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SUSTAINABLE USE AND APPLICATIONS OF BRICK KILN COAL FLY ASH IN AGRICULTURE SECTOR FOR PROMOTION OF LEGUME PRODUCTIVITY

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Abstract

Brick kiln coal fly ash is an industrial solid waste and creates environmental problems due to their unfair utilization but it have potential to serve as a fertilizer for improving the soil textures and provides some macro- and micro- nutrients to the plants and enhances the soil fertility.

This experiment was conducted to investigate the impact of different levels (25gm, 50gm, 100gm/m^2) of fly ash on Morpho-physiological and biochemical attributes of *Vigna mungo* L.

Plants grown in randomized block designed plots which were treated with fly ash and analyzed biochemical assay like proline, leghaemoglobin, chlorophyll, protein, nitrate reductase, nitrite reductase and morpho-physiological assay.

The perusal of the data reveal that 25gm/m^2 level of fly ash dust amendments in soil was found to be an ideal level for the better plant growth and yield of *V. mungo*. From the obtained results after mathematically as well as statistically analysis of data, it can be evinced that the lower amount (25gm/m^2) of fly ash has sufficient quantity of macro- and micro-nutrients, which appear to be useful for the plant metabolic activities.

At the same time it will be safe and eco-friendly disposal option for the huge amount of fly ash. In future line, it could be used as a soil manure/fertilizer to enhance the legumes crop productivity. It can be adduced that there is an ample scope for the secure utilization of fly ash in agriculture without any serious harmful effects on soil and plants under skilled jurisdiction.

Key words : Brick kiln coal fly ash dust, *Vigna mungo* L., nitrogen fixation enzymes, plant growth and yield.

Introduction

Air and soil pollution have become a major threat to the survival of plants in the industrial areas. Air pollutants emitted from various industrial sources cause damage to plant leaves, impair plant growth and productivity according to the sensitiveness as well as response of the plants to pollutants (Ulrich, 1984). Thus, pollution stress can alter plant growth and development. Its effects are often extensive. Rapid urbanization and industrialization in recent years have escalated the demand for bricks not only in India but worldwide too. The accompanying growth of brick kilns in India has consequently magnified pollution problems mainly as an industrial waste product and pollutant. It is a result of coal combustion in thermal power plants and other different industrial processes (Kakkar *et al.*, 2012). These waste products are generated in enormous amounts and are disposed off openly at dumping sites occupying a large area of land. BKCFA (Brick kiln coal fly ash) deteriorates the air, water, and soil quality of adjacent areas due to accumulation, leaching, and increased bioavailability of heavy metals, and other contaminants posing a threat to human health and environment. Hence, safe disposal of such wastes is not only a major challenge but also a deepening environmental concern these days. In present scenario the use of BKCFA in agriculture has become

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quite popular around the world. It is an abundant source of many essential micro- and macro-plant nutrients (Ca, Si, Fe, Mg, Na, K, S, Mo, Ni, Cu, Co, Cd, Pb, Zn, etc.,) except lacking N and organic C (Singh *et al.*, 2014).

Although land application of this waste has multiple benefits like improvement in soil's physico-chemical properties, recycling of beneficial plant nutrients, substitutes to inorganic fertilizers, and ameliorates soil acidity (Gupta *et al.*, 2012), along with agronomic and economic benefits. Apart from these benefits, BKCFA can be evaluated as an approach to integrated solid waste management. Being simultaneously more stable and less likely to causes environmental pollutions. BKCFA has potential benefits in boosting plant growth and serves as a composting ingredient to neutralize alkaline soil. BKCFA can be used as a valuable resource not as waste in agriculture. Being in conformity with the principles of integrated waste management hierarchy, this state's recycling of wastes to be more environmentally preferred than disposal methods like land filling, open, and ocean dumping, and incineration. The present study is an attempt to investigate the potential use of BKCFA as a plant growth medium through assessment of physiological, biochemical, growth, and yield responses of the black gram (*Vigna mungo* L.) to determine the useful concentration(s) which can be used further at different amendment rates/doses in soil to derive maximum fertilizing benefits for plants and minimum environmental risk.

Materials and Methods

Study Area

The experiment was conducted at the agricultural field of Botany Department, Chaudhary Charan Singh University Meerut, Uttar Pradesh, India between March to June during 2018 and 2019.

