



Soil amendment with fly ash and farmyard manure improves soil health growth and floral traits of tuberose (*Polianthes tuberosa* L.) in partially sodic soils

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ABSTRACT

A two-year field experiment was conducted to evaluate the effect of fly ash (FA) amended with farmyard manure (FYM) on the growth, floral attributes, and soil properties of tuberose (*Polianthes tuberosa* L.) cultivated in partially sodic soil. Fly ash, an industrial by-product generated from thermal power plants, was integrated with FYM to assess its potential as a soil ameliorant and nutrient source. The combined application of FA and FYM significantly enhanced key floral parameters, including number of spikes per plant, rachis length, number of florets per spike, and flower yield per plant during both years of study. Soil chemical and biological properties were also evaluated to determine the impact of amendments on soil health. The manure-amended FA treatment significantly reduced soil pH and electrical conductivity (EC), indicating improvement in sodicity and salt stress conditions. Furthermore, soil enzyme activities dehydrogenase, β -glycosidase, alkaline phosphatase, and acid phosphatase were markedly increased, reflecting enhanced microbial activity and nutrient cycling. The results demonstrate that FA enriched with FYM can effectively improve plant growth, floral yield, and soil biological activity in sodic soils. This integrated approach not only supports sustainable floricultural production but also promotes environmentally sound utilization of fly ash as a soil conditioner and reclamation agent.

Key words: Alkaline phosphatase, dehydrogenase, farm yard manure, fly ash, sodic land.

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.), recently reclassified as *Agave amica*, is a perennial bulbous ornamental crop belonging to the family Asparagaceae. Native to Mexico, it is widely cultivated for its attractive, fragrant white flowers borne on long spikes. The crop is highly valued as a loose and cut flower and is extensively used for garland making, floral decorations, religious offerings, and essential oil extraction. Due to its high market demand, long vase life, and economic importance in the floriculture industry, tuberose is considered one of the most important commercial flower crops in tropical and subtropical regions (Muruganatham *et al.*, 12). Modern agriculture has caused serious setback to soil health and increasing pressure on existing land resources, force us to look for increasing arable land for sustainable agriculture development. At present, a large area of the world's arable land comes under degradation because of its deteriorating soil quality due to salt stress (Fan *et al.*, 5).

Due to the climate challenge and human interference globally, excess salt content in the soil has been now a worldwide issue affecting agriculture

production, not only by severely reducing soil fertility and crop productivity but also reducing the agriculture land gradually (Cao *et al.*, 3). Such type of problematic soil can be remediated by applying chemicals such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), calcite (CaCO_3), and calcium chloride (CaCl_2) providing Ca^{2+} to replace Na^+ from the exchange site (Srivastava *et al.*, 16). Generally, it has been seen that saline soils are poor in organic matter content. In Uttar Pradesh, serious attention was given earlier by different state agencies like UP Bhumi Sudhar Nigam and Department of Agriculture, Govt. of UP by running many programmes like distribution of gypsum, to treat the soil for quick reclamation and cultivation of field crops. However, these ambitious programmes could not get much success, as expected. The reasons of failure of these programmes were due to high cost of regular application of chemical fertilizers and restoration of salts at surface level which create salinity of the soil. Generally, cost benefit study is always a point of consideration during soil management. Therefore, a sustainable method to remediate these problem soils may be application of organic amendments like well decomposed farm yard manure (FYM) or compost for escalating organic content of the salt-affected soil (Montiel Rozas *et al.*, 11).

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Fly ash, which is an industrial waste from thermal power plants, possesses many of qualities of gypsum, can also be used as an agronomic amendment to sodic soil in a feasible way, whereby the soluble concentration of Ca^{+2} in the soil, will increase (Kabir *et al.*, 7). Several studies have shown its possible use as a soil amendment to improve plant growth by nutrient-enriching properties of the soil. It is found that mixtures of Farm yard manure (FYM) along with fly ash not only improves the quality of sodic soil also creates well-balanced nutrient content in the soil (Romero *et al.*, 14). Therefore, application of FA along with organic materials in an integrated way can avoid the use of chemical fertilizers and also improve the fertilizer use efficiency (Gopinath *et al.*, 6).

