EFFECT OF FLY ASH ON GROWTH, PHYSIOLOGICAL AND BIOCHEMICAL TRAITS AND YIELD IN GROUNDNUT [*Arachis hypogaea* (L.)]

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1. INTRODUCTION

The impact of green revolution has made India self sufficient in production of cereals but this situation as far as oil seeds are concerned, is not very bright. Although, India is the only country in the world having the largest number of oil seed crops *viz.,* groundnut, rapeseed, mustard, sesame, linseed, castor, sunflower, niger, soybean and number of minor oil seed crops, the demand for vegetable oil is likely to grow unabated in the coming years due to the burgeoning population,

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop for its varied uses. It is the 13^{th} most important food crop of the world. It is the world's fourth most important source of edible oil and third most important source of vegetable protein. Groundnut seeds contain edible oil (50%), easily digestible protein (25%) and carbohydrates (20%) (Taru *et al*., 2010).

Groundnut is the native of Brazil and it was introduced to India during the first half of the sixteenth century from the Pacific islands of China. Groundnut is grown in nearly 100 countries, throughout the world. Major groundnut producers in the world are China and India.

In India, major area is confined to five states *viz.* Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra which account for 84% of total, area and production of India (Alexander, 2008). Rest of the area and production are distributed mainly in the states of Rajasthan, Uttar Pradesh and Punjab.

In Karnataka, groundnut is cultivated in an area of 0.82 million hectares with the production of 0.51 million tonnes of pod. The average productivity is 589 kg ha^{-1}. Area under groundnut in Karnataka accounts for 13.30 per cent of the total area.

The oil content of the seed varies from 44 to 50 per cent, depending on the varieties and agronomic conditions. Groundnut oil finds extensive use as a cooking medium both as refined oil and *Vanaspati* Ghee. It is also used in soap making and manufacturing cosmetics and lubricants, olein, stearin and their salts. Kernels are also eaten as raw, roasted or sweetened. They are rich in protein and vitamins A, B and some members of B_2 group. Their calorific value is 349 cal per 100 g. Residual oilcake contains 7 to 8 per cent of N, 1.5 per cent of P_2O_5 and 1.2 per cent of K_2O and is used as a fertilizer. It is an important protein supplement in cattle and poultry feeds. It is also consumed as confectionary product. The cake can be used for manufacturing artificial fiber. The haulms (plant stalks) are fed (green, dried or silage) to livestock. Groundnut shell is used as fuel for manufacturing coarse boards, cork substitutes, etc. Groundnut has value as rotation crop. Being a legume with root nodules, it can fix atmospheric nitrogen and therefore improve soil fertility.

Fly ash is a residue resulting from pulverized coal combustion. Approximately 260 million tonnes of coal is consumed per annum by 82 utility thermal power plants (TPPs) in India. It constitutes nearly 70 per cent of the total power generation, which, in turn, produced 108 million tonne of fly ash per annum. The annual generation of fly ash is projected to exceed 175 million tonne per annum by 2012 (considering the plans to double the power generation over next 10 years) (Nas *et al*., 1993). This large volume of fly ash occupies large area of land and possesses threat to environment. As such, there is an urgent and imperative need to adapt technologies for gainful utilization and safe management of fly ash on sustainable basis.

Physically fly ash occurs as very fine particles having an average diameter or less than 10 mm, low to medium bulk density, high surface area and very light texture. Chemically, the composition of fly ash from the thermal power station consists oxides of Si, Al, Fe and Ca and about 0.5 to 3.5% of Na, P, K and S and the remainder of the ash is composed of trace elements. Fly ash consists of practically all the elements present in soil except of organic carbon and nitrogen. Thus, it was found that this material could be used as an additive or amendment material in agriculture applications (Rautoray *et al*., 2006). Calcium is also a dominant cation in fly ash followed by Mg, Na and K (Matti *et al*., 1990), aluminium in fly ash is mostly bound in insoluble aluminosilicate structures, which considerably limits its biological toxicity. The pH of fly ash can vary from 4.5 to 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. According to Anisworth and Rai (1987), fly ash with Ca/S ratios of less than about 2.5 generated acid extracts, whereas, fly ash with Ca/S ratios higher than 2.5 produced alkaline extracts.

Fly ash consists mainly amorphous glass and a few crystalline phases. The crystalline phases of fly ash consist gypsum ($CaSO_4$ $2H_2O$), aluminosilicate glass, mullite ($3Al_2O_3$ $2SiO_2$), quartz (SiO_2), magnetite (Fe_3O_4), anhydrite ($CaSO_4$), ettringite (3CaO Al_2O_3 $3CaSO_4$ $32H_2O$), opaline SiO_2, hematite (Fe_2O_3), lime (CaO), chlorite, feldspars and spinel ($FeAl_2O_4$) depending on the mineralogy of the feed coal.

In the recent years, there has been a growing interest in using fly ash for crop production, especially for regenerating wasteland (Pathan *et al.*, 2003) for agriculture. The soils which are predominantly poor in fertility need high amounts of nutrients for their restoration. However, there is a major constraint of providing such nutrients despite a relatively high total concentration in fly ash. This problem is very apparent with phosphate nutrition from fly ash. While, the total occurrence of phosphorus in fly ash may be as high as the concentrations observed in many organic manures,

Though, the beneficial effects of fly ash have been well documented, but the information and scientific data of its use in agriculture and on specific crop is lacking. Hence, different strategies and approaches have to be followed for finding a solution to fly ash disposal and its utilization in agriculture. Since, the available information on the effect of fly ash on crop performance and soil health at different stages are meagre, a study was conducted using the fly ash from West Cost Paper Mill Ltd., Dandeli, which also produces enormous quantity of fly ash and is situated 75 km from Dharwad city in Karnataka State. In the present investigation an attempt was made to ascertain the effect of fly ash on growth, physiological traits and yield of groundnut in clay soil of Main Agricultural Research Station (MARS), Dharwad with the following objectives:

1. To study the effect of fly ash on growth and development in groundnut.
2. To study the effect of fly ash on physiological and biochemical traits in groundnut.
3. To study the effect of fly ash on yield, yield components and quality attributes in groundnut

2. REVIEW OF LITERATURE

Oilseed crops have been the backbone of agricultural economy of India from time immemorial. On the oilseed map of the world, India occupies a prominent position both in terms of area grown and production. It is mostly grown under dry land conditions.Its energy requirements need to be met with the application of optimum quantities of plant nutrients through application of manures and fertilizers. Inadequate availability of essential nutrients is cited as a reason for its low average yield compare to other countries (Alexander, 2008). With limited scope to bring additional area under groundnut crop, further increase in production has to come primarily from technologies highlighting a combination of high yielding varieties, good crop management primarily through proper seed and nutrient management.

Due to global warming there is shortage of water for human consumption, for agriculture production as well as for hydroelectric power generation. Hence there is an increased use of alternate sources of power production. Coal is a prime energy source for power production with high amount of fly ash as by-product and its proper disposal is a challenge. Fly ash contains essential plant nutrients inclusive of micronutrients (Khungar, 1998) and elements like (K, Na, Zn, Ca, Mg, and Fe) and it is suited for agriculture due to its efficiency to improve soil health and crop performance (Manisha *et al.,* 2009). Therefore use of fly ash is attracting attention of scientists and farmers. In this chapter, available literature pertaining to the use of fly ash in agriculture is reviewed with emphasis on following topics.

2.1 Characteristics of coal fly ash

2.2 Effect of fly ash on growth and development of crops

2.3 Effect of fly ash on physiological and biochemical traits of crops

2.4 Effect of soil application of fly ash on soil health

2.5 Effect of soil application of fly ash on crop productivity

2.1 Characteristics of coal fly ash

Fly ash is a heterogeneous mixture of amorphous and crystalline phases and generally considered as ferroaluminosilicate. It comprised of about 69 per cent silt and clay size fractions. Low value of its particle density established its potential for dust formation (Sharma *et al*., 2001). High water holding capacity of ash was due to its dominant silt and clay size fractions. Fly ash contained about 93 per cent of silica and sesquioxides (Al_2O_3 and Fe_2O_3). In remaining portion, Ca^{2+} was the dominant cation followed by Mg_2^+, Na^+ and K^+. The bulk density of fly ash was 1.01 Mg/m^3. Organic carbon content in the ash was 0.36 per cent. Water holding capacity of fly ash was 56.9 per cent. Reaction and electrical conductivity values were 6.98 and 0.65 dS/m, respectively (Sharma *et al*., 2001).

Fly ash was established as a source of essential plant nutrients like calcium, magnesium, potassium, phosphorus, copper, zinc, manganese, iron, boron and molybdenum (Sengupta 2002) as well as a rich source of micronutrients (Doran and Martins, 1972 and Page *et al*., 1979). Growing body of evidence suggests that fly ash contains many essential and micronutrients that are required for agricultural production (Hill and Lamp 1980; Weinstein *et al*. 1989; Kalra *et al*., 1997). Physically fly ash occurs as very fine particles having an average diameter or less than 10 mm, low to medium bulk density, high surface area and very light texture. Chemically the composition of fly ash from the thermal power station consists of oxides of Si, Al, Fe and Ca and about 0.5 to 3.5 per cent consists of Na, P, K and S and the remainder of the ash is composed of trace elements. In fact, fly ash consists of practically all the elements present in soil except of organic carbon and nitrogen. Thus, it was found that this material could be used as an additive or amendment material in agriculture applications (Rautoray *et al*., 2009).

2.2 Effect of fly ash on growth and development of crops

The effect of fly ash application in various crops has been investigated on crop production for quantity and quality products for safe human consumption (Doran and Martins, 1972 and Page *et al*., 1979). Fly ash application was found to be beneficial in cereals (Plank *et al.* 1975 Vipin and Singh, 2010; Zhi *et al* 2011;), pulses and oil seeds (Thanunathan *et al.,* 2001; Manisha *et al.* 2010; Patil *et al.,* 2010; Shou Chen *et al.,* 2011), vegetables (Bharud *et al.,* 2002; Prasanthrajan and Kannan 2007; Rizvi and Khan 2009; Patil *et al.,* 2010; Zhi *et al.* 2011) and in tree species (Sudha and Dinesh, 2010; Pourrut *et al.,* 2011).

Effect of fly ash on growth and development of crops were reported from 1975. Plank *et al.* (1975) conducted a field investigation to study the effect of a weathered fly ash sample on yield and nutrient concentration of corn (*Zea mays* L.) and to determine rates of fly ash that could be applied to soils without adversely affecting plant growth. Application of weathered ash at the rates ranging from 18 to 288 metric tons/ha did not decrease corn grain yields on either Groseclose silt loam or Woodstown loamy fine sand. Corn grain yields were increased on the Woodstown soil in 1972 where cumulative rates of 216 and 288 metric tons/ha of fly ash applied, which was attributed in part to increased soil moisture. Plant analysis data indicated that B and Mn concentrations were not increased to toxic levels. Calcium content obtained through fly ash application was not sufficiently high to affect increases in Ca content of corn tissue. The weathered fly ash used for study could be applied to soils at cumulative rates of 288 metric tons/ha without inimically affecting crop growth (Plank *et al.,* 1975). Treatments of coal ash at 100 g/kg or calcium carbonate at 1.0 g/kg promoted the height, bearing spikelets, grains per spike, 1000 grains weight and yield of wheat (Patil *et al*., 2010). In cotton -wheat cropping system, in light textured soil, application of fly ash during the first year increased the seed cotton yield and there was a residual beneficial effect on subsequent wheat crop (Singh *et al*., 2009). Applications of coal fly ash increased the shoot dry weight and significantly increased foliar and stem N, P, and K content in spring wheat at harvest compared with the control (Zhi *et al.,* 2011).

Growth characters such as plant height and number of branches, as well as the yield parameters, number of capsules plant^{-1}, number of seeds capsules^{-1} and 1000 seed weight, grain yield, and N P K uptake were maximum when fly ash was applied at 30 t ha^{-1} in sesame cv VRI (Thanunathan *et al.,* 2001). Fly ash when applied in combination with organic wastes and chemical fertilizers increased the pod yield in groundnut in acid lateritic soils to the extent of 24.7 per cent as compared to the control (Manisha *et al*., 2010). A similar increase in yield and other physiological parameters was observed in soybeans when fly ash was applied in combination with farmyard manure (Shou chen *et al*., 2011).

An investigation was carried out during the dry season (February - May) of 1996 and 1997 at the Indian Institute of Technology, Kharagpur, to study the effect of paper factory sludge and fly ash on groundnut (*Arachis hypogaea* L.) and to find out their suitable time of incorporation in acid lateritic soils. Paper factory sludge along with fly ash and chemical fertilizers increased the dry matter accumulation, leaf area index and nodule number/plant compared to farmyard manure and their combination along with fly ash and chemical fertilizers. The beneficial effect was also recorded in yield attributes, yield, oil content in kernel, nutrient uptake and chemical properties of soil. Their incorporation at 15 days before sowing or at sowing was more advantageous than that at 30 days before sowing (Karmakar *et al.,* 2001).

The application of fly ash did not affect the duration of physiological maturity of Cauliflower variety 'Kuari No.3'. However, the considerable increase in leaf area per plant, number of leaves per plant, chlorophyll content and yield (2 to 29 per cent) was observed due to various levels of fly ash. More pronounced and beneficial effects were noticed with the application of higher dose of fly ash (Bharud *et al.,* 2002). Application of coal fly ash could increase the shoot dry weight of processing tomato, and the foliar N content, but decreased the foliar and stem P content at the flowing stage. However, coal fly ash could increase the foliar N, P and K content at the harvest stage (Zhi *et al.,* 2011). Fly ash applied as bio-compost (Sludge + fly ash + Coir pith) in vegetable cowpea significantly increased various growth parameters viz., crop growth rate (19.5%) and relative growth rate (32%), pod (26%) and haulm (22.3%) yield (Prasanthrajan and Kannan (2007). Rizvi and Khan (2009) reported that 20 per cent level of fly ash and 30 per cent level of brick kiln dust amendments in soil to be ideal level for the better plant growth and yield of egg plant.

Biomass accumulation in the stems and roots of Populus saplings increased with increase in the rate of fly ash application up to 20 per cent whereas the biomass accumulation in leaves as well as total biomass accumulation in the s saplings increased with fly ash application up to a level of 10 per cent only. Bio concentration of micronutrients Fe, Mn and Zn in stem and leaves of *Populus deltoides* displayed higher values up to 10 per cent level of fly ash application, and thereafter declined by a magnitude of 78, 71 and 62 per cent, respectively (Sudha and Dinesh, 2010). Fly ash was effective to decrease Cd, Pb and Zn concentrations in above-ground parts of trees of *Alnus glutinosa*, *Acer pseudoplatanus* and *Robinia pseudoacacia (*Pourrut *et al,* 2011).

Fly ash application in combination with organic as well as inorganic fertilizers has resulted in better crop growth and soil health. However when applied in combination with other sources of nutrients, fly ash was more beneficial. Fly ash was applied along with well decomposed farm yard manure (FYM) at 12.5 t ha^{-1} and recommended fertilizer schedule of N, P_2O_5 and K_2O ha^{-1}in sesame. Yield parameters, number of capsules $plant^{-1}$, number of seeds $capsules^{-1}$ and 1000 seed weight, grain yield, and N P K uptake were maximum when fly ash was applied at 30 t ha^{-1} along with FYM (Thanunathan *et al.,* 2001). An appreciable increase in physiological attributes and pod yield were recorded in vegetable cowpea when fly–ash was applied with paper board mill solid waste bio-compost (Sludge + fly ash + Coir pith) @ 6 t ha^{-1} along with recommended level of NPK (Prasanthrajan and Kannan, 2007). Fly ash was mixed with brick kiln dust in the ratio 20:30 respectively was found to be ideal for the better plant growth and yield of brinjal (Rizivi and Khan, 2009). Integrated application of fly ash, organic wastes and chemical fertilizers increased the pod yield in groundnut to the extent of 24.7 per cent over sole application of coal fly ash (Manisha *et al*., 2010). Fly ash mixed with coal gangue contaminated soil and diary manure improved the yield of soybean (ShouChen *et al*., 2011).

Fly ash when applied as a soil amendment in an acceptable medium along with bacterial culture improved growth and yield in groundnut (Muthumani and Jhansi, 2009). Jeyanthi *et al*., 2010 observed that when fly ash was used for vermin-compost along with earthworms for 40 days, the bacteria that colonized the fly ash vermin-compost belonged to the Genera *Flavobacterium, Pseudomonas, Vibrio, Micrococcus* and *Moroxella*. Vipin and Singh, 2010 demonstrated that fly ash could be utilised safely as carrier in bio-fertilizer formulations (Azotobacter and Azospirillum) and thus finding an effective alternative use for fly ash. Rhizobium strains (VR^{-1} and VA^{-1}) isolated from plants grown in fly ash contaminated soil registered tolerance to fly ash (Chaudhary *et al*., 2011) and improved plant growth when it was inoculated in 100 % fly ash conditions This study suggested that an integrated approach employing biotechnological means and inoculation of plants with host-specific fly ash tolerant Rhizobium strain may prove a stimulus to a fly ash management programme.

2.3 Effect of fly ash on physiological and biochemical traits of crops

As evident from the reviews in the previous section, soil application of fly ash improved the crop growth performance. However studies on the underlying physiological and biochemical mechanism that resulted in the superior performance, is meagre. In this section physiological and biochemical mechanism underpinning the improved growth and yield in crop plants due to fly ash application is presented.

Reports on germination studies hint that fly ash had positive as well as negative impact on seed germination. Lower levels of fly ash application enhanced seed germination as well as seedling growth and at higher levels either delayed or inhibited these processes drastically in *Vicia faba* (Singh *et al*., 1997). Application of fly ash @ 3% and 6% in sandy soil improved germination of *Brassica parachinensis* and *B. chinensis* seeds and 12 and 30% fly ash application in sandy soil and 30% fly ash in sandy loam reduced the germination (Wong and Wong, 1989). Yunusa *et al.* (2009) germinated six crop species *viz.* barley (*Hordeum vulgare*) and ryegrass (*Secale cereale*) canola (*Brasica napus*), radish (*Raphanus sativus*), field peas (*Pisum sativum*), and lucerne (*Medicago sativa*) on media amended with fly ash to note that fly ash addition had no significant effect on germination by any of the six species. In another report, increasing concentration of fly ash effluent, enhanced germination rapidly in maize (Yeledhalli and Ravi, 2008a). However, germination and early growth was affected adversely in wheat but did not cause any harmful effect in sorghum (Aggarwal *et al* 2009) when fly ash was used.