Experimental Design

BKCFA was collected from Hastinapur Brick kiln Uttar Pradesh, India. Seeds of Black gram (*Vigna mungo* L.) as test plant material were procured from IARI, New Delhi. The experiments in the field were set on randomized block design with three replicates, each with different treatments. Twelve plots of 1×1 m^2 size having a margin of 0.25 m between each plot were prepared. The soil of Agricultural field dug up to a depth of 30 cm, was collected, air dried and thereafter mixed uniformly with BKCFA in four different ratios *viz.*, 0 (Control), 25, 50, 100 gm/m^2 designated as A, B, C, and D, respectively and were left for two days to stabilize the soil. The healthy seeds of *V. mungo* were surface sterilized with 0.2 percent of $HgCl_2$ for two minutes and thoroughly washed with tap water. Necessary moisture levels had been maintained in soil and then fifty seeds were sown manually in each plot at equal distances. The test plants were grown up to maturity and standardized agronomic practices were given during the period. Climatic variables like minimum and maximum rainfall, humidity, temperature, etc. were measured throughout the growing period of the plants. Selected physiological and biochemical parameters were quantified during vegetative and reproductive phases of plants for assessing the impact of different BKCFA concentrations on some quantitative and qualitative parameters. Upon maturity, plants were harvested to examine the crop responses with respect to the yield.

Analyses of Morphological and Physiological Parameters

For the analysis of morphological, growth, and biomass determination, *V. mungo* plants were harvested in triplicate from different plots of each treatment at 65 days (D) after sowing. Morphological parameters *viz.*, root and shoot lengths, fresh and dry biomass, nodule number, weight, and volume were assessed according to Rajpoot *et al.*, (2018). Physiological parameter *viz.*, germination % at different intervals (5, 10, 15 D) was calculated as done by ISTA (1966) and photosynthetic pigments as done by Arnon (1949).

Estimation of Biochemical Parameters

Biochemical activities of test plant were measured by estimation of enzymes and different biochemical's from fully expanded fresh leaves at 40-60 D. These estimations were done through methods given by Bates *et al.*, (1973) for proline, Bradford *et al.*, (1976) for protein content, Bergersen *et al.*, (1980) for leghaemoglobin, Snell and Snell (1967) for nitrogen content, and Hageman (1980) and Guerrero (1982) for nitrate and nitrate reductase activity.

Statistical Analysis

The mean values of two years (2018, 2019) data and standard deviation of different qualitative and quantitative parameters were calculated by Microsoft excel (2017) and graphs were prepared as by Graph Pad Prism Software. Correlation between qualitative and quantitative parameters and dose-response analysis of yield against fly ash treatment were performed using SPSS software version 10.

Result and Discussion

Physiological and Biochemical Response

The mean graphs of two-year data show maximum chlorophyll content in 25 gm/m^2 BKCFA dust treated plots as compared to untreated and other treated plots as shown in fig. 1C. A lower amount of BKCFA increases photosynthetic pigments chlorophyll *a* and *b*. However, applications of a higher amount of fly ash are reported to cause inhibition of photosynthetic pigments due to the toxic effects of metal ions (Pallavi, 2017). Metal ions (Cu, Zn, Cd, Pb, Ni) present in the form of free radicals degrade the chlorophyll pigments through replacement of Mg^{2+} ion in chlorophyll molecules (Kupper *et al.*, 1998). Vazquez *et al.*, (1987) suggested that metals possess a known property which changes the photosynthesis processes rate by disturbing the structure of chloroplast.

Protein content shows a positive correlation with the chlorophyll content ($p \leq 0.01$) and negative correlation with the proline content ($p \leq 0.01$) as shown in table 1. As the BKCFA concentration increases the protein percentage of seeds was found significantly decreasing. The proline content increases as shown in fig. 1A and 1B. Lower amount of BKCFA exhibits a positive effect on protein content, but inflated amount of BKCFA activates the proteases or other catabolic enzymes (metal catalysts such as Fe, Cu, Ni and Cr, increase the activity of proteases or other catabolic enzymes as reported earlier (Pani *et al.,* 2015). A higher amount of BKCFA reduces the protein content due to free radicals of metals ions which degrade the chlorophyll molecules, ultimately affecting the photosynthesis process and protein content in seeds (Dash and Sahoo, 2017). On the other hand, proline is a key player in plant abiotic stress tolerance. An increased level of proline contents in BKCFA treated plots of *V. mungo* except 25gm/m^2 treated plots indicate that fly ash at a higher amount induces drought stress in plants. It may be explained on account of the fact that heavy metals of fly ash such as Fe, Cu, Ni, Cr, Pb, and Cd accumulate and disrupt the metabolic pathways of the plants and enhance the drought stress conditions. Such findings are in conformity with those of Singh *et al.*, (2012) and Pallavi (2017).