Revegetation of degraded sodic land by cultivating floriculture and aromatic crops like *Polianthes tuberosa*, *Helianthus*, marigold, carnation, sunflower, lemongrass, gladioli and lily may be a way to sustainably utilize such types of land. Moreover, fly ash mixed with FYM can be applied to low fertility soils, resulting in a significant increase in plant height, biomass and flower production. The efforts also caused significant improvement in soil texture coupled with an increase in P and Ca levels of the soil. Fly ash mixed with materials like commercial peat moss has also been used for cultivating Chrysanthemums (Chou *et al.*, 4). Nevertheless, the most fascinating aspect is that the risk of food contamination (with toxic metals etc. present in fly ash) and bio-magnification through food chain is avoided while practicing floriculture (rather than growing food crops) on these lands. Therefore, FA application for floriculture crops may be a better option comparatively to edible crops to avoid the hazardous effect of heavy metals. Investigating further prospects in this direction can be very fruitful as the developing countries like India, are expected to emerge as world players in the export of floriculture products.

Keeping these points in mind to sustainably utilize the sodic waste land by using fly ash (an industrial waste) as soil ameliorant, a study was conducted to explore the effects of fly ash amended with FYM on the growth and yield of tuberose. A study was also undertaken to assess the response of soil microflora to the after-effects of the treatments on soil.

MATERIALS AND METHODS

Study was conducted at Gehru Research Centre of CSIR-National Botanical Research Institute, Lucknow (80°45'53" E 26°40'45" N), Uttar Pradesh. A field experiment was laid out with six treatments *i.e.* T1 (Control); T2 (FYM @ 10t/ha); T3 (FA @ 2.5 t/ha + FYM @ 7.5 t/ha); T4 (FA @ 5.0 t/ha + FYM @ 5.0 t/ha); T5 (Recommended dose of fertilizer - RDF);

T6 (1/2 RDF + FA @ 2.5 t/ha + FYM @ 2.5 t/ha) in a randomized block design with three replications. A recommended dose of fertilizer (RDF) for nitrogen, phosphorus, potassium and zinc @ 250 kg, 40 kg, 40 kg and 25 kg per ha, respectively was applied. Sources of fertilizer were Urea (46% N), Single super phosphate (16% P), Muriate of Potash (60 % K) and Zinc sulphate (21 %). All the dose of fertilizers except urea were applied at the time of sowing however half dose of urea is added before at the time of sowing and then rest is added in equal amounts at the interval of 1 month till August. Other intercultural operations like irrigation and weeding were also done time to time.

After 4 months of sowing, at the onset of flowering, following characteristics were measured: Plant height (cm); number of leaves/plant; length of leaves (cm); number of spikes/plant; length of rachis (cm); number of florets/spike; floret yield /spike (g) and flower yield /plant (g) during both the years. Bulb yield per plant was also observed at the time of harvesting in second year.

Soil was collected from different treatments of the experimental field after harvesting of the crop. Soil was grounded to fine powder and the samples were sieved to remove debris. The processed samples were air dried and used for physico-chemical analyses. pH and electrical conductivity (EC) were estimated using soil: water (1:2) suspension with digital pH meter and EC meter.

Different soil enzyme activities in the soil samples collected from the experimental site were assessed. In brief dehydrogenase activity was determined in 1 g of soil using triphenyl tetrazolium chloride (TTC) as a substrate. The formation of 1, 3, 5 triphenylformazan (TPF) was determined spectrophotometrically at 485 nm and results were expressed as g TPF g⁻¹ dry sample. Alkaline and acidic phosphatase activity responsible for the release of phosphate (P) from p-nitrophenyl phosphate (PNPP) by catalyzing the hydrolysis of ester-phosphate bonds was measured by the method of Atlas (1). Proteases enzyme responsible for N mineralization was measured in Tris buffer (pH 8.5) suspended soil. Mixture was mixed with 15% TCA and alkaline reagent followed by incubation at RT (15min). Absorbance at 700nm was taken after addition of 33% Folin-Ciocalteu reagent (Ladd & Jackson, 9).