Physiological mechanisms and biochemical constituents in plants had both significant positive and negative changes due to fly ash application. Total chlorophyll, chlorophyll a, chlorophyll b and phenol contents of mango and litchi growing in fly ash affected areas of Farakka of Murshidabad district, West Bengal exhibited lower value while heavy metal (Pb, Cd, Cr, Cu, Zn, Ni and Fe) concentration in the fly ash affected leaves showed higher value compared to unaffected leaves of mango and litchi (Chatterjee *et al.,* 2009). Yunusa *et al.* (2009) reported that there was uncertainty as to the rates of coal fly ash needed for optimum physiological processes and growth. Addition of 10 t ha^{-1} fly ash increased growth rates and concentrations of chlorophylls a and b, but reduced carotenoid concentrations in barley (*Hordeum vulgare*) and ryegrass (*Secale cereale*) canola (*Brasica napus*), radish (*Raphanus sativus*), field peas (*Pisum sativum*), and lucerne (*Medicago sativa*). Transpiration in barley was increased due to fly ash application (Yunusa *et al.* 2009). There was no consistent pattern of change in pigment concentrations or instantaneous rates of photosynthesis as compared to plant dry weight *vis-a-vis* amount of fly ash applied. Hence plant dry weight was a more reliable parameter for assessing growth in plants supplied with fly ash (Yunusa *et al.* 2009). Pigment contents (chlorophyll a, b and carotene) and enzyme activities (catalase and peroxidase) of rice were found to be unaffected by fly ash amendments and their repetitions over the years. Nevertheless significant decline in both protein and carbohydrate contents of seeds was recorded due to application of fly ash over the years (Samy *et al.,* 2010). Nagajyoti *et al.* (2009) opined that the treatment of ground nut in pot culture with 25% of the effluent had stimulatory effect on all the biochemical parameters. Carbohydrates, starch, aminoacids, protein, nitrate and nitrite reductase enzymatic activities increased in 10, 15, 20 DAS (days after sowing) and decreased thereafter. This study indicated that the power plant effluent had stimulatory effect on all the biochemical contents at lower concentration, and at higher concentration they had deleterious effects. Fly ash effluent when applied to maize increased Chlorophyll-a, chlorophyll-b and the carbohydrate content in leaves of maize. In addition to this biochemical enhancement, percentage of germination and growth parameters had positive correlation with chlorophyll and carbohydrate contents due to nutrients in fly ash effluents in Maize (Yeledhalli and Ravi, 2008a). Fly ash improved root length, chlorophyll content, grain yield per plant and average seed weight of chickpea (*Cicer arietinum*) (Gupta and Singh, 2009) Fly ash application in *B. campestris* increased total chlorophyll content of the leaf significantly, whereas carotenoid content showed non-significant increase as compared to control. Translocation of most of the tested metals (Pb, Mn, Cd, Ni, and Fe) in the shoot of the plant was found higher except Cr, Cu, and Co. (Gupta *et al.,* 2010). *Vigna radiata* and *Vigna angularis* grown in fly ash inoculated with Rhizibioum showed marked increase root-shoot length, biomass yield, photosynthetic pigment, protein content and nodulation frequency compared to uninoculated plant grown in 100% fly ash (Chadhury *et al*., 2011). Fly ash was used as a coating agent to prepare control release fertiliser from common compound fertilizer, N-P_2O_5-K_2O: 15–15^{-1}5 (Xian Kui *et al.,* 2011).

This slow release fertiliser when applied in Chinese cabbage increased chlorophyll content, photosynthetic rate, transpiration rate and stomatal conductance and decreased stomatal limitation during its late growth stage, and improved the plant parameter characteristics, and biomass per head by 0.10-0.33 kg, yield by 9.72 - 33.1 per cent. In addition, the coated controlled release fertilizers decreased NO_3- N significantly and organic acid contents by a certain extent in the functional leaves of the plant, and improved sugar-acid ratio and soluble sugar and VC contents of the head of the plant at the harvest stage (Xian Kui *et al.,* 2011). Soybean plant chlorophyll content and photosynthesis rate at the flowering and seed-filling stages were more significant when fly ash was applied in combination with diary manure than fly ash alone (Shou Chen *et al.,* 2011).

2.4 Effect of soil application of fly ash on soil health

In this section reviews on effect of fly ash on soil health parameters will be discussed. Fly ash application to agriculture soil is beneficial as it contain micro-nutrients essential for plant life and agricultural crops. Fly ash could correct deficiency of several micronutrients and prevent the toxicity of some metal ions through the neutralization of soil acidity (Doran and Martins, 1972); Page *et al*., (1979 Singh and Yunus 2000). Fly ash has been used as a source of essential plant nutrients like calcium, magnesium, potassium, phosphorus, copper, zinc, manganese, iron, boron and molybdenum and also for boosting crop growth and yield. It has been successfully applied in different agro-climatic conditions and soil types in different parts of the country using doses of 25–500 t ha^{-1} (Sengupta 2002). As fly ash contains trace amounts of heavy metals (Wong and Wong, 1989) application of this by-product has been investigated for safe use for crop production for human consumption (Page *et al.*, 1979; Doran and Martins, 1972; Wong and Wong, 1989). Field demonstration projects taken at more than 50 locations by fly Ash Mission (FAM), now known as Fly Ash Utilisation Programme (FAUP) in varying agro-climatic conditions and different soil - crop combinations supported with laboratory investigations have shown significant fly ash application does not have any adverse impact on soil health because of any reasons including presence of trace heavy metals and radio-nuclides in fly ash. The presence of these elements is too low to make any harmful impact (Vimal Kumar *et al.,* 2005).

Fly ash amendment of soil could improve nutrient status of the soil as it contains considerable amounts of vital plant nutrients like potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and phosphorous (P) (Kalra *et al*., 1997; Singh and Yunus 2000).

Soil solution of weathered fly ash applied at the rates ranging from 18 to 288 metric ha^{-1} in silt loam and in loamy fine sand did not contain toxic amounts of B and Mn. However calcium content was increased in soil solution but was not sufficiently high to affect increases in Ca content of plant tissue (Plank *et al.,* 1975).

The assimilative capacity of the soil with respect to its physical, chemical and biological properties and the perfonnance of crop grown need thorough investigation. Effect of fly ash and sewage sludge (treated city waste) applied to peanut *(Arachis hypogaea* L.) crop on changes in microbial status, nitrogen fixation and crop production in lateritic soil. Such wastes in different doses and combination of wastes to agricultural lands alters the nutrient cycling processes particularly for leguminous crops, where nodulation, N2 - fixation and N - uptake is mainly governed by a group of micro-organisms. Nodule number and N-accumulation in nodules was found to be higher in fly ash treated soil as compared to that of city waste (Sarkar and Khan, 2003).

The electrical conductivity and pH of sandy soils and sandy loam soils were increased, but more so for the sandy soil due to fly ash application. The increase in electrical conductivity may limit the availability of soil water because of the high osmotic pressure, and the increased pH would alter the availability of micro-elements to plants (Wong and Wong, 1989). Similar results were obtained for Gupta and Singh (2009) when they investigated the physico-chemical characteristics (pH, electrical conductivity and trace element concentration) of fly ash applied in soil in the Arpa irrigation project area of Bilaspur District, Chhattisgarh, India. Increased value of these soil properties were found to be favourable and was recommended for the cultivation of chickpea in acidic soil. When fly ash was applied repeatedly over years, among physico-chemical characteristics of soil, pH and electrical conductivity values increased due to the repetitions. Cation exchange capacity and water holding capacity of soil had almost little change with repetitions. It could be stated that, by and large, higher fly ash doses deteriorated the soil quality, and Fly- ash repetitions of lower doses were detrimental even in the third season (Samy et al., 2010). In contrast to the Samy *et al*., 2010 observation, it was noted that three years of the application of fly ash in light textured soil resulted in significant increase in organic carbon, calcium carbonate, Fe, B and Mo content in soils which were beneficial for crop production. The build up of heavy metals was not significant over a period of three years (Singh *et al.,* (2009). Integrated fertilisation with fly ash, organic materials and mineral fertilisers to soil improved pH, bulk density, organic carbon and available nutrients (Rautaray *et al.,* 2009). The water holding capacity of soil increased from 64 to 67.5 per cent due to pond ash @ 40 t ha^{-1} application (Yeledehalli *et al*., 2008b). Water transmission characteristics of soil (saturated hydraulic conductivity) decreased but water retention improved with addition of increasing levels of fly ash (Aggarwal *et al.,* 2009).

Zhi *et al*., 2011 also recorded an increase in the soil pH and soil electrical conductivity by applying Fly ash. Muthumani and Jansi (2009) reported that fly ash improves permeability status of soil and soil texture. The increased percentages of added coal fly ash, used paper and starch significantly decreased the particle and bulk densities of synthetic soil aggregates (SSA) produced by mixing acidic “Kunigami Mahji” soil in Okinawa, Japan, with waste materials, such as coal fly ash, used paper and starch compared with the original “Kunigami Mahji” soil because of the low particle and bulk densities of the coal fly ash (2.10 and 0.96 g cm^{-3}, respectively) (Guttila *et al.,* 2008). The SSA particle density varied between 2.39 and

2.14 g cm^{-3}, and bulk density varied between 0.72 and 0.81 g cm^{-3}, depending on the additional percentages of coal ash from 20–100 per cent. Maximum water-holding capacity and saturated hydraulic conductivity increased with the formation of SSA with coal fly ash, used paper and starch binder compared with the original “Kunigami Mahji” soil. The saturated hydraulic conductivity values of the SSA increased because of their low bulk density compared with the original soil. The addition of coal fly ash, used paper and starch to the acidic (pH = 4.62) “Kunigami Mahji” soil to form SSA increased the pH (6.70–9.96), electrical conductivity, exchangeable cation concentration and cation exchange capacity. The addition of coal fly ash up to 60 per cent increased the aggregate strength (Guttila *et al.,* 2008). Soil EC, $CaCO_3$ and bulk density decreased significantly with conjoint Coal Fly ash (CFA) and farm yard manure (FYM) application over alone CFA applied plots. Soil organic carbon content increased significantly from 0.50 to 0.75% in alone 40 t ha^{-1} CFA amended plots over no-CFA control. Plots dressed with either 20 t CFA/ha or with 20 t FYM/ha, exhibited equal (14%) significant increase in soil OC content over their respective controls (Saini *et al.,* 2010).

Fly ash could be used as a carrier for several bacterial cultures and application of fly ash help to sustain micro-flora of soil. Chaudhary *et al.* (2011) reported that the rhizobium strains were isolated from plants grown in fly ash-contaminated soil and were designated as fly ash tolerant rhizobium strains (VR^{-1} and VA^{-1}). Azotobacter and Azospirillum strains isolated from healthy wheat Rhizosphere soil and was bio-formulated in fly ash (300 meshes). This fly ash carrier based Azotobacter and Azospirillum could maintain the bio-efficacy of bio-fertiliser and improve soil health (Vipin and Singh, 2010). Fly ash has high expediency when used as a soil amendment along with bacterial cultures (Muthumani and Jhansi, 2009). When fly ash was used as a carrier for *Azotobacter chroococcum*, *Azospirillum brasilense* and *Bacillus circulans* showed their maximum viability in fly ash alone whereas *Pseudomonas striata* proliferated most in soil:fly ash (1:1) combination (Sunitha and Gaur, 2004). Bioavailability of nutrients in fly ash was improved through vermicomposting using bacterial colonies belonging to the Genera *Flavobacterium, Pseudomonas, Vibrio, Micrococcus* and *Moroxella* (Jeyanthi *et al.,* 2010). Nevertheless, it can be inferred that fly ash could be used as a good medium / carriers for bacterial cultures and thus implying a safe and alternative use of fly ash

2.5 Effect of soil application of fly ash on crop productivity

By virtue of its nutrient supplying capacity, fly ash finds its usage in agricultural production system. This is considered as the best disposal mechanism for by-product of thermal energy plants. Many studies (Hill and Lamp 1980; Weinstein *et al*. 1989) have demonstrated that coal fly ash increases the crop yield. Agricultural lime application contributes to global warming as Intergovernmental Panel on Climate Change (IPCC) assumes that all the carbon in agricultural lime is finally released as CO2 to the atmosphere. It is expected that use of fly ash instead of lime in agriculture can reduce net CO_2 emission, thus reduce global warming also (Manisha *et al.,* 2009).

Fly ash of Deepnagar thermal power plant located in Bhusawal (MS) when applied around 10 to 15 per cent by weight of black cotton soil was optimum for groundnut and brinjal (Patil *et al*., 2010a) and for ladies finger and cotton (Patil *et al*., 2010b). . In As (III) contaminated soil, compared to the control, wheat yield increased significantly and the content of As in grain decreased very significantly with a treatment of 100 g/kg coal ash (Yun *et al.,* 2009). Addition of 100 g/kg coal ash or 1.0 g/kg calcium carbonate in As (III) contaminated soil could effectively alleviate the toxicity of As (III) to wheat such as improving wheat yield and reducing As content in wheat grain (Yun *et al*., 2009). Application of fly ash in light textured soil to cotton crop before sowing for three years resulted in highest yield increase of 30 per cent in seed cotton yield and of 45 per cent in wheat grain yield (Singh *et al.,* 2009). Application of fly ash during the first year increased the seed cotton yield up to 20 t ha^{-1} of fly ash, whereas the residual beneficial effect on subsequent wheat was only up to 10 t ha^{-1}. Highest yield increase was observed in the third year. Yields when pooled over three years, the average yield increase in cotton was 3, 8, 13 and 19 per cent at 10, 20, 40 and 80 t ha^{-1} of fly ash, respectively, whereas the corresponding increase in wheat was 11, 13, 15 and 1 per cent (Singh *et al.,* 2009).

Direct effect of integrated fertilisation with fly ash, organic materials and mineral fertilisers to soil improved or sustained rice grain yield compared with the mineral fertilisers alone (Rautaray *et al.,* 2009). Yields of potato, groundnut and mustard increased under the residual effect of the integrated fertilisation sources *vis-a-vis* mineral fertilizers. The combined direct and residual effect of fertilisation sources on cropping sequences revealed that equivalent rice grain yield was higher under the integrated sources as compared to the mineral fertilisers alone. This difference was up to 10% for rice-groundnut sequence while 15 per cent for rice-potato, 19 per cent for rice-mustard, and 27 per cent for rice-sweet potato sequence (Rautaray *et al.,* 2009).

Green manure, farmyard manure, sulfitation press mud and lignite fly ash, each applied at 12.5 t ha^{-1} in rice cv. ADT 43 along with sulphur (S) at varying rates, i.e. 0, 20, 40 and 60 kg ha^{-1} responded significantly to the application of S and organics compared to the control (Bhuvaneswari *et al.,* 2007). The highest grain (5065 kg ha^{-1}) and straw yields (7524 kg ha^{-1}) were obtained with 40 kg S/ha. Green manure addition caused 8.9% increase in grain yield and 10.6% increase in straw yield, closely followed by sulfitation press mud. S use efficiency was highest at 20 kg ha^{-1} and higher in the presence of organics. The physical optimum of S worked out through the Mitscherlich and Bray approach showed that 38.8 kg S/ha was needed to obtain 87.5% yield and in the presence of organics, it ranged from 14.4 to 32.3 kg S/ha, resulting in S savings of approximately 6.5-24.4 kg S/ha. Similarly varying levels of fly ash (0, 5, 10, 20 t ha^{-1}) and nitrogen (0, 10, 20, 40 kg ha^{-1}) caused increased grain yield at higher levels of nitrogen and ash i.e. 20 t ha^{-1} coal burnt ash + 120 kg ha^{-1} N (wheat) or 40 kg ha^{-1} N (sorghum). In Muthiani village near National Capital Power Project (NCPP), Dadri, U.P. increased grain yield of wheat and sorghum at higher levels of nitrogen and ash i.e. 20 t ha^{-1} coal burnt ash + 120 kg ha^{-1} N (wheat) or 40 kg ha^{-1} N (sorghum), (Aggarwal *et al.,* 2009) . Nevertheless, Vimal Kumar *et al.,* 2005 opined that the large scale use of fly ash in agriculture and wasteland development holds a potential to increase on an average 15% yield of grains, oil seeds, sugarcane, cotton and about 25–30% of vegetables resulting in another green revolution.

Effect of fly ash was more pronounced when applied along with fertilisers and organic manures. Application of fly ash @ 20 and 40 t ha^{-1} significantly increased the grain yield of rice crop to the tune of 5.6 and 12.5 t ha^{-1}, respectively (Baskar and Selvakumari., 2005). However the highest yield of 17.26 t ha^{-1} was recorded in the treatment which received fly ash @ 40 t ha^{-1} along with fertilizer and compost. Post harvest soil analysis indicated that application NPK fertilizers significantly increased available NPK status of the soil, while application of fly ash significantly increased available P, K, Ca, Mg, S, Si and B content of the soil (Baskar and Selvakumari., 2005).

In Maize total yield of 35.7 q ha^{-1} was recorded in treatment receiving pond ash @ 40 t ha^{-1} along with FYM @ 20 t ha^{-1} followed by fly ash @ 30 t ha^{-1}. The yield over control was 53.3 and 45.0 per cent, respectively (Yeledhalli *et al.,* 2008a). Fly ash which had high silicate was applied in Rice as an alternative to silicate fertilizer after mixing with a by-product of gypsum to remove alkalinity and high boron content of the fly ash. The highest rice yield was achieved following the addition of 40 Mg ha^{-1} of the mixture to the soil. Mixture of fly ash and gypsum increased uptake of silicate and phosphate and the amount of exchangeable calcium in the soil. Plant elemental uptake revealed that application of the fly ash and gypsum mixture did not result in an excessive uptake of heavy metals by the rice in the submerged paddy soil. The amount of available boron increased with the increase in the amount of fly ash up to 0.62 mg kg^{-1} following the application of 60 Mg ha^{-1} of the mixture, but did not reach toxicity levels for rice, probably due to the dilution and leaching effects under the submerged growing conditions. It was concluded that fly ash and gypsum mixture could be a good alternative to inorganic soil amendments to restore the soil nutrient balance in paddy soil (Yang *et al.,* 2003). Another study was conducted by the same authors in 2003 to confirm that fly ash and gypsum mixture is good to restore nutrient balance in paddy soil. Fly ash gypsum mixture of 25 Mg ha^{-1} increased the maximum grain yield by 8 per cent. With increasing N uptake of rice, the mixture could decrease nitrogen application level to about 50 kg N ha^{-1} to produce the target yield i.e. the maximum yield in the non-amendment treatment.

The use of the mixture increased the uptake of silicate by rice, but did not result in an excessive uptake of heavy metals. Level of available B increased with the mixture application up to 1.5 mg kg^{-1} in the surface soil at initial stage, but did not reach toxicity levels. In conclusion, the mixture was considered to be a good alternative as a soil amendment to restore the nutrient balance in paddy soils and to reduce the nitrogen application rate of rice (Yang *et al.,* 2003).

The growth and yield of komatsuna and soybean crops with synthetic soil aggregates (SSA) produced by mixing acidic "Kunigami Mahji" soil in Okinawa, Japan, with waste materials, such as coal fly ash, used paper and starch as a crop growth medium showed the highest growth and yield when grown with SSA containing 20 per cent of coal fly ash. Synthetic soil aggregates containing more than 20 per cent of coal fly ash reduced plant growth and yield. Therefore, SSA produced from "Kunigami Mahji" soil with 20% of coal fly ash, used paper and starch can be successfully used as a medium for crop growth (Guttila *et al.,* 2008).

The study revealed that, the pod yield and haulm yield of groundnut increased favorably with increasing leads of fly ash and FYM *i.e.* addition of 30 t ha-1 of fly ash gave maximum yields as compared to yields obtained due to lower levels of fly ash and it was highest with the application of 30 t ha-1 of FYM. The nitrogen content in pod and haulm was decreased with the application of 30 t ha-1 fly ash while it resulted in increase in phosphorus and potassium content and FYM application @ 30 t ha-1 showed maximum concentration and uptake of nitrogen, phosphorus and potassium in pod and haulm of groundnut. The pod and haulm yield showed favourable increase with the application of increasing levels of fly ash and FYM whereas the test wt. (100 grain yield) of groundnut was non–significantly affected by fly ash and FYM (Dange and Nagle, 2010).

