Annals of Plant and Soil Research 26(4): 585-594 (2024)
https://doi.org/10.47815/apsr.2024.10404

Exploring the potential benefits of fly ash in wheat growth: Key insights from field studies

NISHANT VASHISTHA[1] AND ASHISH TEJASVI[2*]

[1]Department of Botany, J.S. University, Shikohabad, Firozabad (U.P.), India

Received, August, 2024; Revised accepted, November, 2024

ABSTRACT

Proper handling of such a huge amount of fly ash which is being produced in the process of electricity generation through coal based thermal power stations is really needed. It is also a matter of great environmental concern. Because, fly ash is a coal residue, it is entirely organic in composition. It contains many micro and macro nutrients like soil. The present study was conducted at farmer's field near district Firozabad to find out the effect of fly ash on growth and yield parameters of wheat. Fly ash (FA), organic manure like farmyard manure (FYM) and chemical fertilizer (CF) were used alone and also in different combinations. Two wheat varieties HD-2967 and PBW-343 were used in this study. Experimental plots (2m x 2m) were prepared using above treatment combinations. The treatments were replicated thrice in randomized block design (RBD) and a total of 48 plots were prepared for two varieties of wheat. Field trials for two successive years were performed and periodic observations of growth and yield parameters of test crops were recorded. Most of the growth and yield parameters get increased for both wheat varieties over control.

Keywords: Coal residue, Fly ash, Growth, RBD, Treatments, Varieties

INTRODUCTION

Throughout the course of cultural evolution, human behavior has drastically impacted the environment, resulting in extensive contamination. This has been caused by the fast-paced growth of urban centers, advances in transportation technology, untamed industrialization and inadequate farming strategies. These activities have forced all life to face the serious issue of pollution, which casts a dark shadow on the sustainability of nature's balance. Industrialization and rapid population growth have exacerbated severe environmental crises over the past decade. Pollution of soils, water and air is one manifestation of these crises. Water pollution can be contained within national and international boundaries, whereas soil pollution tends to be localized, confined to a particular region. Air pollution, on the other hand, does not know such bounds, transcending all boundaries. A vital component of terrestrial ecosystems, soil is irreplaceable and non-renewable. Collectively, soil and its biota constitute a natural asset that needs to be protected. Although soil plays a significant role in global environmental shifts, its slow-paced processes often make it difficult to trace the changes that occur within it. About 17% of the world's soils show signs of degradation induced by humans. The rapid population growth in countries like India has put incredible strains on few land resources. Industrialization and consumption have drastically changed the state of the soil, rendering it progressively lower quality as pollutants and harmful microorganisms spread into the air, water and food sources. A major contributor to this hazardous pollution is human behavior. The release of pollutants into the soil of the surrounding regions results in the loss of vital properties like fertility, water retention capacity, permeability and cohesiveness.

After China and the United States, India is the world's third-largest coal producer. The country's energy generation heavily relies on coal. A total of 76% of India's coal consumption is used for power generation, accounting for 60% of its installed capacity and 70% of its power output. In order to realize its "Power for All" vision, the government is aiming to increase coal consumption. Coal is still an important source of electricity production, but it brings with it environmental burdens. It releases substantial volumes of carbon dioxide in addition to considerable quantities of sulfur dioxide (Sox), nitrogen oxides (Nox) and particulates, all of which can cause harm to crops and human

*[2]Department of Botany, Agra College, Agra (U.P.), India, *E-Mail: tejasvi.botany@gmail.com*

health. Polluting effects are even greater when using lower-grade domestic coal, due to the higher levels of ash produced as a result. The annual expenditure allocated to road transport for the disposal of fly ash is approximately Rs. 50 crores, according to the study conducted by Vitekari *et al.* in 2012. Fly ash, a byproduct of various industrial processes like coal combustion, has been a subject of concern due to its potential environmental impact. Finding innovative ways to utilize fly ash can yield significant benefits. Studies conducted by Krishnamoorthy (2000) and Naik and Tyson (2000) have indicated that replacing one ton of cement with fly ash in concrete production can lead to notable environmental benefits. With this substitution, two tons of carbon dioxide, a major greenhouse gas linked to global warming, would be avoided from being emitted during the cement manufacturing process. Not only is this effective in terms of managing fly ash disposal but also serves as a means for reducing carbon dioxide emissions. According to Vasistha, 2014 coal is the only natural resource available in abundance in India so it is used widely as a thermal energy source and also as fuel for thermal power plants producing electricity. Thermal power plants in India consume more than 430 million tons of coal and produces fly ash around 145.42 million tons. India depends mostly (55.60%) on coal based thermal power plants which annually generates 235 million tons fly ash and is projected to exceed 1000 million tons by the year 2031-32 (Kumar and Jha, 2014). Management of this huge amount of fly ash is really a great environmental and economic concern all over the world. Because such a large amount of fly ash is generated each year, a great deal of research needs to be conducted to determine the feasibility of utilization in agriculture (Raj and Mohan, 2014). According to Sharma *et.al*., 2016 fly ash is rich in different trace elements like As, B, Ca, Mo, S, Se, Sr etc. Fly ashes can be utilized in many ways, such as landfill material, alkaline amendments, cement and grout substances. It delivers an abundance of soluble salts and leachable macro/micronutrients which makes them a great option when it comes to soil amendment. This serves as a substitute for fertilizers and lime, particularly in the case of alkaline fly ash which works to counteract acidity and raise pH levels in acidic soils. It is imperative to exercise caution and ensure that adequate alkalinity is added to the fly ash; otherwise, this could result in the release of elevated levels of potentially toxic elements. Moreover, incorporation of fly ash can help enhance the quality of soils that have unfavorable physical attributes. For instance, it can assist with improving soils that are coarse-textured or rocky by augmenting silt and sand fractions. This subsequently leads to improved aggregation, infiltration and water retention capacity (Skousen *et al.* 2013). Productivity of soil increases on the addition of significant amount of fly ash due to the presence of different micro and macronutrient. Aggarwal *et. al*., 2009 concluded that application of fly ash modify the physical and chemical properties of soil along with the growth and yield of wheat. Fly ash also contains heavy metals in its composition but it can be used in agriculture as a source of fertilizer for soil which can increase the plant growth performance (Raj and Mohan, 2016; Tejasvi, 2017, 2020, 2021; Vashistha and Tejasvi, 2021, 2022, 2023). The use of fly ash reduced the growth of several soil borne pathogenic microbes whereas the population of *Rhizobium sp.* were increased under the soil amended with fly ash (Chandrakar *et. al*., 2015).