The experimental data were analysed by following standard statistical procedure for randomized block design (RBD). The significance of treatments was also tested. The standard error of means was computed and critical differences at 5 percent level of probability were calculated for significant differences only.

RESULTS AND DISCUSSION

Application of FA amended with well decomposed FYM in different proportions in the form of treatments showed significant variation in most of the growth and floral characteristics of tuberose in both years. The highest value of plant height and length of leaves were obtained from T3 followed by T4, T5 and T2 in both the years (Table 1). However, for first year these values were not significant. The values were significant, later in stage may be due to slowly release of Gibberellins hormone from FYM, which is mainly responsible for growth of the plant. These findings are in conformity with the findings of Kabir *et al.* (7). Significant higher number of leaves per plant was obtained from T4 which was statistically at par with T3 in second year. These results indicated that essentiality of nitrogen in organic form enhanced to constitute chlorophyll

which leads to better growth of leaves over control. Kumar (8) also reported similar results supported with effect of nitrogen fertilization on anatomical structure of tuberose.

Significantly higher values of the floral characteristics of tuberose viz., number of spikes per plant, number of floret per spike and floret yield per spike were obtained through application of FA@2.5t/ha amended with FYM@ 7.5t/ha (T3) in second year of the crop (Table 2). However, the higher values for the same parameters were obtained from T2 in first year. Significant effect of FA amended with FYM on the growth and floral characteristics might be due to easily availability of mostly nutrients to the plants. The obtained results are in accordance with the earlier findings of Bhalla *et al.* (2) in gladiolus and Sunitha *et al.* (17) in African marigold.

Table 1: Effect of fly ash amended with farm yard manure on plant growth characteristics of tuberose.

Treatment	Plant height (cm)		Number of leaves/plant		Length of leaves (cm)		Length of rachis (cm)	
	1 st yr	2 nd yr	1 st yr	2 nd yr	1 st yr	2 nd yr	1 st yr	2 nd yr
T1	96.22	98.89 ^d	180.78 ^c	187.78 ^c	45.22	46.30 ^{cd}	26.44 ^d	27.44 ^e
T2	109.22	104.72 ^{abc}	193.44 ^{bc}	205.31 ^{bc}	48.22	49.50 ^{ab}	32.00 ^a	33.12 ^a
T3	109.22	110.72 ^a	196.89 ^{bc}	217.72 ^{ab}	47.33	51.10 ^a	30.33 ^{ab}	32.33 ^{ab}
T4	103.11	108.30 ^{ab}	218.11 ^a	238.11 ^a	47.22	50.70 ^{ab}	27.89 ^{cd}	26.89 ^{ef}
T5	102.89	106.34 ^{ab}	191.00 ^{bc}	207.72 ^{bc}	47.56	50.30 ^{ab}	31.00 ^{ab}	31.00 ^{bc}
T6	101.67	103.22 ^{bcd}	198.33 ^{ab}	201.33 ^{bc}	46.78	47.30 ^c	28.22 ^c	29.22 ^d
CD (P=0.05)	NS	6.87	19.85	20.92	NS	1.71	1.96	1.54
SE (m±)	2.87	2.18	6.22	6.55	0.80	0.53	0.61	0.48

Means, in columns and within the same year, followed by the same letters are statistically similar at p < 0.05 among the treatments. T1 = Control; T2 = FYM @ 10 t/ha; T3 =FA @ 2.5 t/ha + FYM @ 7.5 t/ha; T4 = FA @ 5.0 t/ha + FYM @ 5.0 t/ha; T5 = Recommended dose of fertilizer – (RDF); T6 = 50% RDF + FA @ 2.5 t/ha + FYM @ 2.5 t/ha. (FYM) Farm yard manure, FA = Fly Ash, NS = Non-significant.

Table 2: Effect of fly ash amended with farm yard manure on floral characteristics and yield of tuberose.