On sandy loam soil of Agronomy Instructional Farm, Sardarkrushinagar, sludges and soil conditioners were applied in wheat-pearl millet-green gram crop sequence to identify with the uptake of heavy metals and yield (Desai *et al.,* 2010). Significantly higher uptake of cobalt and cadmium was registered with the use of effluent treatment plant (ETP) sludge @ 20 t ha^{-1}, while incorporation of fly ash @ 20 t ha^{-1} registered higher uptake of lead and nickel by grain and straw of all the three crops grown in sequence one after another. The mean values of heavy metals in the grain and straw of crops were far below the tolerance threshold for livestock and toxicity values for plants. Application of ETP sludge @ 20 t ha^{-1} resulted in significantly higher grain yield of wheat, pearl millet and green gram crops (Desai *et al.,* 2010). A conjoint application of coal fly ash (CFA) and farm yard manure (FYM) at 20 t ha^{-1} each in cotton resulted in a significant increase in P, K, Ca and B concentration of leaf petiole when compared with either control (no-CFA/FYM) plots or plots amended separately with CFA and FYM. FYM application alone, in contrast exhibited significant decrease in B concentration by 28.5% over no-FYM amended plots. However, Cu concentration in leaf petioles exhibited significant increase (26.3%) with CFA application at 40 t ha^{-1} conjointly with FYM at 20 t ha^{-1}. Leaf petiole Mn concentration increased by 15.3 and 28.0% with conjoint CFA and FYM application over no-CFA control (Saini *et al.,* 2010a).

Fly ash incorporation in soil increased the grain yield of rice to the tune of 7.9 and 16.9%, for 20 and 40 t ha^{-1} of fly ash and with combination of 20 t ha^{-1} of FYM it was 4.4 and 8.2% over their respective control. Concentration of macro and micronutrients in rice showed considerable increase when grown in fly ash incorporated soil with and without FYM application. Uptake of macro and micronutrient by rice grain also increased correspondingly with increasing level of fly ash application. Uptake of P, K, Ca, Mg, Zn, Fe, Mn and B was relatively higher where FYM was also applied along with fly ash (Saini *et al.,* 2010b). Grain and straw yield of rice were significantly increased with fly ash, FYM and their interactions in fine loamy mixed hyperthermic Typic Haplustept soil (Reddy *et al.,* 2010). The highest grain (5.84tha^{-1}) and straw yield (7.87 t ha^{-1}) were recorded by combined application of fly ash @ 10 t ha^{-1} and FYM @ 10 t ha^{-1}. Among the different combinations, application of fly ash @ 15 t ha^{-1}+FYM @ 10 t ha^{-1} recorded the highest available N (224.6 kg ha^{-1}), P (24.6 kg ha^{-1}), K (366.7 kg ha^{-1}), S (8.80 mg kg^{-1}), Fe (10.62 mg kg^{-1}) and Zn (0.95 mg kg^{-1}) contents after harvest of rice crop. Available Mn content was the highest in FA10 FYM 10 (6.69 mg kg^{-1}).

The available Cu content was not significantly influenced by fly ash levels; however, it was significantly higher in FYM treated plots. Application FA10 FYM10 had resulted in the build up of available nutrients (N-5.8%), (P-64.5%), (K^{-1}03.3%), (S-2.8%), (Fe-22.2%), (Mn-23.3%), (Cu^{-1}56.9%) in post harvest soils except (Zn^{-1}0.5%) when compared to their initial status (Reddy *et al.* (2010).

Fly ash/pond ash was applied at 30-40 t ha^{-1} (one time and repeat application) in sunflower and maize with recommended dose of NPK fertilizers alone or along with farmyard manure (FYM) at 20 t ha^{-1} resulted in yield of 35.7 q ha^{-1} in treatment receiving pond ash at 40 t ha^{-1} along with FYM at 20 t ha^{-1} followed by fly ash at 30 t ha^{-1}. The yield of maize in control was 14.8 q ha^{-1}, which increased significantly due to application of either fly ash or pond ash (Yeledhalli *et al.,* 2008b).

Manisha *et al.* (2010) reported that Fly Ash (FA), applied along with organic wastes like farmyard manure (FYM), vermicompost (VC) and green manure (*Sesbania rostrata*) (GM) and chemical fertilizers improved the yield of groundnut during rainy season. Integrated application of FA, organic wastes and chemical fertilizers increased the pod yield to the extent of 24.7 per cent over sole application of CF. Thetwar *et al.* (2006) opined that, fly ash amended acidic soil along with plant hormones like gibberellic acid and indole acetic acid could be used to increase crop yield and oil-contents, avoiding the aluminium ion toxicity, which might had affected the quality and the medicinal values of sesame seed oil. The seed and oil quality parameters from plants grown in plain and fly ash, hormone treated soils were compared after pot experiments.

Thus from this review it can be concluded that application of fly ash alone or in combination with organic and inorganic fertilisers could positively improve growth and productivity of crops. Nevertheless, it can also influence on soil health depending upon the quantity applied and soil types.

3. MATERIALS AND METHODS

Fly ash is a rich source of plant nutrients with negligible amounts of heavy metals hence it is suited for crop production and thus facilitate alternate use for fly ash. In view of this, in the present study, the treated fly ash of West Cost Paper Mill Ltd., Dandeli Uttar Kannada district was characterized for its nutritive value. A series of laboratory and field experiments were conducted to study its effect on growth, physiological traits and yield of groundnut and also on soil health during 2011-2012. The details of materials used and the methods employed in the investigation are given below.

3.1 Experimental site

A field experiment was conducted in plot number 126 of `E` Block, at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, which is situated at 15^0 26^1 N latitude and $75^0 07^1$ E longitude with an altitude of 678 m above mean sea level.

3.2 Climatic conditions

The data on weather parameters such as rainfall (mm), mean maximum and minimum temperature (^oC) and relative humidity (%) were recorded at Meteorological Observatory, MARS, University of Agricultural Sciences, Dharwad during the experimental year and mean of the last 60 years (1950-2010) are presented in Table 1.

The mean annual rainfall for the past 60 years at MARS, Dharwad was 804.38 mm and the a maximum rainfall 150.45 mm was received in the month of august followed by July (137.72 mm) the total rainfall during 2011-12 was 922.7 mm and the maximum of 219.7 mm in October. The months of December and January did not receive any rainfall during the experimental year. The relative humidity ranged from 63.0 per cent (January and February) to 85.0 per cent (July) during 2010-11. While it ranged from 54.41 (February) to 89.18 per cent (July) for the last 60 years, mean maximum temperature ranged from 34.9^0 C (April) to 26.2^0 C during 2011. The months of March, April and May were hottest. While the mean maximum temperature during past 60 years indicated that it was maximum 34.9^0C followed by May 34.7^0C the lowest temperature of 28.1^0C was recorded in September. The minimum temperature ranged from 14.0^0C (February) to 21.3^0 C (May) during 2011-12. The average of last 60 years indicated that the mean minimum temperature was highest during May and June (21.3^0C) and lowest during December (13.7^0C).

3.3 Characteristics of fly ash

Fly ash which is used in the experiment and its sample was analyzed for its physical and chemical properties and the details are presented in Table 2.

3.4 Soil and its characteristics

The experimental site consists of clay soil. Composite soil sample was analyzed for its physical and chemical properties and the details are presented in Table 3.

3.4.1 Design and lay out

The experiment was laid out in randomized block design with three replications.

The plan of lay out of the experiment is given in Fig. 1.

Table 1: Monthly meteorological data for the experimental year 2011 and average of 60 years (1950-2010) at Main Agricultural Research Station, UAS, Dharwad

Months	Rainfall (mm)		Mean Temperature (^oC)				Relative humidity (%)	
	2011	1950-2010	Maximum		Minimum		2011	1950-2010
			2011	1950-2010	2011	1950-2010		
January	0.0	0.039	29.2	28.7	12.5	14.07	59	64.81
February	21.6	0.684	30.8	31.6	14.0	16.56	48	54.41
March	0.8	15.02	32.2	34.9	18.6	19.71	44	64.24
April	77.4	41.54	34.9	36.6	20.2	20.11	57	78.05
May	66.6	65.74	34.7	35.2	21.3	20.95	61	75.78
June	194	107.51	27.5	30.2	21.3	21.68	84	86.29
July	131	137.72	26.9	27.3	20.6	20.85	85	89.18
August	124.2	150.45	26.2	27.2	20.7	20.16	87	88.6
September	82.8	132.33	28.1	27.9	19.9	19.96	80	86.68
October	219.7	97.63	29.9	29.5	19.5	18.65	73	79.4
November	4.6	53.49	29.8	28.9	15.8	15.93	55	73.62
December	0.0	2.26	29.6	27.8	13.7	13.20	57	69.12
Total	**922.7**	**804.38**	**-**	**-**	**-**	**-**	**-**	**-**

3.5 Experimental details

Crop	Groundnut
Variety/Hybrid	GPBD-4
Design	RCBD
Replications	3 (Three)
Treatments	11
Spacing	30 x10 cm
Fertilizer	25:50:25, $N:P_2O_5:K_2O$ kg/ha
Gross plot size	5 m x 5 m
Net plot size	4.7 m x 4.6 m

Table 2: Characteristics of fly ash

Parameters	**Fly ash**
A. Physical properties	
Specific gravity	2.07
Clay size	4.0 %
Silt size	85.0 %
Fine sand size	11.0 %
Liquid limit	59.0 %
Plastic limit	Non-plastic
Shrinkage limit	Varies with initial water
B.Chemical properties (%)	
Silica ($Si O_2$)	57.00
Alumina ($Al_2 O_3$)	23.00
Ferric oxide ($Fe_2 O_3$)	8.32
Calcium oxide (CaO)	2.70
Magnesium oxide(MgO)	0.83
Titanium Oxide ($Ti O_2$)	0.23
Loss on ignition	7.92

Table 3: Physical and chemical properties of the soil in the experimental site

Sl. No.	Particulars	Values	Method
I.	**Physical property**		
1.	**Particle size analysis**		
a.	Coarse sand (%)	6.28	International Pipette method (Piper, 1966)
b.	Fine sand (%)	14.27	
c.	Silt (%)	27.46	
d.	Clay (%)	51.99	
II.	**Chemical properties**		
1.	pH (1:2.5 soil: water extract)	7.60	pH metre (Piper, 1966)
2.	Electrical conductivity (dS m^{-1}) (1:2.5 soil: water extract)	0.20	Conductivity bridge (Piper, 1966)
3.	Organic carbon (%)	0.47	Walkley and Black wet oxidation method (Jackson, 1967)
4.	Available nitrogen (kg ha^{-1})	221.00	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorous (kg P_2O_5 ha^{-1})	32.4	Olsen's method (Jackson, 1967)
6.	Available potassium (kg K_2O ha^{-1})	318.7	Flame photometer method (Jackson, 1967)

Table 4: **Salient features of groundnut cultivar GPBD 4 used in the present investigation**

Sl. No.	Characteristic/parameter	GPBD-4
1.	Pedigree Maturity (days) 105-110	KRG1 x ICGV868554.
2.	Resistance	Late leaf spot and rust
3.	Growth habit	Bunch
4.	Maturity (days)	105-110
5.	Kernel oil content (%)	48
6.	100-kernel weight (g)	38.2
7.	Shelling percentage (%)	77

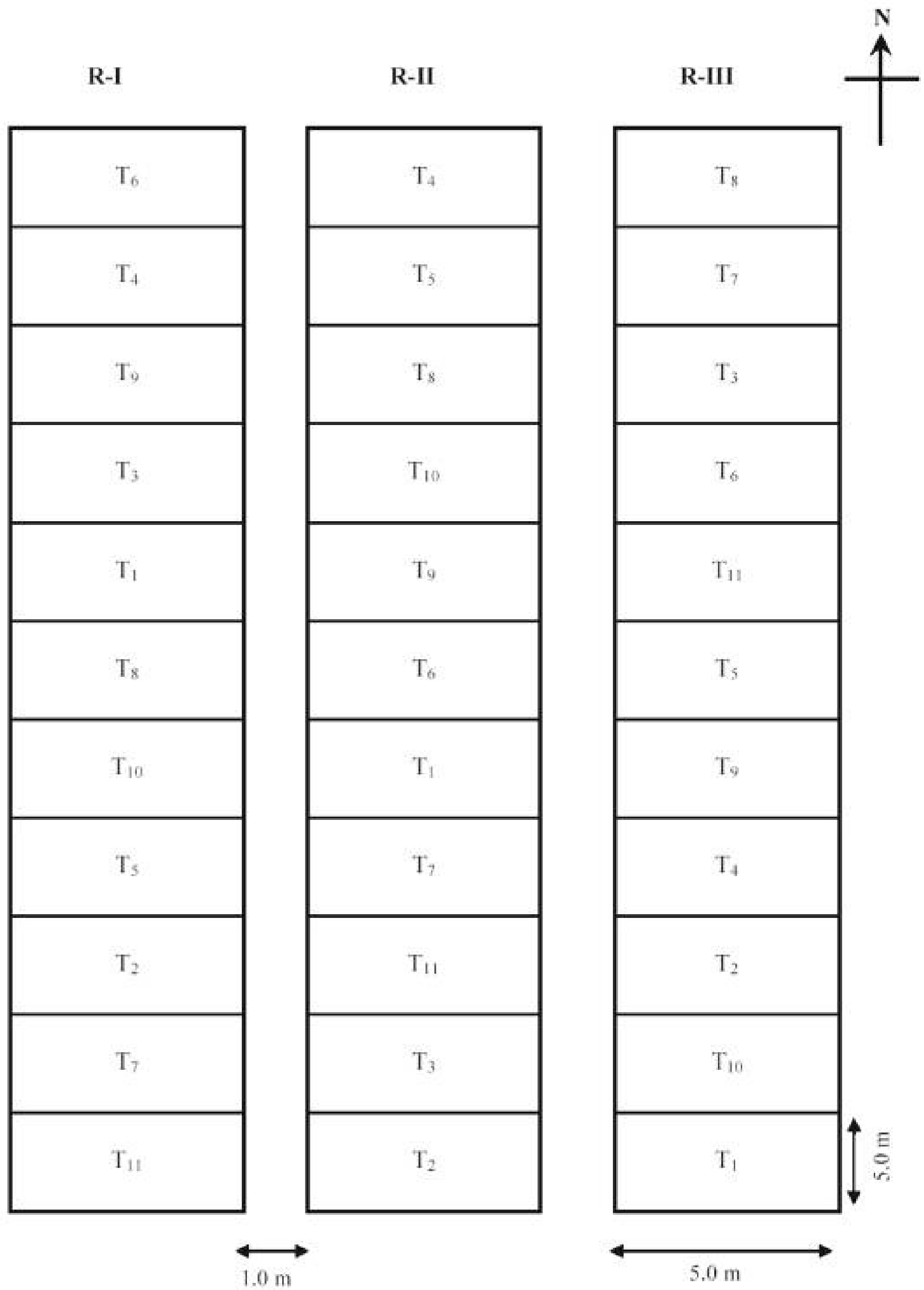

Fig. 1: Plan of layout of the experiment

Fig. 1: Plan of layout of the experiment

Treatment details

T_1 : RPP*

T_2 : RD NPK + 20 t fly ash / ha

T_3 : RD NPK + 30 t fly ash / ha

T_4 : RD NPK + 40 t fly ash / ha

T_5 : T_2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe

T_6 : T_3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe

T_7 : T_4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe

T_8 : T_2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe

T_9 : T_3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe

T_{10} : T_4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe

T_{11} : Bhoochetana**

*Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

**Bhochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

Note: RD FYM and Bio fertilizer was common to treatments T_2 –T_{10}

Bhoochetana

Mission Project on Rainfed Agriculture: To address the issues of stagnant agricultural growth in the state during 2002-2008, Government of Karnataka (GoK) embarked on a mission mode project to approach the yield gaps through science-led interventions for sustainable use of natural resources in Karnataka since 2009. The mission mode project referred as “Bhoochetanna” is technically supported by the ICRISAT and has adopted a consortium approach for implementation across 30districts by the Department of Agriculture. The goal of Bhoochetana is to make a difference in the lives of farmers in all 30 districts of Karnataka through increasing average productivity of selected crops by 20% in four years.

Plate 1: General view of experimental plot

Plate 2: T_4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe – (T_7) (90 DAS)

Plate 3: Bhoochetana (90 DAS)

The ICRISAT-led consortium comprised of knowledge-generating institutions like State Agricultural Universities of Bengaluru, Raichur and Dharwad with knowledge-transforming departments like Department of Agriculture, Watershed Development Department along with Department of Economic and Statistics. The Bhoochetana has adopted farmer participatory holistic approach in partnership with community based organizations (CBOs) for increasing the crop yields with improved management practices.

Salient features of the variety

The details of characteristics of GPBD-4 groundnut variety used in Table 4.

3.6 Cultural practices

The details regarding various cultural operations carried out during the course of investigation are furnished here.

3.6.1 Land preparation

The land was ploughed once with tractor drawn mould board plough and later on worked twice with tine cultivator. Stubbles and weeds were picked up from the experimental plots. The land was harrowed and smoothened to bring seed bed to a fine tilth.

3.6.2 Sowing and intercultural operation

The crop was sown on 30^{th} June 2011. The seeds were dibbled at 30 cm apart row spacing, at optimum depth and spacing of 10 cm was maintained between the plants. One hand weeding and two intercultural operations were done at 20 and 40 days after sowing (DAS) in order to keep the plots free from weeds.

3.6.3 Fly ash application

100% of fly ash was applied before sowing

3.6.4 Fertilizer application

Furrows were made with the help of a marker at a distance of 30 cm. Recommended dose of 25:50:25 kg N, P_2O_5, K_2O per ha was applied at 2.5 cm away from seed and 2.5 cm deep in the soil at the time of sowing

3.6.5 Harvesting

The crop was harvested on 16 October 2011. The border rows were harvested first leaving the net plot area. Net plot area plants were sun dried in order to facilitate the separation of pods, seeds and weighed separately.

3.7 Days required for phenological stages

The days required for attainment of flower initiation and peg initiation were observed. Flower initiation started from 30 days after sowing and peg initiation started from 60 days after sowing.

3.8 Collection of experimental data

Five plants from each plot were tagged randomly at 30 days after sowing (DAS) for recording various morphological, physiological, biochemical and yield attributes. The details of observations taken and standard procedures adopted are described below.

3.8.1 Morpho-physiological characters

3.8.1.1 Plant height

Plant height was measured from the ground level to the growing tip at 30, 60, 90 and DAS and at harvest on five tagged plants; the average was worked out and expressed in cm.

3.8.1.2 Number of branches per plant

Number of branches per plant was counted from five plants at 30, 60, 90, 120 DAS and at harvest and the mean was taken as number of branches per plant.

3.8.1.3 Measurement of leaf area

Leaf area measurement was done by leaf disc method and expressed as dm^2 per plant. For this purpose 25 leaf discs of known diameter were taken from all over the canopy at different time intervals and dried in oven at 80 ^0C to a constant weight. After complete drying, their dry weight was recorded accurately. Care was taken to avoid midrib portion while selecting the discs. Rests of the leaves from the plant were separated and oven dried similarly at 80 ^0C to a constant weight. Leaf area per plant was calculated by gravimetric method by using area and dry weight of discs.