Among qualitative traits nitrogen and leghaemoglobin did not show any kind of correlation with the other biochemical assays *i.e.* neither with positive nor with negative as shown in table 1. But were found with significant difference among the different doses (Fig. 1A and 1B). At a lower amount of BKCFA in soil there is seen nitrogen availability resulting from high nitrogen uptakes by plants. The higher amount of BKCFA reduces the nitrogen content of plant tissue which is related to the presence of salt in fly ash which might increase the osmotic potential and finally inhibit the absorption of nutrients resulting lower uptake of nutrients.

Nitrate reductase (NR) at 25D shows correlation with N and chlorophyll *a* at $p \leq 0.01$ levels but at 65D no correlation with any other biochemical parameters (Table 1). At the same time nitrite reductase (NiR) shows correlation with chlorophyll *a*, total chlorophyll and NR 25D at $p \leq 0.01$ levels. NR and NiR enzymatic activities get enhanced at 10-40D (pre flowering stage of crop) but inhibited thereafter because of senescence of nodulation (Melavanki and Vijaykumar, 2012). NR and NiR enzyme activity were dignified in 25 gm/m^2 BKCFA dust treated plots (Fig. 1E). A presence of Mo, Fe, and S in BKCFA increases the NR and NiR enzyme activity because NR activity depends on N and Mo (Cazetta *et al.*, 2004). NR activity also indirectly got affected by the presence of P and S. These two elements show synergetic effects on the plants. P is also involved in phosphorylation and changes glucose to glucose 6-phosphate in respiration process, as a result, oxidation of photosynthates produce more reducing power (NADPH and ATP) agents, subsequently reducing the nitrate mediated NO^{3-}. The deficiency of these two elements leads to the accumulation of amino acids, which is assumed down to regulate the nitrogen uptake and its assimilation. These findings are also in agreement with those of Qurratul and Khan (2014), Ahmad *et al.*, (2017) and Melavanki and Vijaikumar (2012).

Presence of Mo, S, and Fe in fly ash and sufficient quantity of N present in soil increases the leghaemoglobin, NR and NiR enzyme activities (Ahmad *et al.*, 2017). Further NR activity vice-versa enhances the nitrogen content in leaves of the plant. So the nitrogen content in the soil gets enhanced by the lower amount of fly ash (Sarangi and Mishra, 1998; Kumar and Kumar, 2017).

Phosphorus is responsible for numerous kinds of function in the growth and development of plants (Sultenfuss, 1999). The growth of plants is enhanced by the phosphorus and lack of phosphorus leads to weak growth of plants. Its main role is to stimulate root development necessary for the plants to get nutrients from the soil. It is also responsible for the maturity of the plant at the right time. In current findings 25 gm/m2 BKCFA dust treated plots of *V. mungo* manifest significantly excessive values as compared to control and other treated plots (50 gm, 100 gm/m^2) (Fig. 1A). Such correlation with N and NR ($p \leq 0.01$) validate the above results. A phosphorous element of fly ash at the lower amount is not readily available to the plants. Despite that, an enormous amount of BKCFA contains a considerable quantity of phosphorous which is readily available to the plants. But as the concentration of fly ash increases the number of toxic metal increases proportionally, consequently creating adverse effects on the plants.

Similar kind of results were also observed earlier by Shaheen *et al.,* (2014).

Morphological, Growth and Yield Response

It was found that soil amendment with lower BKCFA enhances the seed germination significantly whereas at 50 and 100% BKCFA application rate, inhibited seed germination % was seen. The 100% fly ash amendment delayed the seed germination by 4-5 days (Fig. 1D). It might be due to a higher concentration of BKCFA containing higher amount of trace elements such as Ni, Se, Cu, Co, Al, and Cr, etc. which held are responsible for delayed or inhibited germination process (Vollmer *et al.,* 1982). Germination % of seeds shows significant correlation with biomass, length and yield at lower dose whereas higher dose (50-100%) retarded the plant growth and dry matter production. Similar findings were also informed by Arshad *et al.,* 2020.