Treatment	Number of spikes/plant		Number of florets/spike		Floret yield/spike (g)		Flower yield/plant (g)	
	1 st yr	2 nd yr	1 st yr	2 nd yr	1 st yr	2 nd yr	1 st yr	2 nd yr
T1	11.00 ^{de}	11.30 ^f	29.33 ^d	28.67 ^{de}	25.56 ^c	24.82 ^c	334.44 ^e	361.44 ^f
T2	17.00 ^a	18.30 ^{ab}	31.67 ^{ab}	34.37 ^{ab}	28.22 ^{ab}	29.22 ^{ab}	431.11 ^{bc}	541.11 ^b
T3	16.22 ^{ab}	19.70 ^a	31.44 ^{bc}	35.44 ^a	28.89 ^{ab}	29.67 ^a	475.56 ^a	565.56 ^a
T4	13.33 ^{cd}	15.33 ^{cd}	32.67 ^a	31.67 ^{cd}	29.00 ^a	28.12 ^{ab}	445.56 ^b	475.56 ^d
T5	14.22 ^c	16.22 ^c	31.56 ^{ab}	32.12 ^c	28.56 ^{ab}	28.67 ^{ab}	417.78 ^{cd}	497.78 ^c
T6	12.44 ^d	13.64 ^{de}	30.89 ^c	30.08 ^d	28.22 ^{ab}	28.00 ^{ab}	407.78 ^d	467.78 ^{de}
CD (P=0.05)	1.54	1.78	1.14	2.06	2.22	1.91	22.74	19.28
SE (m±)	0.48	0.56	0.36	0.65	0.70	0.60	7.12	6.04

Means, in columns and within the same year, followed by the same letters are statistically similar at p < 0.05 among the treatments. T1 = Control; T2 = FYM @ 10t/ha; T3 =FA @ 2.5 t/ha + FYM @ 7.5 t/ha; T4 = FA @ 5.0 t/ha + FYM @ 7.5 t/ha; T5 = Recommended dose of fertilizer – (RDF); T6 = 50% RDF + FA @ 2.5 t/ha + FYM @ 2.5 t/ha. FYM= Farm yard manure, FA = Fly Ash, NS = Non-significant.

The data pertaining to the effect of FA and FYM on total flower and bulb yield of per plant presented in table 2 and figure 1, respectively, indicate that application of FA@2.5t/ha properly mix with FYM @ 7.5 t/ha recorded the highest flower and bulb yield in both the years in comparison to other treatments. The higher flower yield may be due to increased nutrient availability and growth promoting substances in the soil from combined application of FYM and FA which might have enhanced the availability and uptake of nutrients and water by the plants in turn favored the boosting of initial growth of the plant. Similar results were obtained by Natywa & Selwet, (13) in rose and in tuberose. A significant increase in overall crop growth and flower and bulb yield attributes with application of FA amended with FYM might also be due to ameliorative effect of these treatments in mitigating sodicity in experimental soil over a period of more than two years (Yaduvanshi & Swarup, 20). The combined treatment improved the soil properties and soil fertility consequently supported better productivity in terms of vegetative growth and higher yield (Shafi *et al.*, 15).

There was a lowering trend of soil pH and EC values were observed by application of FA along with FYM, might be due to the formation of organic acids and CO₂ through FYM decomposition, facilitating dissolution of CaCO₃ and releasing of calcium ions from FA for the replacement of sodium ions. Both soil pH and EC values varied significantly among various treatments (Table 3). Application of FA @5.0 t/ha along with FYM @ 7.5 t/ha decreased pH (7.68) and EC (88.73) of the soil showed the favourable effect of the FA along with FYM, by improving the soil porosity and infiltration rate, which could have resulted in enhanced leaching of salts during investigation