3.8.1.4 Growth parameters

Various growth attributes were calculated at different stages from the data obtained on dry weight of different plant parts as indicated below

3.8.1.5 Leaf area index (LAI)

The LAI was calculated by using the formula as suggested by Watson (1954)

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{ / plant)}}{\text{Land area occupied by individual plant}}$$

3.8.1.6 Specific leaf weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967) and expressed as mg cm^{-2}.

$$\text{SLW} = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

3.8.1.7 Net assimilation rate (NAR)

It is the rate of increase in dry weight per unit leaf area per unit time and is expressed as g per dm^2 per day (Radford, 1967).

$$\text{NAR (gm}^{2\ -1}\text{)} = \frac{(\log_e L_2 - \log_e L_1)\ (W_2 - W_1)}{(L_2 - L_1)\ (t_2 - t_1)}$$

Where,

W_1 and L_1 = Total dry weight and leaf area of the plant, respectively at time t_1

W_2 and L_2 = Total dry weight and leaf area of the plant, respectively at time t_2

3.8.1.8 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area in unit time (Watson 1954). It was calculated by using the following formula and expressed as g m^{-2} day^{-1}

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{p}$$

Where,

W_1 = Total dry matter (g) at time t_1

W_2 = Total dry matter (g) at time t_2

t_2-t_1 = Time interval between two stage (days)

p = unit land area (m^2)

3.9 Biochemical parameters

3.9.1 Estimation of chlorophyll content (mg g^{-1} fresh weight)

The chlorophyll pigments *viz.*, chlorophyll `a`, chlorophyll `b` and total chlorophyll contents in leaf were determined by Dimethyl sulfoxide (DMSO) method. Top fully expanded young leaves were brought in ice box and cut into small pieces. Known weight of leaves (100 mg) was homogenized with 7 ml of Dimethyl sulfoxide (DMSO) in a test tube and kept in oven at 65˚C for about 30 minutes. Leaf residue was removed by decanting the solution and final volume was made to 10 ml by DMSO. The absorbance of the extract was measured at 645 and 663 nm, systronics UV-VIS in a spectrophotometer-118 and blank was run using DMSO. The chlorophyll `a`, chlorophyll `b` and total chlorophyll content, were calculated using the following formula and expressed in mg g^{-1} fresh weight.

Chlorophyll `a` = 12.7 (A663) – 2.69 (A645) x v/ (100 x w x a)

Chlorophyll `b` = 22.9 (A645) – 4.68 (A663) x v/ (100 x w x a)

Total chlorophyll = 20.2 (A645) – 8.02 (A663) x v/ (100 x w x a)

Where,

(A645) = Absorbance of the extract at 645 nm

(A663) = Absorbance of the extract at 663 nm

A = Path length of the extract at 663 nm

V = Volume of the extract (ml)

W = Fresh weight of the sample (mg)

3.9.2 Estimation of nitrate reductase activity (NRA)

Nitrate reeducates activity (NRA) *in vivo* was estimated at regular interval by following the method of Saradhambal *et al.* (1968). Leaves were cut into small round discs weighed and suspended in 0.1 M KNO_3 under bright light for 1 hour for complete stomatal opening. These discs were transferred to 25 ml volumetric flasks containing 5 ml of stock solution having 0.1 M phosphate buffer (pH 7.5), 0.02 KNO_3 propanol (5%) and 2 drops of chloremphenical (0.5 mg/ml). The flasks were incubated at 30˚C for 30 minutes in dark and the reaction was stopped by adding 0.1 ml of zinc acetate (1.0 M) and 1.9 ml of ethanol (70%). The contents were centrifused at 3000 rpm for 10 minutes and the supernatant was collected. To the supernatant 1.0 ml of sulfanilamide (1%) and 1ml of NNEDA (N-Naphthyl ethylene diamine dihydro chloride 0.02%) were added and incubated at room temperature for 20 minutes. The activity of nitrate reductase was determined from a standard curve of KNO_3 and expressed as µ mole NO_2 formed h^{-1} g $fr.wt^{-1}$.

3.10 Physiological parameter

3.10.1 Relative water content (RWC)

Relative water content of the fully expanded top most leaf was estimated using the formula as suggested by Barrs and Weatherly (1962) at the chosen stages.

$$\text{RWC (\%)} = \frac{\text{Fresh Weight - Dry Weight}}{\text{Turgid Weight - Dry Weight}} \times 100$$

3.11 Yield and yield components

Five plants were randomly selected and tagged in each treatment and the same were used for various morphological characters. Same tagged plants were uprooted and used for recording yield and yield components.

3.11.1 Number of pods plant^{-1}

Total number of pods (at maturity) were counted from the randomly selected five labeled plants at maturity individually and the average was worked out and expressed as number of pods plant^{-1}.

3.11.2 Shelling percentage

From each treatments (500 g) clean pods were shelled and the kernel weight was recorded. The shelling percentage was worked out by using the following formula.

$$\text{Shelling per cent} = \frac{\text{Weight of kernel (g)}}{\text{Weight of pods (g)}} \times 100$$

3.11.3 Yield per plant

Developed pods from each plant were separated and sun dried. The average weight of 5 plants in each was taken and expressed as g/plant

3.11.4. Harvest index (HI).

It was calculated by using the formula of Donald (1968) and expressed in per cent.

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.11.5 Oil content

Oil content in seed were determined by nuclear magnetic resonance (NMR) instrument. It is a rapid and non-destructive method of oil detection and expressed in percent.

The oil yield (kg ha^{-1}) was calculated by using the following formula

$$\text{Oil yield (kg ha}^{-1}) = \frac{\text{Oil content (\%)}}{100} \times \text{kernel yield (kg ha}^{-1})$$

3.11.6. Test weight (g)

One hundred seeds in three replications from each treatment were randomly selected and weighed using an electronic balance and expressed in g.

3.12 Allied parameters

3.12.1 Disease scoring

The incidence of the disease was recorded as disease score as per the modified scale given by Subbarao *et al*. (1990). The response was recorded by using the following scale indicated.

3.12.2 Germination percentage

The standard germination test was carried out by following the between paper method. Eight replications of 50 randomly selected seeds were used for germination test in each varieties. The germinator was maintained at 25^{0}C temperature with 95 + 1 per cent relative humidity. On tenth day of the test, the number of normal seedlings were separated as per the procedure stated in ISTA rule (Anon., 1999) and were counted then average of eight replications was worked out and expressed as germination percentage.

$$\text{Germination (\%)} = \frac{\text{No. of seeds germinated}}{\text{No. of seeds placed for germination test}} \times 100$$

3.12.3 Seedling vigour index

Seedling vigour index was calculated as per the formula given by Abdul-Baki and Anderson 1973) and expressed in whole number.

Seedling vigour index = Germination (%) × [Root length (cm) + shoot length (cm)]

3.13 Economics

3.13.1 Cost of cultivation

The cost of cultivation was worked out treatment wise. The prices of the inputs that were prevailing at the time of their use and selling price for groundnut as approved by the university of Agricultural Sciences, Dharwad were taken in to account the details are given in table 20a and 20b.

3.13.2 Net returns

The net profit per hectare was calculated by deducting the cost of cultivation per ha from the gross returns per hectare

3.13.3 Benefit Cost ratio

It was worked out as follows

$$\text{B:C ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.14 Statistical analysis

Data on various characters recorded from field experiment were subjected to Fischer's method of analysis of variance and interpretation as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P = 0.05. The experimental data were statistically analyzed using MSTAT-C programme.

Disease score	Description	Disease severity (%)
1	No disease	0
2	Lesions present largely on lower leaves; no defoliation	1-5
3	Lesions present largely on lower leaves; very few lesions middle leaves; defoliation of some leaflets evident on lower leaves	6–10
4	Lesions are present on lower and middle leaves but severe on lower leaves; defoliation of some leaflets evident on lower leaves	11-20
5	Lesions are present on all lower and middle leaves; over 50% defoliation of lower leaves	21-30
6	Lesions severe on lower and middle leaves; lesions present on top leaves but less severe; extensive defoliation of flower leaves; defoliation of some leaflets, evident on middle leaves	31-40
7	Lesions present on all leaves but less severe on top leaves; defoliation of all lower and some middle leaves	40-60
8	Defoliation of all lower and middle leaves; lesions severe on top leaves and some defoliation of top leaves evident	61-80
9	Defoliation of almost all leaves leaving bare stems; some leaflets be present but with severe leaf spots	80–100

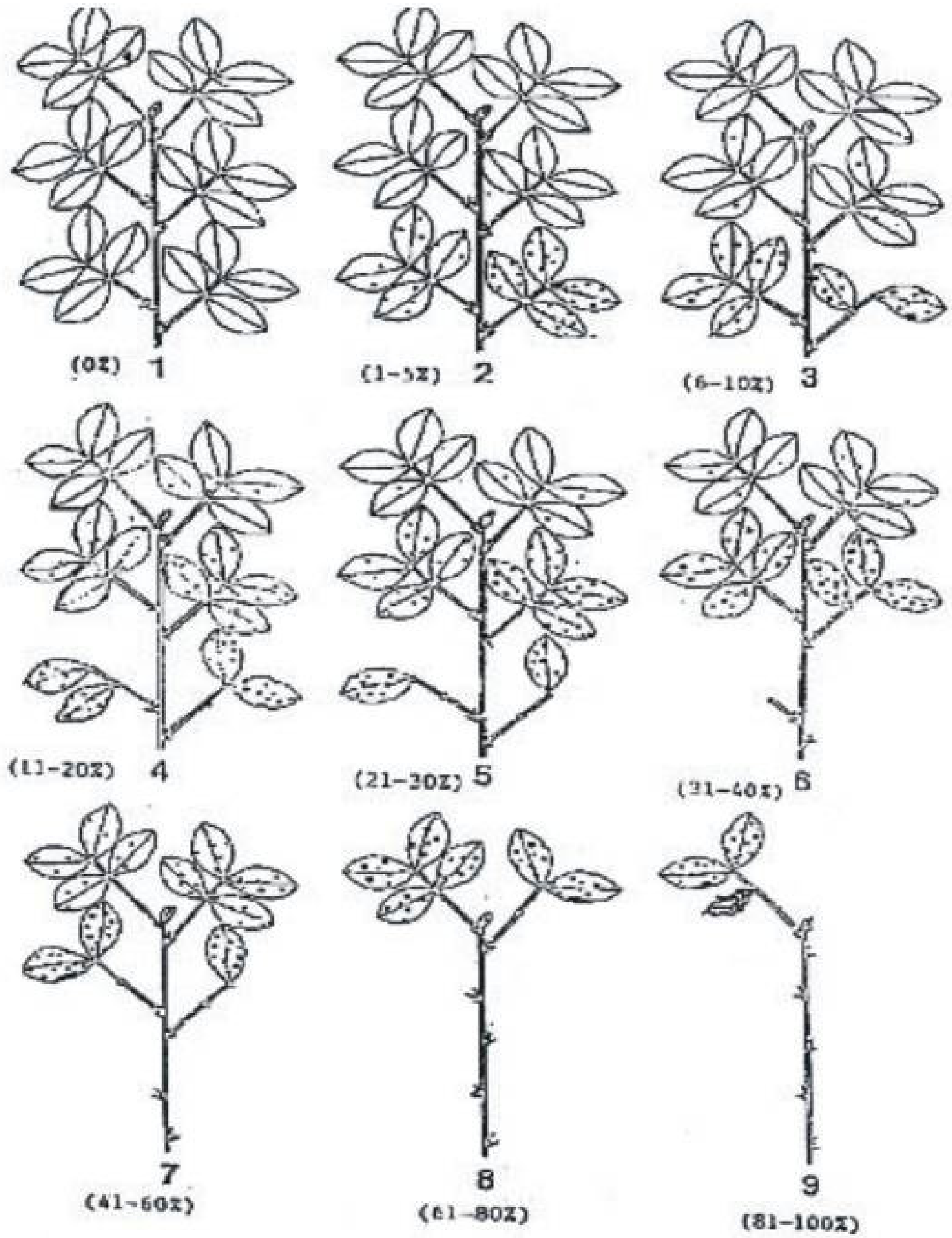

Fig. 2: Description of the modified 9-point field disease scale for leaf spot of groundnut

4. EXPERIMENTAL RESULTS

Fly ash, once it was considered as a solid waste material, is now converted to wealth by applying it to agricultural fields to improve the soil fertility, soil physical properties and crop yields to significant level. Utilization of fly ash during 1993-94 was one million tonne only, as against the generation of 60 million tonne. The increase in fly ash utilization from one million tonne during 1993-94 to 60 million tonne level was though quite satisfying but the quantum of unutilized fly ash also increase from 39 million tonne per year to 70 million tonne per year. Further, it is projected that lignite/coal would continues to remain the major source of energy, as planning commissions upto the year 2031-32 indicate that the coal requirement and generation of fly ash during the 2031-32 would be around 1800 million tonne and 600 million tonne, respectively. On one hand, the management of such a large volume of fly ash and mitigation of its likely impact on environment as well as demand on land for its deposition or missing storage is a mammoth task. On the other hand, fly ash has been proved to be a useful material for a number of applications with potential to conserve valuable minerals, substitute materials inter-alia protection of environment by decreasing mining activity and reducing CO_2 produced during a process of production materials that can be substituted by fly ash. Thus, there lies a challenge to convert the threat to an opportunity. Fly ash also holds potential to improve the physical health of agricultural soil, provide micro nutrients and as a result increase the yield of cereals, oil seeds, pulses, cotton and sugarcane etc. by 10-15 per cent, vegetables by about 20-25 per cent and root vegetables by 30-40 per cent (Arivazhagan *et al.,* 2011). In view of this, an experiment was carried out to study the effect of fly ash on growth, physiological traits and yield in groundnut during 2011-2012.On the clay soils of MARS Dharwad the results of the investigation are presented in this chapter.

4.1 Morpho-physiological traits

4.1.1 Plant height (cm)

Significant difference in plant height due to fly ash application and recommended dose of NPK along with gypsum, Zn and Fe were noticed at all the growth stages (Table 5). Plant height increased from 30 days, till harvest at various doses of fly ash application. The data indicated that the plant height increased with an increase in the fly ash level from 20 to 40 t/ha along with recommended dose of NPK and 50 per cent recommended dose of gypsum Zn and Fe. The maximum plant height at maturity (41.76 cm) was recorded in T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) and the least plant height was noticed (31.14 cm) was noticed in T_{11} (Bhoochetana) treatment.

Plant hight increased sharply from 30 to 90 DAS, with a marginal increase between 90 DAS to maturity. Per cent increase in plant height due to T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) was 58.06, 78.65, 7.251 and 74.56 per cent at 30, 60, 90 DAS and at maturity, respectively.

4.1.2 Number of branches per plant

Significant differences due to various levels of fly ash were observed in number of branches at all the stages (Table 6). It was also observed that number of branches increased rapidly between 30 to 60 DAS and a marginal increase was observed between 60 to 90 DAS. Number of branches remained more or less constant after 90 DAS. Fly ash application along with RDNPK, 50% RD of gypsum, Zn and Fe recorded higher number of branches at all the stages of growth.

At 30 DAS, the maximum number of branches recorded in T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) were followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) respectively. While, T_{11} (Bhoochetana) recorded the minimum number of branches (5.06). Similar trend was observed at al the stages of plant growth. The maximum number of branches (9.07) was recorded in T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) and the lowest (7.46) in T_{11} (Bhoochetana) at maturity and differed significantly. Application of fly ash in different levels along with RDNPK recorded significantly lower number of branches compared to treatment recorded in T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe).

Table 5: Effect of fly ash on plant height (cm) of groundnut

Treatment	Plant height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At maturity**
T_1– RPP	14.00	29.45	36.03	38.08
T_2– RD NPK + 20 t fly ash / ha	9.77	25.00	29.29	32.24
T_3– RD NPK + 30 t fly ash / ha	10.40	26.73	31.33	34.47
T_4–RD NPK + 40 t fly ash / ha	11.30	27.90	33.53	36.10
T_5– T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	12.82	28.12	33.63	36.57
T_6– T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	14.66	30.22	36.79	39.75
T_7– T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	15.50	31.11	38.57	41.76
T_8– T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	10.58	26.83	31.49	35.22
T_9– T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	13.05	28.28	35.25	37.50
T_{10}– T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	15.00	30.93	37.67	40.06
T_{11}– Bhoochetana	9.00	24.47	27.97	31.14
SEm±	1.23	1.36	1.62	1.87
CD at 5%	3.63	4.01	4.79	5.52

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 6: Effect of fly ash number of branches per plant of groundnut

Treatment	Number branches per plant			
	30 DAS	60 DAS	90 DAS	At maturity
T_1– RPP	5.95	7.54	8.44	8.52
T_2 – RD NPK + 20 t fly ash / ha	5.27	6.87	7.67	7.76
T_3 – RD NPK + 30 t fly ash / ha	5.46	7.04	7.82	7.85
T_4–RD NPK + 40 t fly ash / ha	5.61	7.20	7.99	8.03
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	5.74	7.36	8.17	8.20
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	6.11	7.68	8.49	8.58
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	6.55	8.18	9.00	9.07
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	5.49	7.10	7.91	7.95
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	5.84	7.43	8.25	8.28
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	6.30	7.90	8.72	8.76
T_{11} – Bhoochetana	5.06	6.67	7.44	7.46
SEm±	0.28	0.24	0.19	0.17
CD at 5%	0.82	0.72	0.56	0.55

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

4.1.3 Leaf area (dm^2 plant^{-1})

The data on leaf area per plant indicated nearly 3 fold increase between 30 and 90 DAS and decreased at maturity (Table 7). Significant difference were noticed between fly ash along with RDNPK, 50% RD gypsum, Zn and Fe compared to T_{11} (Bhoochetana) at all the stages.

At 30 DAS, maximum leaf area was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (4.89 dm^2 plant^{-1}) and the least was in T_{11} (Bhoochetana) (3.42dm^2 plant^{-1}). However, significant difference were observed between T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe), T_1(RPP), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe), RD NPK + 20 t fly ash / ha+ 50% RD Gypsum +50% RD Zn + 50% RD Fe and RD NPK + 40 t fly ash / ha, at 60 DAS maximum leaf area was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (10.70 dm^2 plant^{-1}) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (10.40 dm^2 plant^{-1}) and T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (10.30 dm^2 plant^{-1}) and were on par to each other. The lowest (7.99 dm^2 plant^{-1}) was recorded with T_{11} (Bhoochetana) and was significantly lower, compared to all other treatments. Fly ash application along with RDNPK recorded significantly lower leaf area compared to fly ash application with RD NPK+ 50% of RD gypsum, Zn and Fe.

At maturity, the leaf area dm^2/plant reduced in all the treatments compared to 90 DAS indicating decrease in leaf area. The per cent decrease in leaf area was more in T_{11} (Bhoochetana) (49.90%) compared to T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) indicating beneficial effect of fly ash, RDNPK 50% gypsum, Zn, and Fe.

4.1.4 Leaf area index

Leaf area index increased from 30 to 90 DAS and then declined drastically in all the treatments at maturity. In general, leaf area index increased in all fly ash RD NPK, 50% of gypsum Zn and Fe at all the stages. Except at maturity leaf area index signficiantly differed at all the stages compared to T_{11} (Bhoochetana). Overall there was 3 fold increases in leaf area index from 30 to 90 DAS.

At 30 DAS, significantly higher leaf area index (1.63) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.57), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (1.49), T_1(RPP) (1.47), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.46), T_5 (RD NPK + 20 t fly ash / ha + 25% RD Gypsum +25% RD Zn + 25% RD Fe) (1.39). Significantly lower LAI (1.14) was recorded in T_{11} (Bhoochetana). Similar trend was also observed at 60 and 90 DAS indicating the beneficial effect of flay ash, RDNPK, RD 50% of gypsum, Zn and Fe, over T_{11} (Bhoochetana) maximum leaf area index (4.50) was recorded at 90 DAS. Whereas, lowest LAI (3.43) was in Bhoochetana. At maturity the maximum leaf area index was (3.56) recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) which was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (3.26) and T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (3.06), differed significantly with respect to all other treatments. The lowest (1.78) LAI was recorded in T_{11} (Bhoochetana).