The maximum mean values of nodule attributing characters such as number, weight, and volume were observed in 25 gm/m^2 BKCFA treated plots of *V. mungo* as compared to 0, 50, and 100 gm/m^2 BKCFA treated plots in both the years of the experiments (Table 2 and Fig. 1C). According to Faizan and Kausar (2010) 25% BKCFA application causes a positive effect on the

Table 1: Correlation values among the different quantitative parameters of *Vigna mungo* L.

	CHL.A	CHL.B	T.CHL	PTN	N	LB	NR 25D	NR 65D	NIR 25D	NIR 65D	P	PLN
CHL.A	1											
CHL.B	0.856	1										
T.CHL	0.974*	0.946	1									
PTN	0.696	0.885	0.768*	1								
N	0.892	0.648	0.847	0.319	1							
LB	0.649	0.710	0.648	0.934	0.238	1						
NR 25D	0.984*	0.794	0.948	0.564	0.959*	0.503	1					
NR 65D	0.536	0.329	0.523	-0.131	0.851	-0.291	0.675	1				
NIR 25D	0.978*	0.874	0.981*	0.631	0.934	0.518	0.986*	0.666	1			
NIR 65D	0.047	-0.254	-0.021	-0.655	0.492	-0.714	0.226	0.830	0.168	1		
P	0.928	0.659	0.865	0.381	0.990**	0.339	0.978*	0.777	0.941	0.410	1	
PLN	-0.986*	-0.840	-0.970*	-0.608	-0.946	-0.522	-0.996**	-0.664	-0.996**	-0.187	-0.961*	1

*****Correlation is significant at the 0.05 level (2-tailed) ******Correlation is significant at the 0.01 level (2-tailed).

*****CHL-chlorophyll, PTN-protein, N-nitrogen, LB-Leghaemoglobin, NR-Nitrate reductase, NIR-nitrite reductase, PLN-proline.

Table 2: Correlation values among the different quantitative parameters of *Vigna mungo* L.

	NOD.N	NOD.W	NOD.V	SL	RL	TL	DSW	DRW	TDW	FWS	FWR	TFW	P/P	S/P
NOD.N	1													
NOD.W	0.740	1												
NOD.V	0.490	0.927	1											
SL	0.917	0.535	0.349	1										
RL	0.819	0.992**	0.888	0.636	1									
TL	0.961*	0.704	0.527	0.977*	0.787	1								
DSW	0.924	0.914	0.780	0.832	0.957*	0.931	1							
DRW	-0.188	0.515	0.692	-0.426	0.401	-0.229	0.136	1						
TDW	0.842	0.975*	0.883	0.705	0.992**	0.840	0.980*	0.332	1					
FWS	0.928	0.866	0.740	0.881	0.919	0.961*	0.993**	0.050	0.955*	1				
FWR	0.964*	0.839	0.585	0.779	0.893	0.872	0.923	0.028	0.884	0.894	1			
TFW	0.943	0.873	0.729	0.879	0.926	0.961*	0.996**	0.048	0.958*	0.998**	0.918	1		
P/P	0.546	0.801	0.902	0.576	0.799	0.683	0.807	0.389	0.848	0.820	0.524	0.792	1	
S/P	0.946	0.916	0.721	0.782	0.958*	0.892	0.975*	0.142	0.957*	0.950*	0.981*	0.965*	0.676	1

***** Correlation is significant at the 0.05 level (2-tailed) ******Correlation is significant at the 0.01 level (2-tailed)

* NOD.N- Nodule number, NOD.W- nodule weight, SL-shoot length, RL-root length, TL-total length, DSW-dry shoot weight, DRW-dry root weight, TDW-total dry weight, FWS- fresh weight shoot, FWR-fresh weight root, TFW- total fresh weight, P/P- pod per plant, S/P- seeds per pod.

Table 3: Mean and standard deviation (SD) of different quantitative parameters of *Vigna mungo* L.