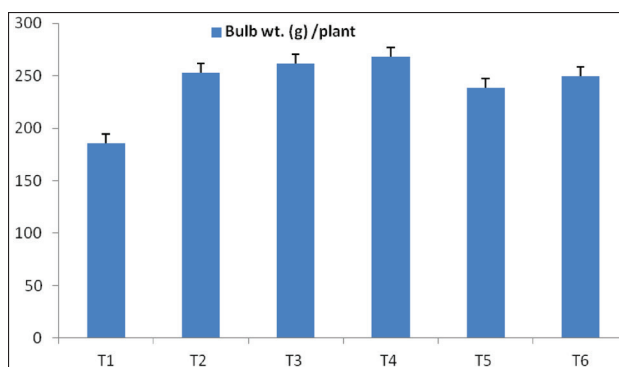


Fig. 1. Effect of fly ash amended with farm yard manure on bulb yield (g/plant) of tuberose Error bar in the figure shows the critical difference at P < 0.05 among the treatments. T1 = Control; T2 = FYM @ 10t/ha; T3 =FA @ 2.5 t/ha + FYM @ 7.5 t/ha; T4 = FA @ 5.0 t/ha + FYM @ 5.0 t/ha; T5 = Recommended dose of fertilizer – (RDF); T6 = 50% RDF + FA @ 2.5 t/ha + FYM @ 2.5 t/ha.

(Yadav *et al.*, 19). The highest pH value was observed in control conditions where no amendment was used for amelioration of the soil however, application of FA along with FYM reduces the soil pH significantly from 8.47 to 7.68 after two years of consecutive cultivation of tuberose on the sodic land with significant lowering of the salt concentration in the soil (Tsadilas *et al.*, 18).

The higher soil OM provides enough substrate during mineralization to support higher microbial biomass and enzyme production (Yuan & Yue, 21). Variations in the dehydrogenase activity (DHA) were observed during the harvesting of tuberose. DHA activity was higher in treatments comprising well-decomposed FYM. The dehydrogenase enzyme

Table 3: Effect of fly ash amended with farm yard manure on soil chemical properties and enzymatic activities

Treatment	pH	EC Unit (mS/m)	Protease (ug tyrosine.g ⁻¹ soil.h ⁻¹)	DHA (ug TPF.g ⁻¹ soil.h ⁻¹)	β-glucosidase (ug pNP.g ⁻¹ soil.h ⁻¹)	Alk P (ug pNP.g ⁻¹ soil.h ⁻¹)	Aci P (ug pNP.g ⁻¹ soil.h ⁻¹)
T1	8.47 ^a	115.62 ^a	1.33	6269.04 ^d	36.19 ^e	210.28 ^a	80.82 ^e
T2	7.71 ^b	88.73 ^{cd}	1.88	22936.04 ^a	44.40 ^c	195.58 ^d	88.88 ^e
T3	7.84 ^b	96.67 ^{bc}	1.79	16572.95 ^b	57.59 ^a	193.49 ^{de}	92.41 ^b
T4	7.68 ^d	102.10 ^{ab}	1.88	11821.53 ^c	50.23 ^b	190.49 ^e	96.24 ^a
T5	8.17 ^{ab}	107.97 ^{ab}	1.50	7940.51 ^d	40.36 ^{de}	202.78 ^b	83.61 ^{de}
T6	8.02 ^b	99.07 ^{bc}	1.72	11499.44 ^{cd}	41.07 ^d	199.32 ^c	84.69 ^d
CD (P=0.05)	0.33	15.00	NS	2253.79	2.93	3.44	1.94
SE (m±)	0.10	4.70	0.44	706.12	0.92	1.08	0.61

Means, in columns and within the same year, followed by the same letters are statistically similar at p < 0.05 among the treatments. T1 = Control; T2 = FYM @ 10t/ha; T3 =FA @ 2.5 t/ha + FYM @ 7.5 t/ha; T4 = FA @ 5.0 t/ha + FYM @ 5.0 t/ha; T5 = Recommended dose of fertilizer – (RDF); T6 = 50% RDF + FA @ 2.5 t/ha + FYM @ 2.5 t/ha.