4.1.5 Total dry matter (TDM, g plant^{-1})

Generally there was increase in total dry matter (TDM) from 30 DAS till the maturity with the increase being significant from 60 DAS on words. Increase in TDM was evident with an increase in fly ash along with RDNPK, gypsum, Zn and Fe. Increase was very high at 40 t/ha along with RDNPK, 50% of RD gypsum, Zn and Fe. Increase in TDM was rapid between 30 to 60 DAS and there after, there was a steady increase in TDM from 60 DAS to till maturity. Overall, there was 13 fold of increase in TDM in fly ash along with RDNPK, 50% gypsum, Zn and Fe compared to 10 fold increase in T_{11} (Bhoochetana).

Table 7: Effect of fly ash on leaf area (dm^2 $plant^{-1}$) of groundnut

Treatment	Leaf area (dm^2 $plant^{-1}$)			
	30 DAS	**60 DAS**	**90 DAS**	**At maturity**
T_1– RPP	4.42	10.17	13.78	9.33
T_2– RD NPK + 20 t fly ash / ha	3.61	8.67	11.36	6.31
T_3– RD NPK + 30 t fly ash / ha	3.87	9.56	12.29	7.26
T_4–RD NPK + 40 t fly ash / ha	4.11	9.90	13.04	8.07
T_5– T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	4.17	10.02	13.24	8.29
T_6– T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	4.47	10.30	13.97	9.48
T_7– T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	4.89	10.70	15.10	10.68
T_8– T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	4.04	9.81	12.64	7.63
T_9– T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	4.38	10.14	13.51	8.59
T_{10}– T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	4.72	10.40	14.52	9.77
T_{11}– Bhoochetana	3.42	7.99	10.41	5.33
SEm±	0.28	0.49	0.71	0.47
CD at 5%	0.79	1.45	2.11	1.38

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 8: Effect of fly ash on leaf area index of groundnut

Treatment	Leaf area index			
	30 DAS	60 DAS	90 DAS	At maturity
T_1 – RPP	1.47	3.39	4.59	2.96
T_2 – RD NPK + 20 t fly ash / ha	1.20	2.89	3.79	2.10
T_3 – RD NPK + 30 t fly ash / ha	1.29	3.19	4.10	2.42
T_4 –RD NPK + 40 t fly ash / ha	1.37	3.30	4.35	2.69
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.39	3.34	4.41	2.76
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.49	3.43	4.66	3.06
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.63	3.57	5.03	3.56
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.35	3.27	4.21	2.54
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.46	3.38	4.50	2.86
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.57	3.47	4.84	3.26
T_{11} – Bhoochetana	1.14	2.66	3.47	1.78
SEm±	0.09	0.16	0.24	0.18
CD at 5%	0.26	0.48	0.70	0.53

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 9: Effect of fly ash on total dry matter (g) of groundnut

Treatment	Total dry matter (g/plant)			
	30 DAS	60 DAS	90 DAS	At maturity
T_1– RPP	2.98	25.17	33.03	38.90
T_2– RD NPK + 20 t fly ash / ha	2.64	19.77	25.38	28.98
T_3– RD NPK + 30 t fly ash / ha	2.72	21.54	27.84	32.14
T_4–RD NPK + 40 t fly ash / ha	2.88	23.69	30.99	36.29
T_5– T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	2.91	23.74	31.15	36.56
T_6– T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	2.99	25.60	33.56	39.52
T_7– T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	3.08	27.91	37.09	44.27
T_8– T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	2.79	22.95	30.04	35.13
T_9– T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	2.96	24.28	31.93	37.57
T_{10}– T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	3.02	26.60	35.36	41.98
T_{11}– Bhoochetana	2.60	18.63	23.65	26.68
SEm±	0.16	1.19	1.69	2.39
CD at 5%	NS	3.51	5.00	7.05

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

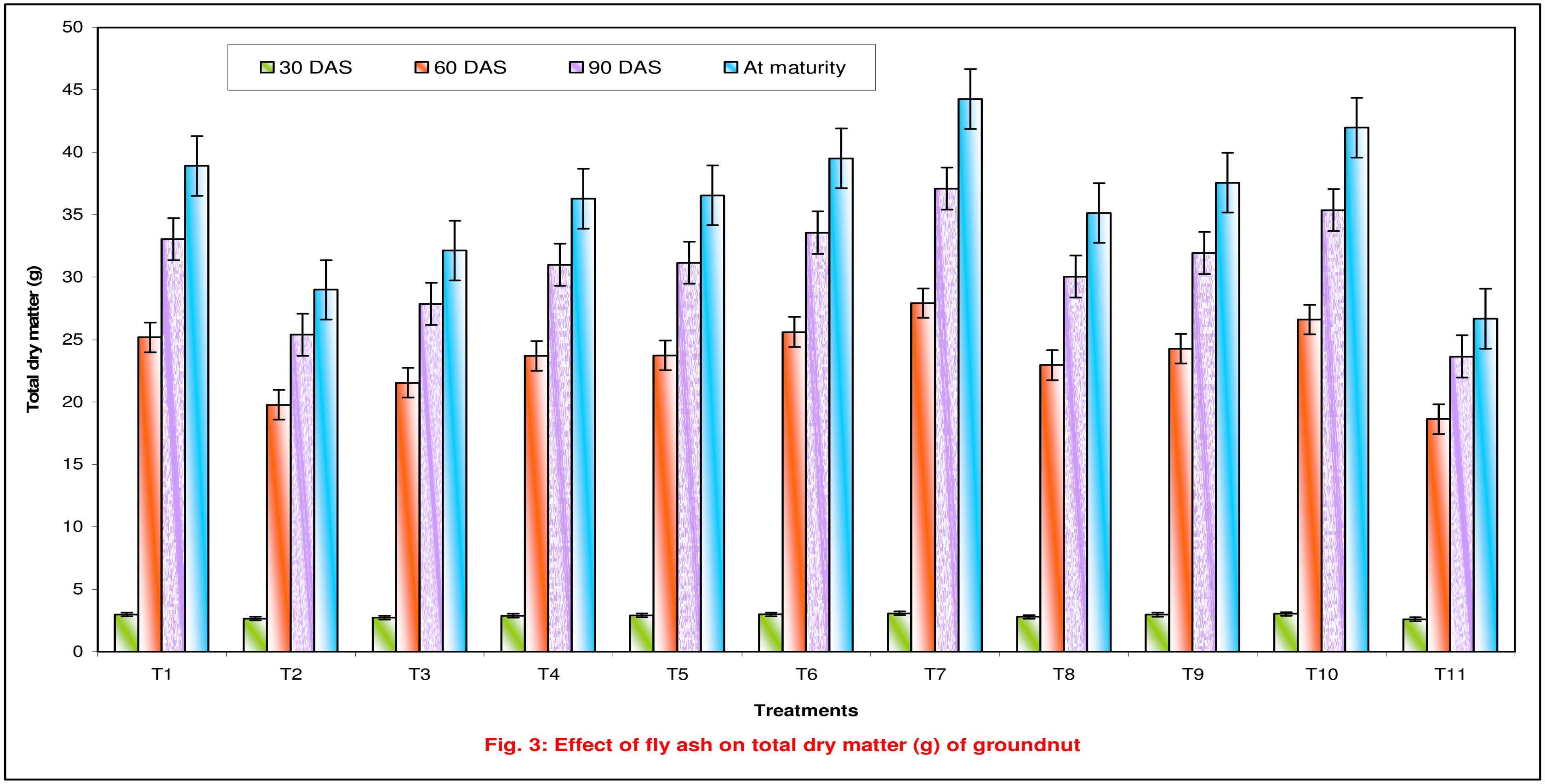

Fig. 3: Effect of fly ash on total dry matter (g) of groundnut

At 60 DAS, significantly higher TDM (27.91 gm) was recorded T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (26.60 g), RDNPK T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (25.60 g) and T_1(RPP) (25.17 gm), all these were significantly superior compared to all other treatments. Wherever, RD 50% gypsum, Zn and Fe along with RD NPK and fly ash was applied, the TDM was more compared to RD 50% gypsum, Zn and Fe was not applied. Significantly lowest TDM (26.68 g) was recorded in T_{11} (Bhoochetana) which was (65.92 g) per cent less compared to T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) compared to all other treatments.

4.1.6 Specific leaf weight (SLW, mg cm^{-2})

Specific leaf weight increased from 30 to 90 DAS and then declined drastically in all the treatments at maturity. In general, specific leaf weight increased in all fly ash RDNPK, 50% of gypsum, Zn and Fe at all the stages. Except at maturity specific leaf weight signficiantly differed at 60-90 DAS compared to T_{11} (Bhoochetana). Overall there was 3 fold increase in specific leaf weight from 30 to 90 DAS.

At 30 DAS, specific leaf weight showed non significant difference. The highest SLW was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (0.389 g dm^{-2}) and the lowest SLW recorded in T_{11} (Bhoochetana) (0.363 g dm^{-2}).

At 60 DAS, significantly higher specific leaf weight (0.687 g dm^{-2}) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.678 g dm^{-2}), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.671 g dm^{-2}), T_1(RPP) (0.667 g dm^{-2}), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.662 g dm^{-2}), RD NPK + 20 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe (0.653 g dm^{-2}). Significantly lower SLW (0.602 g dm^{-2}) was recorded in T_{11} (Bhoochetana). Similar trend was also observed at 90 and at maturity indicating the beneficial effect of flay ash, RDNPK, RD 50% of gypsum, Zn and Fe. Over T_{11} (Bhoochetana) maximum specific leaf weight (0.635 g dm^{-2}) was recorded at 90 DAS. Whereas, the lowest SLW (0.563 g dm^{-2}) was in Bhoochetana. At maturity, the maximum specific leaf weight (0.598 g dm^{-2}) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) which was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.586 g dm^{-2}) and RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe (0.571 g dm^{-2}), T_1(RPP) (0.570 g dm$^{-2)}$ were differed significantly with respect to all other treatments. The lowest (0.534 g dm^{-2}) SLW was recorded in T_{11} (Bhoochetana).

4.1.7 Net assimilation rate (NAR, g dm^{-2} leaf area d^{-1})

The data pertaining to NAR as influenced by fly ash application along with RDNPK, 50% RD gypsum, Zn and Fe levels in ground nut presented in Table 11, indicated significant difference at all stages of crop growth. Maximum NAR was recorded at early stage of crop growth and least during 90 DAS to maturity. At early stages (30 to 60 DAS), significantly high NAR was recorded with RDNPK + 40 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe (0.484 g dm^{-2} leaf area d^{-1}) and was on par with RDNPK T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.475 g dm^{-2} leaf area d^{-1}), RDNPK T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.469 g dm^{-2} leaf area d^{-1}) , T_1(RPP) (0.466 g dm^{-2} leaf area d^{-1}) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.455 g dm^{-2} leaf area d^{-1}). Significantly NAR was less in only fly ash and RDNPK treatments compared to fly ash RDNPK 50% RD gypsum, Zn and Fe treatments. Significantly lower NAR (0.429 g dm^{-2} leaf area d^{-1}) was registered in T_{11} (Bhoochetana) compared to other treatments. Similar trend was also recorded at 60 to 90 DAS, where in NAR was less compared to the previous stage of crop growth. However, maximum NAR (0.104 g dm^{-2} leaf area d^{1}) recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and lowest (0.080 g dm^{-2} leaf area d^{-1}) in T_{11} (Bhoochetana), at maturity NAR was further reduced in all the treatments.

Table 10: Effect of fly ash on specific leaf weight (g dm^{-2}) of groundnut

Treatment	Specific leaf weight (g dm^{-2})			
	30 DAS	60 DAS	90 DAS	At maturity
T_1– RPP	0.380	0.667	0.622	0.570
T_2 – RD NPK + 20 t fly ash / ha	0.368	0.613	0.571	0.541
T_3 – RD NPK + 30 t fly ash / ha	0.369	0.617	0.594	0.547
T_4 –RD NPK + 40 t fly ash / ha	0.371	0.646	0.605	0.553
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.373	0.653	0.613	0.561
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.385	0.671	0.626	0.571
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.389	0.687	0.635	0.598
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.371	0.624	0.602	0.552
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.378	0.662	0.617	0.566
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.387	0.678	0.631	0.586
T_{11} – Bhoochetana	0.363	0.602	0.563	0.534
SEm±	0.022	0.017	0.013	0.011
CD at 5%	NS	0.051	0.038	0.034

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 11: Effect of fly ash on net assimilation rate (g dm^{-2} leaf area d^{-1}) of groundnut

Treatment	Net assimilation rate (g dm^{-2} leaf area d^{-1})		
	30 -60 DAS	60 -90 DAS	90 DAS- Maturity
T_1– RPP	0.466	0.096	0.076
T_2 – RD NPK + 20 t fly ash / ha	0.431	0.082	0.061
T_3 – RD NPK + 30 t fly ash / ha	0.433	0.084	0.065
T_4 –RD NPK + 40 t fly ash / ha	0.451	0.093	0.074
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.453	0.093	0.074
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.469	0.096	0.076
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.484	0.104	0.081
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.449	0.092	0.074
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.455	0.094	0.075
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.475	0.103	0.080
T_{11} – Bhoochetana	0.429	0.080	0.058
SEm±	0.011	0.004	0.005
CD at 5%	0.033	0.013	0.014

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Significantly maximum NAR (0.081 g dm^{-2} leaf area d^{-1}) was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.080 g dm^{-2} leaf area d^{-1}), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.076 g dm^{-2} leaf area d^{-1}), T_1(RPP) (0.076 g dm^{-2} leaf area d^{-1} g dm^{-2} leaf area d^{-1}) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.075 g dm^{-2} leaf area d^{-1}) which were on par with each other.

4.1.8 Crop growth rate (CGR, gm^{-2} day^{-1})

The data pertaining to CGR as influenced by fly ash application along with RDNPK, 50% RD gypsum, Zn and Fe levels in ground nut presented in Table 12, indicated significant difference at all stages of crop growth. Maximum CGR was recorded early stage of crop growth and least during 90 DAS to maturity. At early stages (30 to 60 DAS). Significantly high CGR was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (0.276 g dm^{-2} land area day^{-1}) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.262 g dm^{-2} land area day^{-1}), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.251 g dm^{-2} land area day^{-1}), T_1(RPP) (0.247 g dm^{-2} land area day^{-1}) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.237 g dm^{-2} land area day^{-1}). Significantly CGR was less in only fly ash and RDNPK treatments compared to fly ash RDNPK, 50% RD gypsum, Zn and Fe treatments. Significantly lower CGR (0.178 g dm^{-2} land area day^{-1}) was registered in T_{11} (Bhoochetana) compared to other treatments. Similar trend was also recorded at 60 to 90 DAS, where in CGR was less compared to the previous stage of crop growth. However, maximum CGR (0.102 g dm^{-2} land area day^{-1}) recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and lowest (0.056 g dm^{-2} land area day^{-1}) in T_{11} (Bhoochetana), at maturity CGR was further reduced in all the treatments. Significantly maximum (0.081 g dm^{-2} land area day^{-1}) was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.074 g dm^{-2} land area day^{-1}), RDNPK T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.066 g dm^{-2} land area day^{-1}), which were on par with each other.

4.2 Biochemical parameters

4.2.1 Chlorophyll `a` content (mg/g fresh weight)

The data on effect of fly ash along with RDNPK 50% of RD gypsum, Zn and Fe on chlorophyll ‘a’ content revealed significant differences at all the stages in groundnut (Table 13) it was observed that the chlorophyll ‘a’ content increased from 30 to 60 DAS and declined their after 90 DAS and at maturity.

At 30 DAS there was no significant difference in chlorophyll ‘a’ content, however, maximum (1.07 mg/gm fresh weight) chlorophyll ‘a’ content recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe)and lowest (0.96 mg/gm fresh weight) in T_{11} (bhoochetana). Chlorophyll ‘a’ differed significantly at 60, 90 DAS and at maturity. At 60 DAS significantly higher chlorophyll ‘a’ content (1.78 mg/gm fresh weight) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.76 mg/gm fresh weight), RDNPK T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (1.75 mg/gm fresh weight), T_1(RPP) (1.72 mg/gm fresh weight) T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.70 mg/gm fresh weight), chlorophyll ‘a’ content was significantly reduced when only fly ash at different levels and RD NPK was applied. However significantly lower chlorophyll ‘a content (1.58 mg/gm fresh weight) was recorded in T_{11} (Bhoochetana). Similar trend was continued in 90 DAS and at maturity. It was also observed that the chlorophyll ‘a’ content was reduced at maturity compared to all other stages of crop growth. Significantly lower (1.19 mg/gm fresh weight) and (0.64 mg/gm fresh weight) chlorophyll ‘a’ content was recorded in T_{11} (Bhoochetana) as 90 DAS and at maturity, respectively.

Table 12: Effect of fly ash on crop growth rate (CGR) (g dm^{-2} land area day^{-1}) of groundnut

Treatment	Crop growth rate (CGR) (g dm^{-2} land area day^{-1})		
	30 -60 DAS	**60 -90 DAS**	**90 DAS - Maturity**
T_1– RPP	0.247	0.087	0.065
T_2 – RD NPK + 20 t fly ash / ha	0.190	0.062	0.040
T_3 – RD NPK + 30 t fly ash / ha	0.209	0.070	0.048
T_4 –RD NPK + 40 t fly ash / ha	0.230	0.081	0.059
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.232	0.082	0.060
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.251	0.088	0.066
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.276	0.102	0.080
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.224	0.079	0.057
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.237	0.085	0.063
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.262	0.097	0.074
T_{11} – Bhoochetana	0.178	0.056	0.034
SEm±	0.015	0.005	0.004
CD at 5%	0.045	0.016	0.012

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 13: Effect of fly ash on chlorophyll a content (mg/g fresh weight) of groundnut

Treatment	Chlorophyll a (mg/g fresh weight)			
	30 DAS	60 DAS	90 DAS	At Maturity
T_1 - RPP	1.04	1.72	1.36	0.75
T_2 - RD NPK + 20 t fly ash / ha	0.98	1.60	1.22	0.65
T_3 - RD NPK + 30 t fly ash / ha	0.99	1.62	1.23	0.69
T_4 -RD NPK + 40 t fly ash / ha	1.01	1.65	1.26	0.71
T_5 - T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.03	1.67	1.30	0.73
T_6 - T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.05	1.75	1.37	0.78
T_7 - T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.07	1.78	1.42	0.81
T_8 - T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.00	1.63	1.24	0.70
T_9 - T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.04	1.70	1.33	0.74
T_{10} - T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.06	1.76	1.40	0.80
T_{11} - Bhoochetana	0.96	1.58	1.19	0.64
SEm$\pm$	0.02	0.03	0.04	0.02
CD at 5%	NS	0.10	0.12	0.07

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Maximum chlorophyll ‘a’ content (1.42 and 0.81 mg/gm fresh weight) was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) at 90 DAS and at maturity respectively and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.40 and 0.80 mg/gm fresh weight), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (1.37 and 0.78 mg/gm fresh weight), T_1(RPP) (1.36 and 0.75 mg/gm fresh weight) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.33 and 0.74 mg/gm fresh weight).

4.2.2 Chlorophyll `b` content (mg/g fresh weight)

The data on effect of fly ash along with RDNPK 50% of RD gypsum, Zn and Fe on chlorophyll ‘b’ content revealed significant differences at all the stages in groundnut (Table 14). It was observed that the chlorophyll ‘b’ content increased from 30 to 60 DAS and declined their after 90 DAS and at maturity.