	0 gm/m² BKCFA (control)				25gm/m² BKCFA				50gm/m² BKCFA				100 gm/m² BKCFA			
Years	**2018**		**2019**		**2018**		**2019**		**2018**		**2019**		**2018**		**2019**	
Mean/SD	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
NOD.N	140.333	±6.110	157.333	±10.504	152.667	±40.612	184.333	±9.504	86.333	±9.292	104.000	±9.539	71.333	±2.886	84.667	±8.963
NOD. W	0.568	±0.012	0.645	±0.026	0.816	±0.101	0.981	±0.008	0.630	±0.065	0.809	±0.062	0.166	±0.046	0.451	±0.019
NOD.V	2.233	±0.153	2.567	±0.153	3.133	±0.208	3.433	±0.153	3.067	0.153	2.967	±0.153	2.300	±0.173	2.133	±0.058
SL	22.333	±1.155	21.667	±1.528	25.000	±2.000	24.000	±2.646	16.333	±1.528	19.333	±1.155	22.333	±2.517	16.333	±1.528
RL	11.667	±0.577	12.000	±2.000	13.333	±0.577	12.667	±2.082	11.000	±1.000	13.000	±2.000	11.000	±2.000	10.000	±1.000
TL	34.000	±1.732	33.667	±3.215	38.333	±2.517	36.667	±4.619	27.333	±2.309	32.333	±2.309	33.333	±2.082	26.333	±0.577
DWS	3.640	±0.065	3.548	±0.136	4.345	±0.441	5.005	±0.141	3.430	±0.200	3.090	±0.040	2.392	±0.567	2.612	±0.448
DWR	0.348	±0.005	0.336	±0.013	0.443	±0.064	0.565	±0.068	0.309	±0.007	1.206	±1.570	0.330	±0.122	0.385	0.120
TDW	3.988	±0.061	3.883	±0.139	4.788	±0.499	5.570	±0.206	3.739	±0.202	4.296	±1.577	2.722	±0.640	2.997	±0.432
FWS	13.700	±0.436	13.600	±0.656	15.413	±2.635	17.133	±0.252	12.583	±0.430	12.767	±1.504	11.707	±0.759	11.333	±0.569
FWR	1.527	±0.101	1.560	±0.157	1.557	±0.273	1.693	±0.074	1.263	±0.262	1.297	±0.133	0.880	±0.422	1.094	±0.114
TFW	15.227	0.525	15.160	±0.809	16.970	±2.592	18.827	±0.180	13.847	±0.397	14.063	±1.621	12.587	±1.181	12.427	±0.458
P/P	7.667	±0.577	8.000	±1.000	13.333	±1.528	14.000	±1.000	10.000	±1.000	10.000	±1.000	8.333	±0.577	8.333	0.577
S/P	8.000	±0.000	8.000	±0.000	8.667	±0.577	8.667	±0.577	7.333	±0.577	7.667	±0.577	6.667	±0.577	6.333	±0.577

*NOD.N- Nodule number, NOD.W- nodule weight, SL-shoot length, RL-root length, TL-total length, DSW-dry shoot weight, DRW-dry root weight, TDW-total dry weight, FWS- fresh weight shoot, FWR-fresh weight root, TFW- total fresh weight, P/P- pod per plant, S/P- seeds per pod.

number and weight of the nodules. Better nodulation was exhibited at 25% BKCFA treatment due to the availability of micronutrients like Fe, Mo, and S which are necessary for nodulation and enhances are known to many physiological processes of the plants. Nitrogenases made of two-component proteins component I and II are the marked salient and best-studied enzymes which are Mo-Fe dependent (Burgess *et al.,* 1996). These proteins are soluble in nature. Component I is known as Mo Fe protein or dinitrogenase and component II is referred to as Fe protein or dinitrogenase reductase (Burris RH., 1991). In nitrogen fixation process, the enzymes named nitrogenase and nitrogenase reductase contain FeS clusters, which require Fe, Mo, Co as a cofactor for nitrogenase and nitrogenase reductase enzymes activity (Seefeldt and Dean 1997, Paul W Ludden 2001). Further, bacteroids contain a very high respiratory requirement demand, abundant cytochromes and other electron donors (Weisany *et al.,* 2013). BKCFA has the potential to provide such kinds of requisite like cofactors and electron donors in the form of metal ions Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+}, Al^{3+}, Fe^{2+}, Mn^{2+}, Zn^{2+},and Cu^{2+} Mo.

