) in surface soil and (1.36 Mg m^{-3}) in subsurface soil was obtained in T_7 which was significantly superior over T_1 . The highest bulk density was observed in T_1 (control) i.e. 1.40 Mg m^{-3} where the depth highest 45-60 cm.

Hydraulic conductivity

The hydraulic conductivity of experimental soil was increase due to fly ash application over initial and (T_1).

The hydraulic conductivity ranged from 0.98 to 1.11 cmh^{-1} in treatment T_7 at 0-15 cm depth, 1.02 to 1.12 cmh^{-1} in T_7 at 15-30 cm depth, 1.05 to 1.15 cmh^{-1} at 30-45 cm depth and 1.07 to 1.15 cmh^{-1} at 45-60 cm depth.

Aggregate stability

The aggregate stability decreased from 61.11 to 59.65 per cent in treatment T_7 at 0-15 cm depth, 61.34 to 60.10 per cent in T_7 at 15-30 cm depth, 60.93 to 59.61 per cent at 30-45 cm depth and 60.98 to 59.90 per cent at 45-60 cm depth.

Mean weight diameter

The MWD increased from 0.76 to 0.81 mm in treatment T_7 at 0-15 cm depth, 0.76 to 0.81 mm in T_7 at 15-30 cm depth, 0.76 to 0.81 mm at 30-45 cm depth and 0.76 to 0.81 mm at 45-60 cm depth.

The larger MWD values for the soils exhibit a further significant improvement in the larger aggregates with the addition of fly ash. However, the mean weight diameter in concern to the soil depth slightly decreased. The highest MWD observed in depth 0-15 cm i.e. 0.81 mm in treatment T_7 and lowest MWD in 45-60 cm in treatment T_1 and T_2 .

Field capacity

The field capacity of soil increased significantly as the treatment of fly ash increased. The field capacity of experimental soil increased from 37.09 to 40.76 per cent in treatment T_7 at 0-15 cm depth, 36.86 to 39.57 per cent in T_7 at 15-30 cm depth, 36.29 to 38.65 per cent at 30-45 cm depth and 35.68 to 37.79 per cent at 45-60 cm depth. The treatment T_7 was observed significantly superior over initial and control.

Permanent wilting point

It was increased slightly due to application of fly ash. The permanent wilting point of experimental soil increased from 18.19 to 20.31 per cent in treatment T₇ at 0-15 cm depth, 17.98 to 19.69 per cent in T₇ at 15-30 cm depth, 17.80 to 19.88 per cent at 30-45 cm depth and 17.65 to 19.64 per cent at 45-60 cm depth. The treatment T₇ was observed significantly superior over initial and control.

5.3 Effect of fly ash on leachate analysis of soil

Effect of fly ash application on cations of soil leachate after 30 and 60 days

Cations

The cations increases in soil (after 30 days) was ranged from (4.83 to 7.5 Ca²⁺, 0.27 to 1.16 Mg²⁺, 1.32 to 2.96 K⁺, 0.58 to 0.59 Na⁺) and cations increases in soil (after 60 days) ranged from (4.53 to 7.1 Ca²⁺, 0.7 to 0.73 Mg²⁺, 1.23 to 2.89 K⁺, 0.58 to 0.59 Na⁺). The highest values of all cations increasing observed in treatment T₇. All the values of cations in soil increased due to the fly ash application are significant over initial and control. Though all the values increased over control and initial, there is treatment T₇ at par with the treatment T₆.

Anions

The data on anions content of soil (after 30 and 60 days of leachate analysis) presented in table 4.9 indicate that the application of fly ash significantly increases the anions of soil. The anions increases in soil (after 30 days) was ranged from (6.33 to 7.1 HCO₃⁻, 5.9 to 5.8 Cl⁻, 2.31 to 2.33 SO₄⁻ and anions decreased in soil (after 60 days) ranged from (6.16 to 6.76 HCO₃⁻, 5.2 to 4.8 Cl⁻, 2.31 to 2.32 SO₄⁻). The highest benefit of treatment observed in treatment T₇ (fly ash @ 25 t ha⁻¹) and treatment T₆ observed at par with treatment T₇.

Conclusions

The treatment fly ash @ 25 t ha⁻¹ (T₇) in soil was observed beneficial in respect of improvement of chemical properties *viz.* pH (8.08 to 8.36), EC (0.19 to 0.42 dSm⁻¹), CEC (47.16 to 49.89 cmol (p⁺) kg⁻¹), organic carbon (0.47 to 0.50 %) and calcium carbonate (6.06 to 7.3 %) increased significantly due to the fly ash application and the physical properties *viz.* bulk density (1.43 to 1.28 Mg m⁻³) and aggregate stability (61.11 to 59.65 %) decreased significantly while hydraulic conductivity (0.98 to 1.15 cm h⁻¹), mean weight diameter (0.76 to 0.81 mm), field capacity (35.58 to 40.76 %), permanent wilting point (17.65 to 20.31 %) increased significantly.

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7. VITAE

Mr. Khelbade Bharat Manikrao

**MASTER OF SCIENCE (AGRICULTURE)
IN
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
2018**

Title of thesis		:	Effect of fly ash on physico-chemical properties of soil.
Major field		:	Soil Science and Agricultural Chemistry
Biographical information			
Personal	Date of Birth	:	14 th February, 1994
	Place of Birth	:	Kapadsingi Dist. Hingoli
	Father's Name	:	Khelbade Manikrao Munjaji
	Mother's Name	:	Khelbade Laxmibai Manikrao
Educational	Bachelor Degree Obtained	:	Completed the Bachelor of Science (Agriculture) degree programme with first class (80.07%) in June 2016 in V.N.M.K.V., College of Agriculture, Parbhani, Dist. Parbhani (M.S.)
	Class	:	First
	Name of University	:	Vasantnao Naik Marathwada Krishi Vidyapeeth, Parbhani, Parbhani
Address			
	Email-id	:	bharatkhelbade@gmail.com
	Contact Number	:	8698696426