At 30 DAS there was significant difference in chlorophyll ‘b’ content. Maximum (0.49 mg/gm fresh weight) chlorophyll ‘b’ content recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and the lowest (0.34 mg/gm fresh weight) was in T_{11} (Bhoochetana). At 60 DAS significantly higher chlorophyll ‘b’ content (0.83 mg/gm fresh weight) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.78 mg/gm fresh weight), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.75 mg/gm fresh weight) and T_1(RPP) (0.74 mg/gm fresh weight). Chlorophyll ‘b’ content was significantly reduced when only fly ash at different levels and RD NPK was applied. Significantly lower chlorophyll ‘b’ content (0.39 mg/gm fresh weight) was recorded in T_{11} (Bhoochetana). Similar trend was continued in 90 DAS and at maturity. However, the chlorophyll ‘b’ content was reduced at maturity compared to all other stages of crop growth. Significantly lower (0.39 mg/gm fresh weight) and (0.26 mg/gm fresh weight) chlorophyll ‘b’ content was recorded in T_{11} (Bhoochetana) as 90 DAS and at maturity, respectively. Maximum chlorophyll ‘b’ content (0.65 and 0.42 mg/gm fresh weight) was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) at 90 DAS and at maturity respectively and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (0.62 and 0.39 mg/gm fresh weight), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (0.59 and 0.37 mg/gm fresh weight) and T_1(RPP) (0.56 and 0.34 mg/gm fresh weight).

4.2.3 Total chlorophyll content (mg/g fresh weight)

The data on effect of fly ash along with RDNPK 50% of RD gypsum, Zn and Fe on total chlorophyll content reviled significant differences at all the stages in groundnut (Table 15) it was observed that the total chlorophyll content increased from 30 to 60 DAS and declined their after 90 DAS and at maturity.

At 30 DAS there was no significant difference in total chlorophyll content. Nevertheless maximum (1.56 mg/gm fresh weight) total chlorophyll content was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) and lowest (1.31 mg/gm fresh weight) was in T_{11} (Bhoochetana). Total chlorophyll at 60 DAS recorded significantly higher total chlorophyll content (2.61 mg/gm fresh weight) in RDNPK + 40 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (2.54 mg/gm fresh weight), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (2.50 mg/gm fresh weight), T_1(RPP) (2.46 mg/gm fresh weight) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (2.40 mg/gm fresh weight), total chlorophyll content was significantly reduced when only fly ash at different levels and RD NPK was applied. Significantly lower total chlorophyll content (2.19 mg/gm fresh weight) was recorded in T_{11} (Bhoochetana). Similar trend was continued in 90 DAS and at maturity. However, the total chlorophyll content was reduced at maturity compared to all other stages of crop growth. Significantly lower (1.58 and 0.90 mg/gm fresh weight) total chlorophyll content was recorded in T_{11} (Bhoochetana) as 90 DAS and at maturity, respectively.

Table 14: Effect of fly ash on chlorophyll 'b' content (mg/g fresh weight) of groundnut

Treatment	Chlorophyll b (mg/g fresh weight)			
	30 DAS	60 DAS	90 DAS	At Maturity
T_1– RPP	0.43	0.74	0.56	0.34
T_2 – RD NPK + 20 t fly ash / ha	0.35	0.63	0.41	0.27
T_3 – RD NPK + 30 t fly ash / ha	0.36	0.65	0.44	0.28
T_4 –RD NPK + 40 t fly ash / ha	0.39	0.67	0.51	0.31
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.41	0.68	0.52	0.33
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.45	0.75	0.59	0.37
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	0.49	0.83	0.65	0.42
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.38	0.65	0.47	0.30
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.42	0.70	0.54	0.33
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	0.46	0.78	0.62	0.39
T_{11} – Bhoochetana	0.34	0.61	0.39	0.26
SEm$\pm$	0.01	0.04	0.03	0.02
CD at 5%	0.04	0.12	0.09	0.06

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 15: Effect of fly ash on total chlorophyll content (mg/g fresh weight) of groundnut

Treatment	Total chlorophyll (mg/g fresh weight)			
	30 DAS	60 DAS	90 DAS	At Maturity
T_1 – RPP	1.47	2.46	1.92	1.09
T_2 – RD NPK + 20 t fly ash / ha	1.33	2.23	1.63	0.92
T_3 – RD NPK + 30 t fly ash / ha	1.35	2.27	1.67	0.97
T_4 –RD NPK + 40 t fly ash / ha	1.40	2.32	1.77	1.02
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.44	2.35	1.82	1.06
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.49	2.50	1.96	1.15
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	1.56	2.61	2.07	1.23
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.38	2.28	1.71	1.00
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.46	2.40	1.87	1.07
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	1.52	2.54	2.02	1.19
T_{11} – Bhoochetana	1.31	2.19	1.58	0.90
SEm±	0.05	0.08	0.09	0.06
CD at 5%	0.14	0.22	0.28	0.19

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

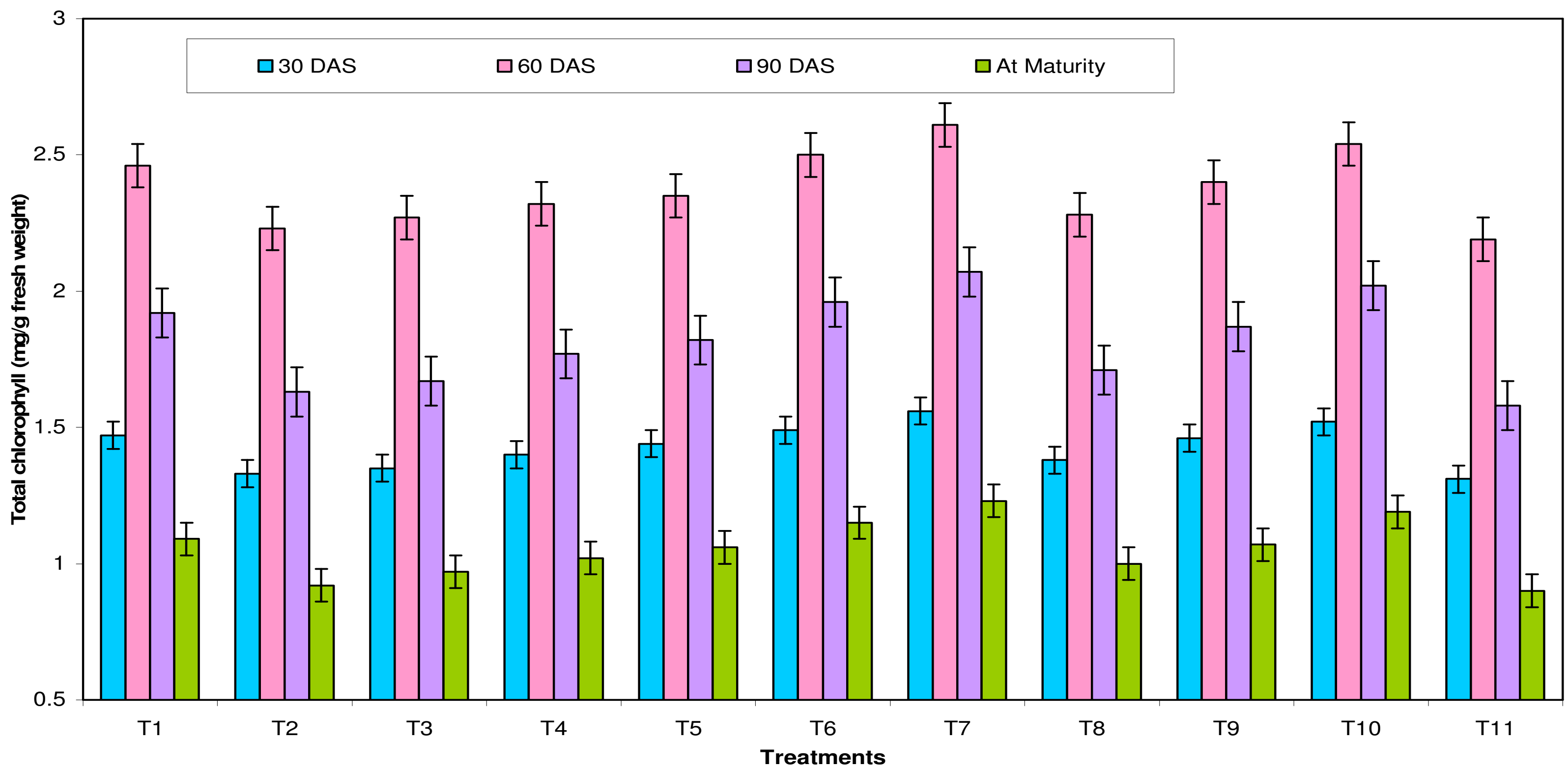

Fig. 4: Effect of fly ash on total chlorophyll content (mg/g fresh weight) of groundnut

Fig. 4: Effect of fly ash on total chlorophyll content (mg/g fresh weight) of groundnut

Maximum total chlorophyll content (2.07 and 1.23 mg/gm fresh weight) was recorded with T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) at 90 DAS and at maturity respectively and was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (2.02 and 1.19 mg/gm fresh weight), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (1.96 and 1.15 mg/gm fresh weight), T_1(RPP) (1.92 and 1.09 mg/gm fresh weight) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (1.87 and 1.07 mg/gm fresh weight).

4.2.4 Nitrate reductase activity (NRA) (µ mole NO_2 g^{-l} fr. wt hr^{-1})

The data on the effect of fly ash levels along with RDNPK, RD gypsum, Zn and Fe on NRA in leaves, presented in Table 16 indicated that NRA increase from 30 to 60 DAS, and then declined there after in all the treatments at all the leavels and fly ash.

At 30 DAS there was no significant differences in NRA activity, however, the maximum activity (524.3 µ mole NO_2 g^{-l} fr.wt hr^{-1}) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (518.91 µ mole NO_2 g^{-l} fr. wt hr^{-1}) and the lowest (571.87 µ mole NO_2 g^{-l} fr. wt hr^{-1}) in T_{11} (Bhoochetana). NRA activity in leaves differed significantly from 60 DAS onwords and trend was continued till maturity. Significantly higher NRA activity (609.60 µ mole NO_2 g^{-l} fr.wt hr^{-1}) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followd by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (596.29 µ mole NO_2 g^{-l} fr.wt hr^{-1}), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (582.18 µ mole NO_2 g^{-l} fr.wt hr^{-1}), T_1(RPP) (574.73 µ mole NO_2 g^{-l} fr.wt hr^{-1}) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (570.11 µ mole NO_2 g^{-l} fr.wt hr^{-1}) and were on par with each other. NRA activiy was significantly lower in leaves,where gypsum, Zn and Fe was not applied. In T_{11} (Bhoochetana) treatment, significantly lower NRA activity (515.31 µ mole NO_2 g^{-l} fr. wt hr^{-1}) was recorded and similar trend was continued at 90 DAS. However, overall activity of NRA in leaves was reduced compared to 60 DAS. At 90 DAS the NRA activity was higher in (T_7) RDNPK + 40 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe and was significantly superior, compared to T_2, T_3, T_4 and T_{11} (Bhoochetana), which was recorded lower (342.54 µ mole NO_2 g^{-l} fr. wt hr^{-1}) NRA activity in leaves at maturity.

4.2.5 Relative water content (RWC) (%)

The data on the effect of fly ash levels along with RDNPK, RD gypsum, Zn and Fe,on relative water content in leaves presented in Table 17, indicated that relative water content was increase from 30 to 60 DAS and then declined there after in all the treatments at all the levels of fly ash.

At 30 DAS there was no significant differences in relative water content, however, the maximum RWC (77.04 %) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (76.25%) and the lowest (69.34%) in T_{11} (Bhoochetana). Relative water content in leaves differed significantly from 60 DAS onwords and the trend was continued till maturity. Significantly higher RWC (70.71) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followd by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (69.17%), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (67.53%) and T_1(RPP) (66.63%) and were on par with each other. Relative water content was significantly lower in leaves, where gypsum, Zn and Fe was not applied in Bhoochetana treatment. At 90 DAS the relative water content was higher in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (60.15%) and was significantly superior, compared to T_1(RPP), T_2(RDNPK+20 t fly ash/ha), T_4(RDNPK+4+0 t fly ash/ha) and T_{11} (Bhoochetana), which was recorded lower (54.25%) relative water content in leaves at maturity. Relative water content was further reduced and was maximum in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (56.08%) and was lowest in (48.67%) T_{11} (Bhoochetana).

Table 16: Effect of fly ash on nitrate reductase activity (NRA) (µ mole NO_2 g^{-l} fr.wt hr^{-1}) of groundnut

Treatment	NRA (µ mole No_2 g^{-l} fr.wt hr^{-1})			
	30 DAS	**60 DAS**	**90 DAS**	**At Maturity**
T_1– RPP	510.09	574.73	391.74	291.10
T_2 – RD NPK + 20 t fly ash / ha	480.23	522.64	346.47	264.51
T_3 – RD NPK + 30 t fly ash / ha	485.15	535.13	351.03	271.04
T_4 –RD NPK + 40 t fly ash / ha	494.90	545.04	368.50	276.06
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	504.71	564.05	374.17	285.69
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	513.52	582.18	397.57	302.73
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	524.30	609.60	439.98	316.99
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	490.08	542.32	357.52	274.63
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	509.11	570.11	387.28	288.76
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	518.91	596.29	413.43	310.07
T_{11} – Bhoochetana	471.87	515.31	342.54	257.65
SEm$\pm$	16.48	17.69	19.64	9.07
CD at 5%	NS	52.18	57.94	26.76

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

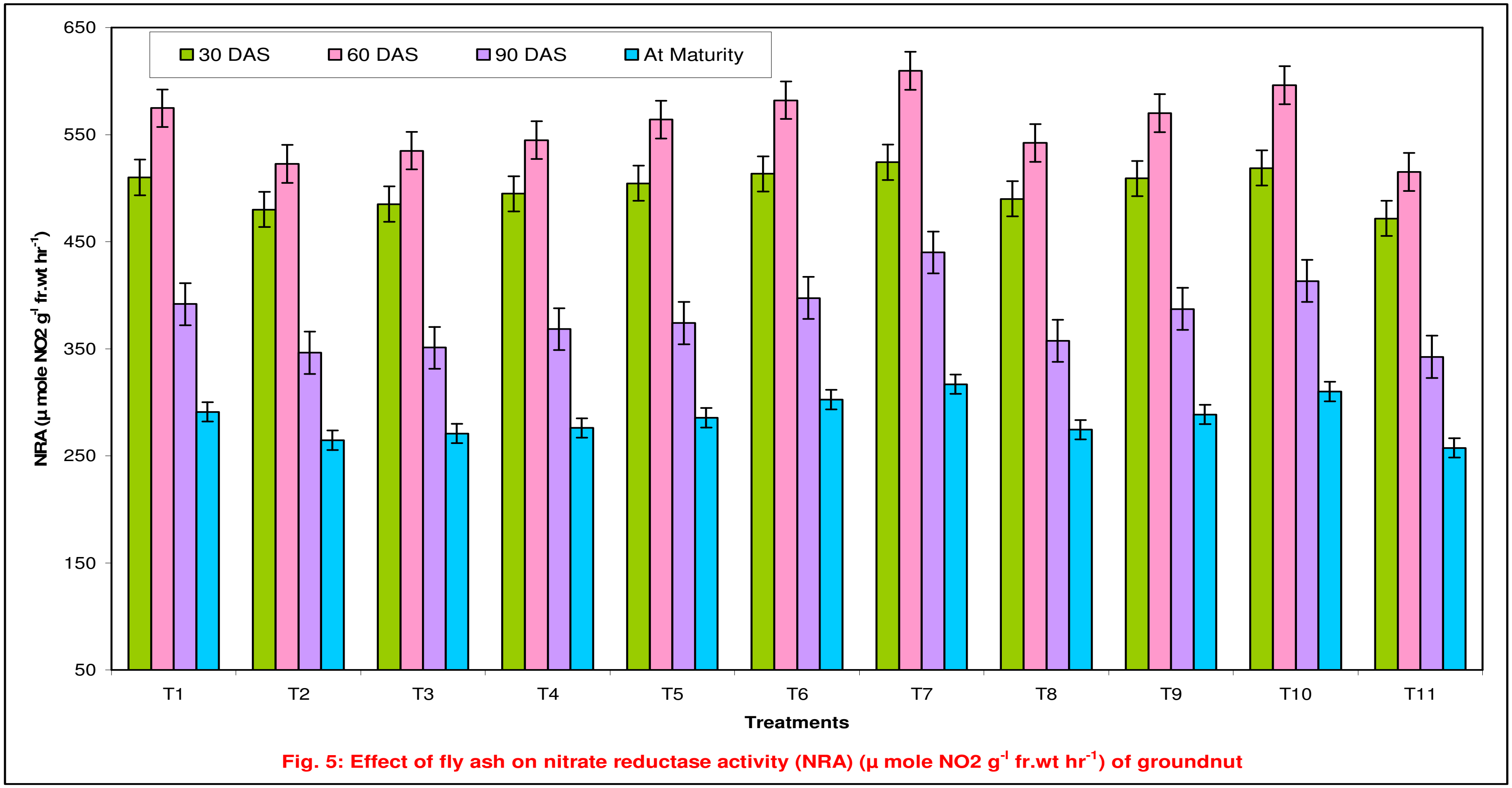

Fig. 5: Effect of fly ash on nitrate reductase activity (NRA) (µ mole NO2 g-l fr.wt hr-1) of groundnut

4.3 Yield and yield components

4.3.1. Number of pods plant^{-1}

Number of pods per plant of groundnut was significantly affected by various doses of fly ash and fertilizers treatment (Table 18)

The data on number of pods per plant indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in number of pods per plant with an increase in the fly ash levels. Significantly higher number of pods per plant (41.17) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (40.24), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (40.05), T_1(RPP) (38.63), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (38.26), T_5 (RD NPK + 20 t fly ash / ha + 25% RD Gypsum +25% RD Zn + 25% RD Fe) (37.54) and were on par with each other. The number of pods per plant was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, 50% RD gypsum, Zn and Fe. Significantly, lower (32.43) number of pods per plant was recorded in T_{11} (Bhoochetana).

4.3.2 Test weight (g)

The data on test weight (100 seed weight) indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in test weight with an increase in the fly ash levels. Significantly higher test weight (43.26 g) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe), followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (43.08 g), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (40.05 g), T_1(RPP) (42.31g), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (42.17g),T_5 (RD NPK + 20 t fly ash / ha + 25% RD Gypsum +25% RD Zn + 25% RD Fe) (41.80 g) and were on par with each other. The test weight was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (39.71g) test weight was recorded in T_{11} (Bhoochetana).

4.3.3 Shelling (%)

The data on shelling percentage indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe it was also observed that there was an increase in shelling percentage with an increase in the fly ash levels. Significantly higher shelling percentage (76.35 %) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (76.10%), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (75.83%), T_1(RPP) (75.24%), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (74.71%) and T_5 (RD NPK + 20 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe) (74.12%) and were on par with each other. The shelling percentage was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (72.34%) shelling percentage was recorded in T_{11} (Bhoochetana).

4.3.4 Oil content (%)

The data on oil content indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in oil content with an increase in the fly ash levels. Significantly higher oil content (51.17%) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (51.12%), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (51.02%), T_1(RPP) (50.89%), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (50.45%), T_5 (RD NPK + 20 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe) (49.74%) and T_4(RDNPK + 40 t fly ash/ha) (49.26%) and were on par with each other. The oil content was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (47.10%) oil content was recorded in T_{11} (Bhoochetana).