EC= Electrical conductivity (millisiemens/m), DHA= Dehydrogenase activity, Alk P = Alkaline Phosphatase, Aci P= Acidic phosphatase FYM= Farm yard manure, FA = Fly Ash, NS = Non-significant.

activity increased proportionately with the increase of application of FYM in the soil (Fig. 2). It followed a strong linear relationship ($R^2 = 0.968$). The trend of the dehydrogenase action in the treatments was as follows: T2> T3> T4 > T6> T5> T1 (Table 3). Maximum dehydrogenase activity ($22936.04 \mu\text{g TPF g}^{-1}\text{h}^{-1}$) was observed for T2 might be due to incorporation of higher dose of FYM. Several authors reported positive correlation between DHA and OM content (Yuan & Yue, 21). Marinar *et al.* (10) also reported that a higher level of dehydrogenase activity was observed in soil treated with vermicompost and manure. DHA is related to quantitative changes in microorganism populations, as only strictly intracellular enzymes can truly reflect microbial activity, because with respect to the degradation processes of extracellular soil enzymes, they will be quickly mineralized by other enzymes like proteases, unless they are either adsorbed by clays or immobilized by humic molecules. During the investigation, higher values for protease enzyme activity in T2 followed by T4 and T3 shows its importance for nitrogen mineralization however, these values were not significant.

Alkaline phosphatase activity displayed a decrease in trend with an increase in quantity of FYM and FA. The activity was found to be higher in the soil with no any amendment while, the lower enzyme activity was observed for T3 followed by T4 and T2. However, an increase in alkaline phosphatase activity was observed for T2 followed by T3. Conversely Acidic phosphatase activity exhibited an increasing trend with the incorporation of FYM and FA in the soil. The activity was found to be higher in T4 followed by T3 and T2. Ratio of alkaline and acidic phosphatase

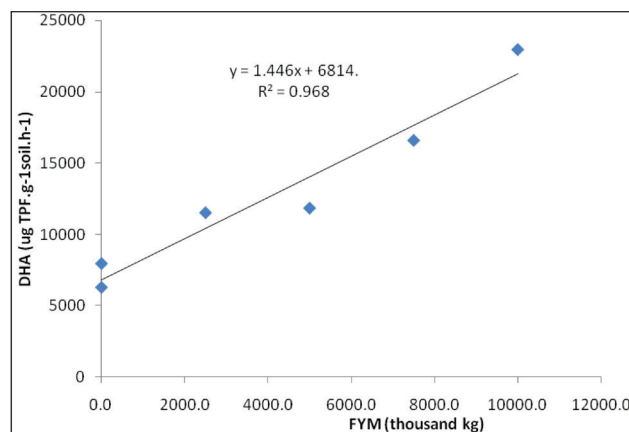


Fig. 2. Effect of FYM application (in thousand kg) on Dehydrogenase enzyme activity in soil. The dehydrogenase enzyme activity increased proportionately with the increase of application of FYM in the soil, which followed a strong positive linear relationship ($R^2 = 0.968$).

activity also showed a decrease in value from 2.6 to 2.0 in a following pattern of T1> T6> T5> T2> T3> T4 after amendment of FA with FYM.

A mounting up trend in beta glucosidase activity was observed by the addition of FA along with FYM ranging from 36.18670 to 57.58973 with an increase of around 59 % over control. β -Glucosidase is a common and predominant enzyme in soils and very sensitive to changes in pH, and soil management practices (Tsadilas *et al.*, 18). Significantly higher values for this activity were observed in T3 followed by T4 and T2. This property can be used as a good biochemical indicator for measuring ecological changes resulting from soil acidification in situations involving activities of this enzyme.

The present study demonstrated that the combined application of FA and FYM significantly improved soil physico-chemical properties, nutrient availability, microbial activity, and overall soil health in partially sodic soils. The integrated amendment enhanced plant growth, flowering, and yield attributes of tuberose by increasing the availability of essential nutrients and stimulating soil biological activity. The findings suggest that FA amended with FYM can serve as an effective and economical soil amelioration strategy, improving soil fertility and crop productivity while promoting sustainable management of sodic soils.

AUTHOR'S CONTRIBUTIONS

Conceptualization of research (RCN); Designing of the experiments (SS); Contribution of experimental materials (SG); Execution of experiments and data collection (SD); Analysis of data and interpretation (SKT, RCN); Preparation of manuscript and literature review (RCN,SS).

DECLARATION

The authors declare no competing interests.

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