From the present experiment one can assume the liking of BKCFA in low concentration that provides two important elements for nitrogenase activity in nodules. Lower amount of BKCFA also maintains the soil environment to allocate deficit elements in the soil for the microbial flora. Availability of nutrients, cofactors such as Mo, Fe sustains the soil pH. Thus the better condition of the soil environment induces the *Rhizobium* to infect the root. More infection meaning more nodulation leads to a higher rate of biological nitrogen fixation (Singh *et al.,* 1996). Lal and Khanna (1994) also reported the higher concentration of BKCFA to take the edge of symbiotic activity of the plants and *Rhizobium.*

Root length and total length of the test plants show correlation with nodule weight at significance level 0.01 and nodule number at significance level 0.05 (Table 2). Test plants of *V. mungo* responded positively to 25 gm/m² BKCFA and showed luxuriant growth (Table 3). No visual symptom attributable to either toxicity of the BKCFA dust or to the deficiency of any nutrient was observed during the course of this experiment. Data in table 3 show that in the test plants root and shoot length got significantly increased in 25 gm/m² BKCFA

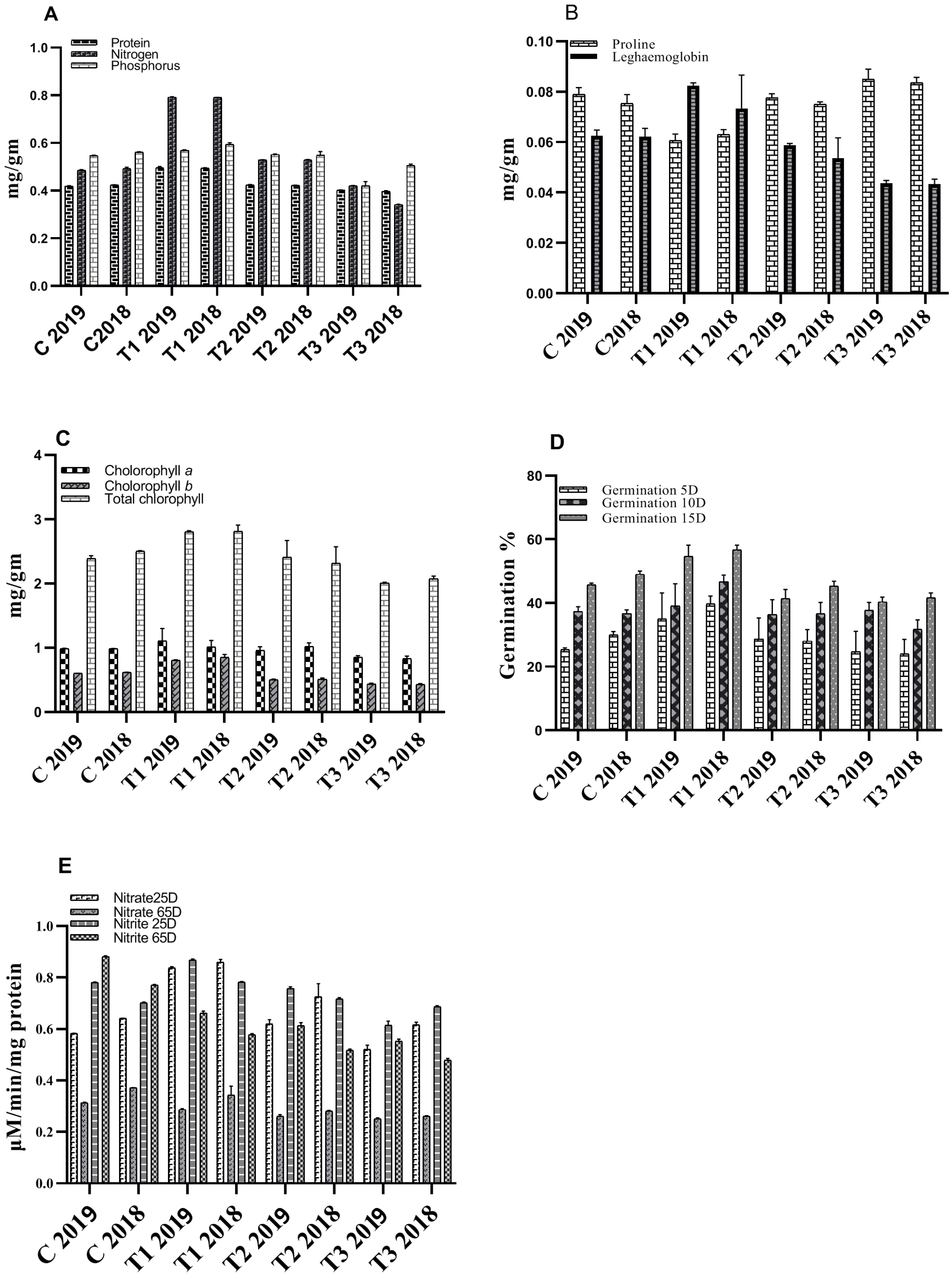

Fig. 1 (A-E): Mean and standard deviation (SD) of different qualitative parameters of *Vigna mungo* L.

treated plots in both the years as compared to respective controls and other BKCFA treatments. This is due to the enormous amount of micro- and macro-nutrients present in the BKCFA. Second reason may be that the BKCFA increases the micro-porosity and water holding capacities which are beneficial for plant root system. The growth of plants is intensifying by the P which is present in BKCFA dust. Its main role is to stimulate root development necessary for the plants to obtain nutrients from the soil. It is also accountable for the maturity of the plant at the right time as the third reason. Campbell *et al.*, (1983); Khan (1996) found that fly ash addition at the rate of 10% increase the water holding capacity by 7.2 and 413.2 times for fine and coarse sands, respectively. Rizvi and Khan (2009) also reported the supplication of BKCFA dust at lower levels as significantly beneficial for the plants' growth and development. Fahrunsyah *et al.,* (2019) and Raj and Mohan (2016) also reported the presence of heavy metals in fly ash, enhancing the plant growth and height at lower concentration but not at a higher amount of fly ash which is known to inhibit the plant growth on account of the toxicity of heavy metals. Khan *et al.,* (1996) and Arshad *et al.,* 2020 also found similar kinds of results but in tomato plants.