Table 17: Effect of fly ash on relative water content (%) of groundnut

Treatment	Relative water content (%)			
	30 DAS	**60 DAS**	**90 DAS**	**At Maturity**
T_1– RPP	74.95	66.63	58.43	53.74
T_2– RD NPK + 20 t fly ash / ha	70.56	62.39	55.03	49.68
T_3– RD NPK + 30 t fly ash / ha	71.28	63.43	55.10	51.43
T_4–RD NPK + 40 t fly ash / ha	72.72	64.34	56.12	52.38
T_5– T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	74.16	64.90	57.34	52.74
T_6– T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	75.46	67.53	59.21	54.34
T_7– T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	77.04	70.71	60.15	56.08
T_8– T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	72.00	63.95	55.84	52.12
T_9– T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	74.81	65.53	57.96	53.31
T_{10}– T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	76.25	69.17	59.63	55.65
T_{11}– Bhoochetana	69.34	61.52	54.25	48.67
SEm±	2.42	1.39	1.21	1.27
CD at 5%	NS	4.09	3.57	3.74

DAS – Days after sowing

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Table 18: Effect of fly ash on yield and yield components of groundnut

Treatment	No. of pods/plant (No.)	Test weight (g)	Shelling (%)	Oil content (%)	Yield per plant (g)	Yield (kg/ha)	Harvest index (%)
T_1– RPP	38.63	42.31	75.24	50.89	16.08	3581.1	41.34
T_2 – RD NPK + 20 t fly ash / ha	33.17	40.32	72.75	47.95	11.49	3114.4	39.63
T_3 – RD NPK + 30 t fly ash / ha	33.82	40.65	73.17	48.31	11.79	3227.3	40.17
T_4 –RD NPK + 40 t fly ash / ha	36.85	41.29	73.98	49.26	14.78	3453.5	40.74
T_5 – T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	37.54	41.80	74.12	49.74	15.00	3542.1	41.04
T_6 – T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	40.05	42.64	75.83	51.02	16.46	3591.6	41.64
T_7 – T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	41.17	43.26	76.35	51.17	18.74	3617.4	42.34
T_8 – T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	35.3	41.04	73.57	48.70	14.13	3375.8	40.24
T_9 – T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	38.26	42.17	74.71	50.45	15.46	3562.3	41.14
T_{10} – T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	40.24	43.08	76.1	51.12	17.61	3605.9	41.94
T_{11} – Bhoochetana	32.43	39.71	72.34	47.10	10.49	2995.1	39.33
SEm±	1.25	0.59	0.77	0.70	0.98	105.98	0.43
CD at 5%	3.67	1.73	2.28	2.06	2.89	312.64	1.28

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

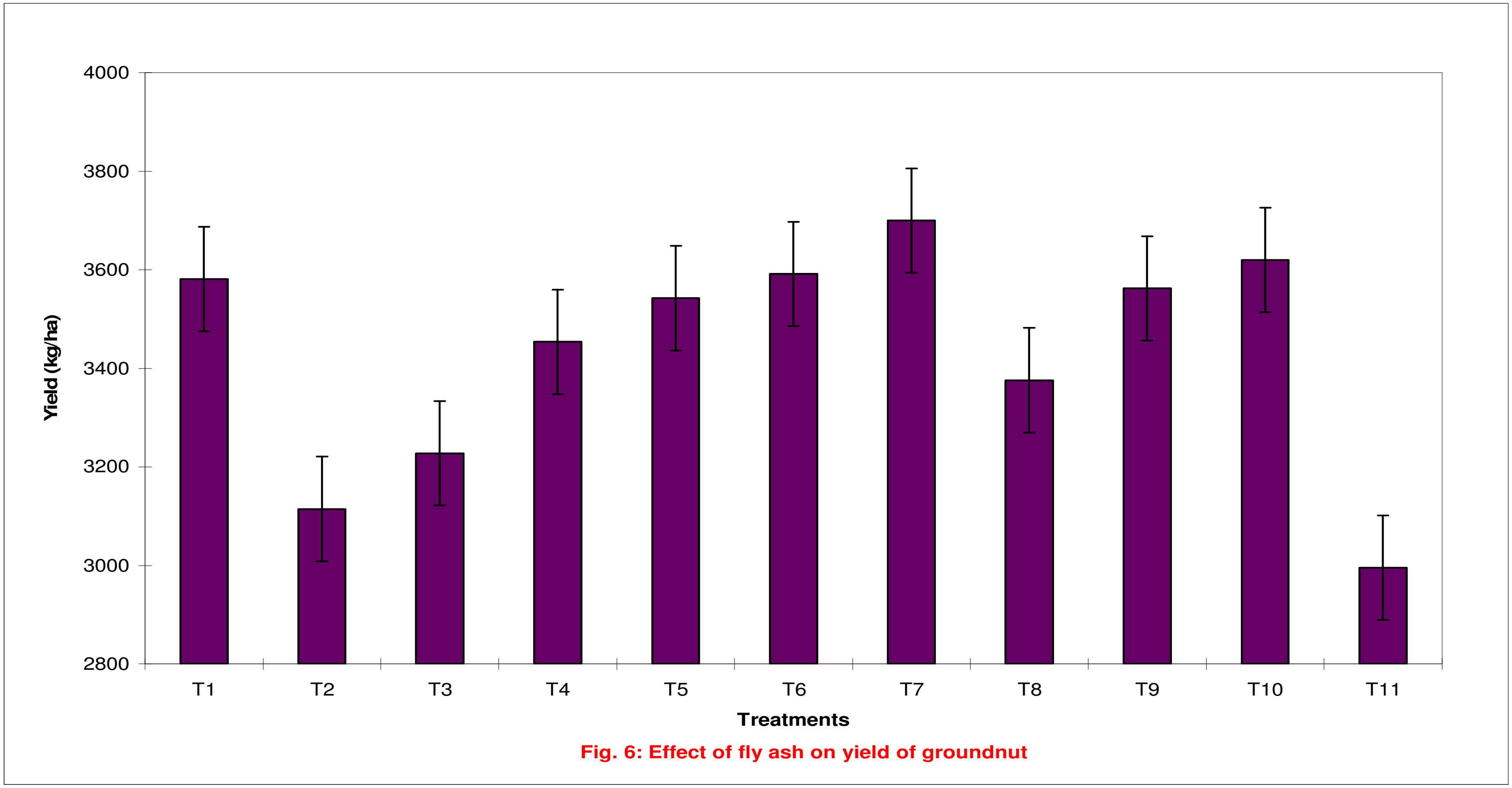

Fig. 6: Effect of fly ash on yield of groundnut

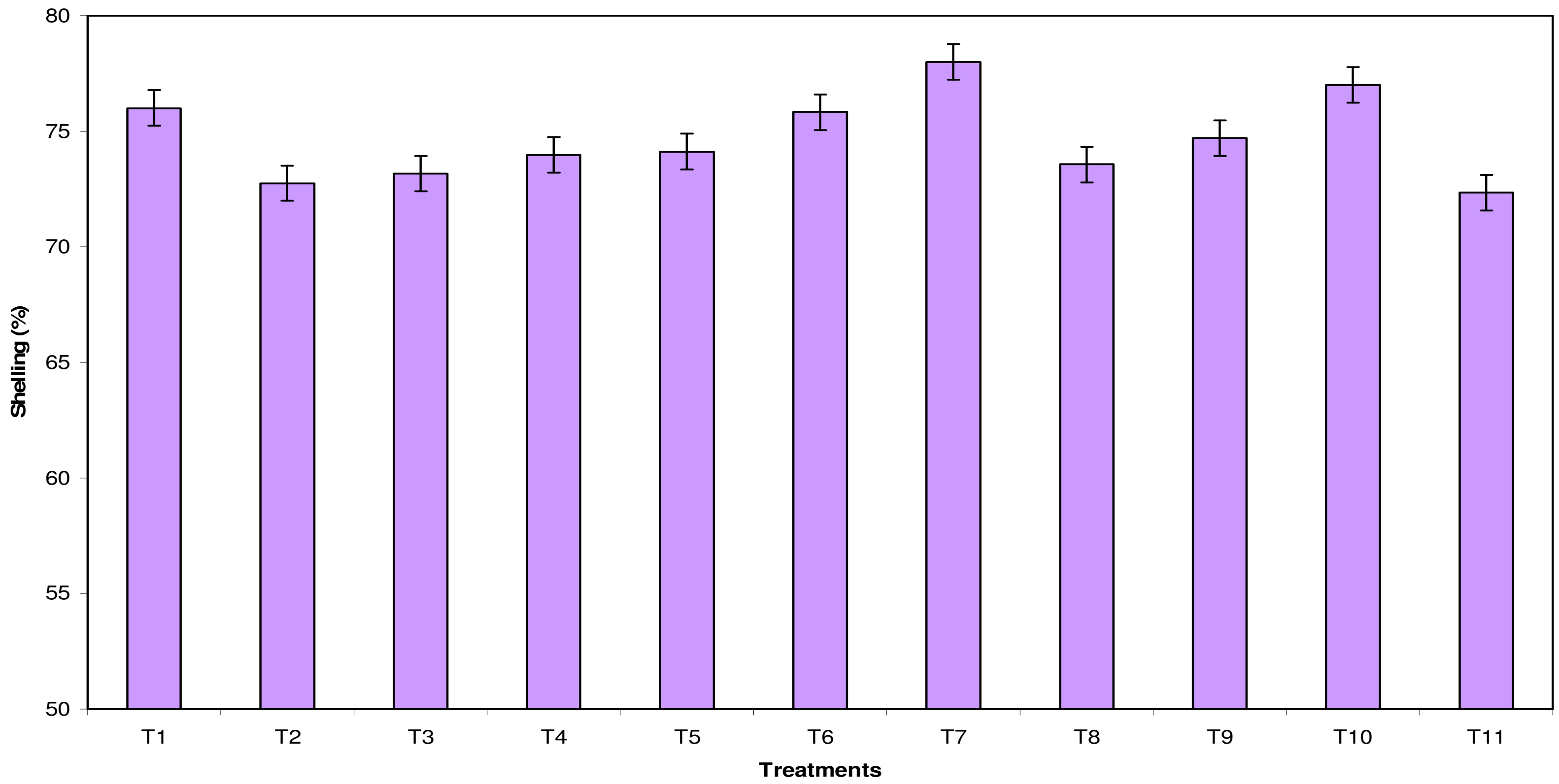

Fig. 7: Effect of fly ash on shelling percentage of groundnut

Fig. 7: Effect of fly ash on shelling percentage of groundnut

4.3.5. Yield per plant (g)

The data on yield per plant indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in yield per plant with an increase in the fly ash levels. Significantly higher yield per plant (18.74 g) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (17.61 g), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (16.46 g) and T_1 (RPP) (16.08 g) and were on par with each other. The yield per plant was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (10.49 g) yield per plant was recorded in T_{11} (Bhoochetana).

4.3.6 Yield (kg/ha)

The data on yield kg per ha indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in yield kg per ha with an increase in the fly ash levels. Significantly higher yield (3617.4 kg/ha) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe), T_1 (RPP) , T_9 (RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) and T_5 (RD NPK + 20 t fly ash/ ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe), T_4 (RDNPK + 40 t fly ash/ha) and T_8 (RD NPK + 20 t fly ash / ha + 25% RD Gypsum +25% RD Zn + 25% RD Fe). The yield kg per ha was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (2995.1 kg/ha) yield kg per ha was recorded in T_{11} (Bhoochetana).

4.3.7 Harvest index (%)

The data on harvest index indicated significant difference due to different levels of fly ash application along with RDNPK, 50% RD Gypsum, Zn and Fe. It was also observed that there was an increase in harvest index with an increase in the fly ash levels. Significantly harvest index (42.34 %) was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) followed T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (41.94 %), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) (41.64 %), T_1(RPP) (41.34 %) and T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (41.14 %) and were on par with each other. The harvest index was decreased significantly at different levels of fly ash, along with RDNPK and compared to fly ash, RDNPK, RD 50% gypsum, Zn and Fe. Significantly lower (39.33 %) harvest index was recorded in T_{11} (Bhoochetana).

4.4 Germination (%)

Germination percentage and seedling vigour index was find out from the seeds collected after the harvest of the crop (Table 19). There was no significant difference in germination percentage, irrespective of treatments indicating no adverse effect of the treatments in the present investigation.

Germination percentage did not differ significantly with application of different doses of fly ash and fertilizers. Highest Germination (90.5%), was observed with application of T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (Table 19) and lowest (87.6%) in T_{11} (Bhoochetana).

4.5 Seedling vigour index

Seedling vigour index differed significantly and was maximum (2212) and T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe), followed by T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe), T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe) and T_1(RPP) which were on par to each other. Significantly lower seedling vigour index (1841) was recorded in T_{11} (Bhoochetana).

Table 19: Effect of fly ash on germination percentage and seedling vigour index of Groundnut

Treatment	Germination (%)	Seedling vigour index
T_1- RPP	89.6	2099
T_2- RD NPK + 20 t fly ash / ha	88.0	1887
T_3- RD NPK + 30 t fly ash / ha	88.0	1926
T_4-RD NPK + 40 t fly ash / ha	88.8	2000
T_5- T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	89.1	2033
T_6- T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	89.8	2145
T_7- T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	90.5	2212
T_8- T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	88.3	1951
T_9- T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	89.3	2056
T_{10}- T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	90.1	2173
T_{11}- Bhoochetana	87.6	1841
SEm$\pm$	1.3	63.78
CD at 5%	NS	188.14

* Recommended package of practise (RD NPK + 7.5 t FYM + 500 kg Gypsum + 25 kg $ZnSO_4$ + 25 kg $FeSO_4$ + Seed treatment with 2.5 kg Rhizobium and 2.5 kg P solubilizer)

** Bhoochetana recommended package (200 kg Gypsum + 55 kg of DAP + 20 kg MOP + 20kg $ZnSO_4$ + 2.5 kg Borax + 1.5 t FYM)

NOTE: RD FYM and Bio fertilizer were common to treatments T_2 –T_{10}

Significantly, higher seedling vigour index was observed when fly ash applied at T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (2212), but it was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (2173), T_6(RD NPK + 30 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe) (2145), T_1(RPP) (2099), T_9(RDNPK + 30 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) (2056), T_5 (RD NPK + 20 t fly ash / ha + 25% RD Gypsum +25% RD Zn + 25% RD Fe) (2033) . It was significantly lower harvest index (1841) in T_{11} (Bhoochetana).

4.6 Disease scoring

With respect to disease scoring, irrespective of the treatments (T_1 to T_{11}), there was very less incidence of early and late leaf spot of groundnut in the present investigation. However, disease appeared at late maturity stage, was uniform in all the treatments and it didn't influence the yield in any manner.

4.7 Economics

Significantly higher benefit cost ratio was recorded in T_7 (RDNPK + 40 t fly ash/ha + 50% RD gypsum + 50% RD Zn + 50% RD Fe) (3.2) compared to Bhoochetana

Data on economics of fly ash application is presented in Table 20a and b, the data revealed that although yield was higher when 40 t/ha of fly ash was applied with RD NPK and 50 % RD gypsum, Zn and Fe, the net return was higher in the treatment where the application of gypsum, Zn and Fe was reduced to25 per cent recommended dose. The lowest return was in T_{11} (Bhoochetana).

Table 20a: Effect of fly ash on Economics of groundnut

Treatment	Economics				
	Yield (kg/ha)	Cost of Cultivation (` ha^{-1})	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	Benefit: cost ratio
T_1– RPP	3581.1	32070	96689	64619	3.01
T_2– RD NPK + 20 t fly ash / ha	3114.4	28970	84089	55119	2.9
T_3– RD NPK + 30 t fly ash / ha	3227.3	28970	87138	58168	3.01
T_4–RD NPK + 40 t fly ash / ha	3453.5	28970	93244	64274	3.22
T_5– T2 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	3542.1	30520	95636	65115	3.13
T_6– T3 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	3591.6	30520	96973	66453	3.18
T_7– T4 + 50% RD Gypsum +50% RD Zn + 50% RD Fe	3617.4	30520	97671	67151	3.2
T_8– T2 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	3375.8	29745	91147	61401	3.06
T_9– T3+ 25% RD Gypsum +25% RD Zn + 25% RD Fe	3562.3	29745	96182	66437	3.23
T_{10}– T4 + 25% RD Gypsum +25% RD Zn + 25% RD Fe	3605.9	29745	97360	67615	3.27
T_{11}– Bhoochetana	2995.1	27259	80867	53608	2.97
SEm±	105.98		2861	2861	0.1
CD at 5%	312.64		8441	8441	0.29

Table 20b: Details of cost of cultivation in different treatments (` ha^{-1})

SL.No	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1	Land preapration											
a)	Deep ploughing	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
b)	Harrowing	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
2	Sowing	850	850	850	850	850	850	850	850	850	850	850
3	Seed cost (groundnut)	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
4	Fly ash	0	0	0	0	0	0	0	0	0	0	0
5	Fertilizers											
a)	FYM	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750	750
b)	Urea	80	80	80	80	80	80	80	80	80	80	0
c)	DAP	1957	1957	1957	1957	1957	1957	1957	1957	1957	1957	2152
d)	MOP	583	583	583	583	583	583	583	583	583	583	467
e)	Zinc	300	-	-	-	150	150	150	75	75	75	240
f)	Iron	300	-	-	-	150	150	150	75	75	75	0
g)	Boi fertilizers	250	250	250	250	250	250	250	250	250	250	0
h)	Borax	-	-	-	-	-	-	-	-	-	-	300
i)	Gypsum	2500	-	-	-	1250	1250	1250	625	625	625	1000
6	Application charges	500	500	500	500	500	500	500	500	500	500	500
7	Intercultivation	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
8	Hand weeding	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
9	Chemical	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
10	Harvesting and threshing	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
11	Cost of cultivation	32070	28970	28970	28970	30520	30520	30520	29745	29745	29745	27259

5. DISCUSSION

Introduction of fly ash has a great potential in agriculture. Physically fly ash occurs as very fine particle having an average diameter of less than 10 micro meter, low to medium bulk density, high surface area and very light texture and chemically the composition of fly ash varies. On an average, 95-99 per cent of fly ash consists, of oxides of silica (Si), aluminum (Al), iron (Fe) and calcium (Ca) and 0.5-3.5 per cent sodium (Na), phosphorus (P), potassium (K) and sulphur (S) along with trace elements. In fact, fly ash consists of practically all the elements present in soil except organic carbon and nitrogen and this material could be used as an additive in supplying micro nutrients to groundnut. Now a days the fly ash utilization in India is gaining momentum. Owing to the strict regulations that Ministry of Environment and Forests is enhancing, the awareness about the benefits of using fly ash (Mittra *et al.*, 2003). To justify the suitability of fly ash in groundnut cultivation and to be create awareness amongst the farmers, field investigation was carried out and the results obtained on the performance of groundnut are discussed here under.

5.1 Morphological characters

Application of fly ash at different levels along with RDNPK, gypsum, Zn and Fe showed, significant influence on various morphological characters such as plant height, number of branches, leaf area, leaf area index, SLW and total dry matter.