The maximum mean value of plant biomass (fresh and dry weight of plant) of the test plant was noticed significantly maximum in 25 gm/m^2 BKCFA treated plots and minimum in 100 gm/m^2 treated plots (Table 3). Similar kinds of results have also been found earlier by Fahrunsyah *et al.,* (2019), and Faizan and Khan (2004). They observed that the plant biomass and yield were found maximum from 25% coal ash amended soil. Contrarily, higher concentration of fly ash reduced biomass, length, and yield of plants (Zurek *et al.,* 2013 and Arshad *et al.,* 2020). Most appropriate quantity of mineral nutrients of the plants not only increases the photosynthesis activity but also lead to the biomass production of the plants. However, a higher amount of mineral nutrient disrupts the metabolic activities which are harmful to the plant. The yield parameters (pods/ plant and seeds/pod) of *Vigna* was counted maximum in 25 gm/m^2 BKCFA treated plots as a contrast with control and other treated plots (Table 1). Faizan and Kausar (2010); Singh *et al.,* (2011); Raj and Mohan (2016) also found the same line of results. Fly ash has the potential to enhance the productivity of some agricultural crops like *V. radiata, V. mungo* Kumar *et al.,* (2002). Among the different measured individual parameters and response parameters and dose-response analysis of yield against BKCFA treatments were found with correlation among and with the all parameters at 0.01 and 0.05 level of significance.

Conclusion

The study points out both sides of the coin *i.e.* positive and negative. Fly ash is known to supply almost all the essential plant nutrients *i.e.,* macronutrients including P, K, Ca, Mg and S and micronutrients like Fe, Mn, Zn, Cu, Co, B, and Mo, except organic carbon and N. For legumes BKCFA have cofactor metals (Mo, Cu, Fe etc.) of nitrogen fixation enzymes which are necessary for nitrogen fixation process. Its application also increases the soil pH and water holding capacity, consequently enhancing the germination rate, nodulation and root growth of the plants. Lower dose of BKCFA (25gm/m^2) was found beneficial for legume crops. Contrarily BKCFA consumption in agricultural sector also has some disadvantages with regard to heavy metals and also it is dose-dependent. However, care must be taken while using BKCFA in agriculture. There is also a need for further study in regard with the presence of radionuclides and heavy metals in BKCFA as there are very few reports on this in literature. Attention should also be given on some other important areas related to its utilization, long term impact of fly ash on soil health and crop quality.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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