It was observed that per cent increase in plant height increased with an increase in fly ash levels along with RDNPK, 50% RD gypsum, Zn and Fe, and such as an increase was more with 40 t/ha fly ash along with RDNPK 50% RD gypsum, Zn and Fe. The per cent increase in plant height was more at 60 DAS than at maturity and other stages indicating that 60 DAS, which coincides with grand growth phase in groundnut is more responsive to the applied fly ash and RD NPK along with 50% RD gypsum, Zn and Fe, due to cell elongation and internodal elongation, the principle mechanism responsible for increase in plant height. It has been observed by Gardner (1988) that the insufficient gibberlicacid can cause increase in plant height and it may become weaker from dilution. Whereas, dry matter accumulation over time the has shown increase following fly ash application along with RDNPK 50% RD gypsum, Zn and Fe, which may be attributed to an increase in the availability of cytokinin to the shoots which inturn may play a role in elongation process, either through cell division or cell elongation (Goodwin and Erwee., 1983). Fly ash when added to the soil at an optimum level benefits biomass production and increase in plant growth which inturn attained significance from the point of ecofriendly disposal of fly ash (Sudha and Dinesh., 2010). Application of fly ash @ 30 t/ha along with FYM resulted increase in the plant height in groundnut (Dange and Nagle., 2010). Chaudhary *et al.* (2011) and in green gram also responded positively to the increase in the plant height (Chaudhary *et al.* 2011)

There was significant influence of fly ash when applied at RDNPK, 50% RD gypsum, Zn and Fe on most of vegetative growth in terms of number of branches, growth and growth attributes and leaf area development. There was rapid increase in number of branches and leaf area between 30 to 60 DAS as compared to other stages. It has been observed that Bhoochetana treatment recorded the lowest number of branches irrespective of growth stages whereas, 40 t/ha fly ash RDNPK, 50% RD gypsum, Zn and Fe recorded maximum number of branches. Such an increase in number of branches could be attributed to increase in cell division activity due to fly ash application along with RDNPK, 50% RD gypsum, Zn and Fe, which might be again due to the increase in availability of CK to the shoots. The present findings are in conformity with Kuchanwar and Matte (1997) and Thanunathan *et al.* (2001), who reported increase in number of branches due to the fly ash application in groundnut and sesame respectively.

The development of assimilatory surface area is essential for crop canopy which inturn increase RUE vis-à-vis CO_2 fixation and dry matter production. As the level of fly ash along with RDNPK, 50% RD gypsum and Zn and Fe application increase, leaf area also increased significantly. The extra protein produced allows the leaf expand and provide a larger surface area available for photosynthesis. The increased availability of nutrients is also known to increase the proportion of protoplasm to cell wall material which has several consequences like increase in size of cells, there by having thinner walls and making the leaves more succulent and it may also increase the proportion of water (Watson, 1946). A low level of nutrient application on the other hand gives leaves with small cells and thick walls and thereby reducing leaf area. Reduction in leaf area in Bhoochetana due to production of less number of cells per leaf (Sivashankar, 1992). The present findings are in accordance with Bharud *et al.* (2002) who reported increase in leaf area and number of leaves per plant due to fly ash application in cauliflower.

The SLW, an indicator of leaf thickness, was maximum at 60 DAS and subsequently at later stages decrease towards the maturity. The increase in specific leaf weight consider with grand growth period of crop, fly ash application along with RDNPK, 50% RD gypsum, Zn and Fe recorded maximum SLW indicating the sufficient availability of the nutrient during critical stages of the crop growth.

The water status of the plant particularly the leaf could conveniently studied with observations like RWC which is an index of turgidity of leaves. In the present study, it showed an increase in fly ash application along with RDNPK, 50% RD gypsum, Zn and Fe, which recorded significant difference in RWC from 60 DAS to maturity. Saikia and Dey (1984) observed a positive correlation between leaf nutrient status and RWC. The findings of our results are also in confirmation with Kumari and Bharati (1992) who reported a positive correlation between leaf nutrient status and RWC. Higher RWC in fly ash application at the rate of 40 t/ha along with RDNPK,50% RD gypsum Zn, Fe could be attributed to the better stomatal regulation which helped in increasing better root growth and water uptake by the plant.

Yield improvement in any crop could be attributed to the better partitioning of photoassimilates towards reproductive or economic sinks. The several factors influence the partitioning efficiency of which nutrient load/supply are also important and the rate of dry matter accumulation may have an influence on dry matter partitioning.

It is clear form the data the there is an increase in the total dry matter with an increase in the fly ash levels along with RDNPK, 50% RD gypsum, Zn and Fe. Such an increase in total dry matter could be attributed to an increase in the component parts of dry matter *viz.,* leaf, stem and reproductive parts. The increase in the leaf and stem dry matter could be attributed to enhance chlorophyll content and increase translocation of photosynthates from leaf to stem. Since, fly ash along with RDNPK, 50% RD gypsum, Zn and Fe contributed towards increased synthesis of chlorophyll molecule, which would further, enhance the photosynthesis and dry matter production Selvakumari *et al.* (2005) and Kumar *et al.,* (1998) were also reported that fly ash along with other nutrient application increase dry matter production and other growth parameters.

5.2 Growth parameters

Several growth parameters were studied to understand the pattern of crop development in a logical sequence and to assign the causes for the differences in physiological events which ultimately leads to differential in yield response through the event that had occurred earlier in the phenology of the crop due to the application of different levels of flu ash along with RDNPK, 50% RD gypsum, Zn and Fe. The dry matter is the product of net photosynthesis which could be measured in terms of growth components like size of the assimilatory surface area, its duration, its efficiency etc (Watson, 1947). An increase in leaf area index (LAI), relative growth rate (RGR) and net assimilation rate(NAR) were observed with increase in fly ash level along with RDNPK 50% RD gypsum, Zn and Fe.

The CGR indicates accumulation of dry matter production per unit area per unit time. The data indicated that the CGR was low at initial stages which was mainly due to slow growth habit of the crop which is conspicuous with slow assimilatory surface, as evident from leaf area and leaf area index (Table 6 and 7). The variation in CGR could be attributed to the accumulation of dry matter which recorded low during initial stage of the crop growth. The increases in CGR due to application of fly ash at 40 t/ha, RDNPK, 50% RD gypsum, Zn and Fe could be attributed to the corresponding increase in leaf area and total dry matter production. The CGR reduced at later stages, in the present study which is in confirmative with Janmatti (1979) who reported that in groundnut crop growth rate declined at later stages of the crop growth.

The NAR indicates the amount of dry matter accumulation per unit leaf area per unit time, which was maximum due to application of fly ash along with RDNPK, 50% RD gypsum, Zn and Fe. In the present study at early stages of the crop growth i.e., 30-60 DAS, NAR was higher and decreased steadily at later stages. The increase in NAR at early stages could be attributed to small and narrow leaves which could have been helpful in avoiding natural shading. The increase in NAR due to fly ash application at the rate of 40 t/ha along with RDNPK, 50% RD gypsum, Zn and Fe could again attributed increase in leaf area (LA), leaf area index(LAI) and total dry matter (TDM).

Development of leaf area is important since it is a major assimilatory organ of the plant as reported by Janmatti (1979) and David and Mack (1991) that LA is not the limiting factor in groundnut. In our study, it has been observed that LA increased with an increase in fly ash level along with RDNPK, 50% RD gypsum, Zn and Fe. The increase in leaf area could be attributed to the fact that sufficient load of nutrient was available especially nitrogen, a part of chlorophyll molecule, which could have helped in increasing chlorophyll content of the leaf and LA. Low leaf area in Bhoochetana could be attributed to the less number of cells produced per leaf (Mahakulkar *et al*., 1992) and there was reduction in leaf area at later stages due to incidence of leaf spot leading to senescence and abscission of leaves. Similarly Boote *et al.,* (1980) reported that LA was maximum during early to mid pod filling stages and decrease there after, mainly due to senescence and abscission leaves. Jadhav and Natkhede (1982) reported that LA per plant LAI increased with an increase in nutrients, especially nitrogen and was higher and growth period.

5.3 Biochemical parameters

Crop productivity is dependent on the inter play of various physiological and biochemical functions in plant and the cause and effect relationships is difficult to understand mainly because of complexity to understanding the several processes and functions. An attempt has been made in present investigation to find out biochemical changes due to application of different levels of fly ash, RDNPK, 50% gypsum, Zn and Fe.

Results revealed that chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents were more when the application of fly ash at higher doses along with RDNPK, gypsum, Zn and Fe. This could be attributed to the fact that sufficient nutrient in the leaf especially nitrogen and Fe. Which are part of the chlorophyll molecule and help in the synthesis of chlorophyll (Chatarjee *et al*., 2009) and it is reported that fly ash application on fruit crops resulted increase in chlorophyll 'a', chlorophyll 'b' and total chlorophyll content. Similarly, Xian Kui *et al.* (2011) also reported increase in chlorophyll content and photosynthetic rate due to fly ash application along with fertilizers in Chinese cabbage and Gupta and Singh (2009) in chickpea.

The NRA which is the key enzyme in nitrogen metabolism is known to be regulated by various environmental factors apart from its own substrate, nitrate. It was observed in general that NRA increased with increase in the application of fly ash along with RDNPK, gypsum, Zn and Fe the activity of NR increased from 30 to 60 DAS and decline their after (Sung and Sun, 1990). NRA was observed even at lower level of fly ash and nutrient application which indicated that for induction of NR in enough quantites of nitrate were observed by plant even at low level of nutrients in the soil.

The peak activity of NR considered with maximum chlorophyll content, thereby complementing the carbon and nitrogen balance in the plant (Chaudhary *et al.,* 2011) and it was reported increase activity of NR, protein content and pigments due to the application of fly ash in *Vigna radiate*. Similar increase in NRA was also reported by Nagajyoti *et al.* (2009) due to fly ash treatment in groundnut and the results of the present investigation are also confirmed with findings of different workers.

5.4 Yield and yield components

Grain yield is the manifestation of morphological, physiological and growth parameters in any crop and pod yield in groundnut is product of its several components, such as number of pods, test weight, shelling percentage, harvest index etc. Duncan *et al.* (1978) concluded that 3 physiological attributes *viz.,* portioning of assimilates between vegetative and reproductive parts, length of pod filling period and rate of pod establishment are most important for determination of yield in groundnut. Apart from variation in morphological, physiological and growth parameters, the variation in yield and its components could be attributed to total assimilation achieved during the growing season and its portioning to economically important parts. The fly ash at different levels along with RDNPK, 50% RD gypsum, Zn and Fe was found to have significant difference on pod yield and other yield components. It was observed that a higher dose of 40 t/ha along with RDNPK, 50% RD gypsum, Zn and Fe recorded significant increase in yield over Bhoochetana. Similar trend was observed even with other yield components studied.

The variation in yield due to different levels of fly ash, RDNPK, 50% RD gypsum, Zn and Fe could be attributed to difference in partitioning in dry matter in reproductive parts. Maximum per cent increase in pod yield in 40 t/ha along with RDNPK, 50% RD gypsum, Zn and Fe as compared to Bhoochetana, could be attributed to higher CGR, NAR apart from other yield components which in turn could be attributed to the special arrangement of leaves and branches in the canopy.

It is observed that shelling per cent and harvest index were maximum at 40 t/ha along with RDNPK, 50% RD gypsum, Zn and Fe which may be due to enhanced availability of the nutrients and improved soil physical environment that might have promoted root proliferation, root value and root weight which in turn enhanced nutrient uptake by the crop, thereby increasing yield due to increase number of mature pods. Increase root proliferation will enable plant to exploit nutrients from various depth of soil. Our results are corroborated with Hati *et al.* (2007). The addition of fly ash along with RDNPK gypsum, Zn and Fe resulted in substantial increase in oil content. The increase in oil content was mainly due to the presence of sulphur, calcium and other micro nutrients in fly ash applied along with gypsum, Zn and Fe. The nutrients present, might have favoured the synthesis of amino acids, methionine and cystin in plants and resulted in higher amounts of oil content. The continuous supply of nutrients, greater uptake of nutrients and favourable physico-chemical condition existed in soil may be attributed for this as reported by Gupta *et al.* (2010) who revealed that application of fly ash sewage sludge to soil is gaining practice and has become alternative to chemical fertilizer in many countries. Application of fly ash to *Brassica campestris* (L.) has recorded in increase in oil content by these workers. Similarly, Thetwar *et al.* (2006) also reported increase in oil content in sesame due to the soil application of fly ash.

5.5 Seed vigour testing

Seed vigour is an important quality parameter which needs to be assessed to supplement germination and viability tests to gain insight on the performance of the seeds lot in the field. As germination test is conducted an optimum condition specific to different species, it is not always possible to get an idea of the preface of the seeds on the bases of germination test in the laboratory. Seed vigour is still a concept rather than a specific property of a seed. Several factors like genetic constitution, environment and nutrition of the mother plant, maturity at harvested, seed weight and size, mechanical integrity, deterioration and ageing and pathogen are known to influence seedling vigour. The performance of the seeds of all the treatments collected after one month of harvest which were subjected for germination and seedling vigour recorded. No significant difference in germination percentage indicating adequate supply of nutrients. Similar finding were also reported by Yunusa *et al* (2009). However, seedling vigour differed significantly and it may be due to the difference in size and shelling percentage in different treatments was evident with significantly higher seedling vigour (2212) and it was lower in Bhoochetana (1841).

5.6 Disease incidence

Late leaf spot (LLS) caused by *Phaeosisariopsis personata* (Berk. and Curt.) is an economically important foliar disease of groundnut. Whereas, crop is grown LLS causes severe defoliation and reduces both haulm and pod yields by more than 50 per cent (Mc Donald *et al.,* 1985). The disease can be effectively managed by adequate supply of nutrients. The disease control by nutrients is more desirable because they are non hazardous, environment friendly and bring about disease resistance through metabolic defense mechanisms and also they supply nutrients for maintaining better growth of plants, besides increasing yield potential Graham and Webb,(1991). Emphasized the significance of interaction of micronutrients in disease resistance in crop plants, many of the potential interactions of nutrients in disease management can be postulated from their intimate and expensive functions in the plants (Huber, 1981). In the present investigation with respect to disease scoring, irrespective of the treatments (T_1 to T_{11}), there was no significant variation in the incidence of early and late leaf spot of groundnut.

5.7 Economics

The present study revealed that benefit cost ratio was highest when 40t/ha of fly ash application with RD NPK along with 25% RD gypsum, Zn and Fe. Although the yield was higher in 40t/ha of fly ash along with RD NPK, 50% RD gypsum, Zn and Fe, the benefit cost ratio was maximum with RD 25% gypsum, Zn and Fe with 40t/ha fly ash and RD NPK. Hence, application of lower dose of gypsum, Zn and Fe is economically beneficial.

Future line of work

From the results it could be concluded that fly ash is potential alternate input which accelerates the availability of nutrients there by it can be effectively utilized for the cultivation of groundnut with less (either organic or inorganic) fertilizers to manage the nutrient requirement of the groundnut crop and also solves the problem of disposal of fly ash. This minimizes the cost of cultivation and hence improves the economy of the farmers. However in future, following research is needed.

- In depth study on yield and quality aspects of different crops over continuous use of coal fly ash.
- Long-term effect of fly ash on physical and chemical properties of soil.
- Effect on the source-sink relationship and various enzymatic changes in the plants due to fly ash application.

6. SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, on medium black clay soil during *kharif* 2011 to elucidate the effect of fly ash on growth, physiological traits and yield of groundnut. The experiment was laid out in Randomized Complete Block Design with eleven treatments at different concentrations with three replications. The results obtained from the present investigation are summarized in this chapter.

1. Application of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe significantly increased the plant height. Significantly lowest plant height was recorded in the treatment Bhoochetana at all the stages of crop growth.
2. Effect of fly ash and fertilizer treatments showed profound effect on number of branches/plant. The number of branches per plant decreased at Bhoochetana. The number of leaves per plant was highest at RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe.
3. Maximum leaf area and leaf area index were recorded at 90 DAS and declined thereafter. The treatment with fly ash and combination of fly ash with fertilizer increased the leaf area and leaf area index and the effect was more pronounced with the fly ash concentration of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe and least leaf area and LAI were recorded at Bhoochetana at all the stages of crop growth.
4. The total dry matter differed significantly due to application of fly ash. Application of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe recorded highest total dry matter. The treatment receiving Bhoochetana recorded significantly lower total dry matter over other treatments at all stages.
5. Application of fly ash at RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe concentration recorded significantly higher SLW as compared to the rest of the treatments. Among the treatments receiving only 40 t/ha and fertilizer the highest SLW was observed at RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe. Significantly lowest SLW was recorded Bhoochetana at all the stages.
6. Application of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe significantly increased the net assimilation rate. Significantly lowest net assimilation rate was recorded in Bhoochetana treatment at all the stages of crop growth.
7. Application of fly ash at RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe recorded highest CGR.
8. The chlorophyll content (`a`, `b` and total chlorophyll) was higher between 60- 90 DAS and declined thereafter. Application of fly ash significantly increased the chlorophyll content at concentration of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe and the least was recorded in treatment receiving Bhoochetana at all the stages.
9. Nitrate reductase activity decreased as growth advanced and significant differences were noticed due to application of fly ash. Application of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe recorded significantly highest nitrate reductase activity. The least NRA was recorded in treatment Bhoochetana at all the stages.
10. Relative water content decreased as growth advanced. Application RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe recorded significantly higher RWC. The least was recorded in treatment receiving Bhoochetana
11. Results on various yield and yield components indicated that, all the yield contributing characters *viz.,* number of pods per plant, test weight, shelling percentage oil content, yield per plant, yield per hectare, harvest index increased due to the application of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe. This was significantly higher when compared to other treatments.

12. At different combination of fly ash, the treatments receiving of RD NPK + 40 t fly ash / ha + 50% RD Gypsum +50% RD Zn + 50% RD Fe improved germination percentage and seedling vigour index. The least germination percentage and seedling vigour index was recorded in treatment receiving Bhoochetana

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* - Originals are not seen ____

EFFECT OF FLY ASH ON GROWTH, PHYSIOLOGICAL AND BIOCHEMICAL TRAITS AND YIELD IN GROUNDNUT [*Arachis hypogaea* (L.)]

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ABSTRACT

A field experiment was conducted during *kharif* 2011 to study the effect of fly ash on growth, physiological and biochemical traits and yield in groundnut [*Arachis hypogaea* (L.)] at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment consisted of eleven treatments consisting different combinations of fly ash with inorganic fertilizers, FYM, Gypsum, Zn, Fe and Borax. The experiment was laid out in randomized complete block design with three replications.

Growth and development parameters i.e., plant height, number of branches, leaf area and total dry matter were significantly highest with T_7 (40 t of fly ash/ha along with Recommended dose of NPK (RD NPK) and 50% gypsum, Zn and Fe) at all growth stages. Chlorophyll content and nitrate reductase activity were also significantly higher with the application of T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe)

Among the different combination of Fly ash application T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) recorded significantly higher pods per plant (41.17), 100 kernel weight (43.26 g), shelling percentage (76.35%), yield per plant (18.74 g), higher pod yield (3617.4 kg ha^{-1}) and harvest index (42.34 %) compared to other treatments. However, T_7 was on par with T_{10} (RDNPK 40 t fly ash/ha + 25% RD gypsum +25% RD Zn + 25% RD Fe) followed by T_6 (RDNPK 30 t fly ash/ha + 50% RD gypsum +50% RD Zn + 50% RD Fe). Similar trend was also recorded with oil content, germination per cent and seedling vigour index. Application of T_7 (40 t of fly ash/ha along with RD NPK and 50% gypsum, Zn and Fe) recorded significantly higher oil content (51.17%), germination (90.5 %) and seedling vigour index (2212) compared to Bhoochetana (T_{11}). It could be inferred from the study that fly ash @ 40 t/ha along with RD NPK and 50% gypsum, Zn and Fe can increase the yield in groundnut.