MATERIALS AND METHODS

For present study, Fly ash was collected in sufficient quantity from National Capital thermal Power Station, Dadri (U.P.). To prepare the field for sowing of wheat heavy crop discing was done in the first week of October. The process was repeated again after two days followed by cross cultivation and planking to make the soil pulverized. The stubbles and weeds were removed and disposed off from the experimental field. A presowing irrigation was given uniformly to the experimental field.

Fly ash (FA), organic manure like farmyard manure (FYM) and chemical fertilizer (CF) were used alone and also in different combinations. Fly ash @ 10 t/ha, FYM @ 1500 kg/ha was applied. In total, eight treatment combinations were used in this study: (1) control (without any application) (ii) CF (recommended dose), (iii) FYM, (iv) FA, (v) FA + CF, (vi) FA +FYM, (vii) CF+ FYM and (viii) CF+ FYM + FA. A uniform nutrient level of 150 kg N, 60 kg P and 40 kg K ha^{-1} through these materials and chemical fertilizers (CF) were maintained for all the treatments except fly ash (FA) and control plots. Two wheat variety HD-2967 and PBW-343 were used in this study. Experimental plots (2m x 2m) were prepared using above treatment combinations for two days before sowing of wheat varieties. A distance of 20 cm was maintained row to row and of 10 cm plant to plant. The sowing was done with the help of a dibbler manually. Thinning was done 21 days after sowing in order to maintain spacing between the plants within the rows. Recommended cultural practices were used for raising the crop. The treatments were replicated thrice in randomized block design (RBD). Thus, a total of 48 plots were prepared for two varieties of wheat and periodic observations on plant growth and yield were recorded. Various growth and yield characteristics were measured including germination percentage, plant height, root length, number of tillers per plant, number of ears per plant, days to 50% flowering, days to maturity, seed yield per plant, 1000 seed weight, biological yield, harvest index percentage and chlorophyll content.

RESULTS AND DISCUSSION

To find out the suitability of fly ash in agricultural practices, field experiments were conducted using fly ash as a soil amendment material. Plant nutrients like farmyard manure (FYM) and chemical fertilizers (CF) were also used for making comparison in winter season of two successive years. In both the Trials, there was a discernible stimulation in germination percentage of wheat plants in all the treatments compared to control (Table 1, 2).

Table 1: Effect of different fertilization sources on germination of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 1)

Treatments	Germination %	
	PBW-343	HD-2967
Control	86.33	87.56
CF	93.26	93.86
FYM	90.16	91.06
FA	89.23	90.33
FA+CF	95.53	95.73
FA+FYM	92.36	92.93
CF+FYM	94.16	94.66
CF+FYM+FA	96.93	98.33
CD at 5 %	0.43*	0.47*

The highest increase in germination percentage was seen when fly ash, farmyard manure and chemical fertilizer were used together, with 12.2 % and 9.3 % for HD-2967 and 12.2 % and 9.7 % for PBW-343 variety over control in Trial 1 and Trial 2, respectively. There was also an increase of 7.1 % and 4.6 % (Fig. 1) for HD-2967 and by 8 % and 4.4 % for PBW-343 variety over control in Trial 1 and Trial 2 respectively, when only chemical fertilizer was used with soil. Nevertheless, among all treatments, the least increase in germination percentage occurred when fly ash or farmyard manure were applied alone without any other fertilizing source. The results remain same when farmyard manure was replaced fly ash as the sole addition to soil (Table 1, 2).

Table 2: Effect of different fertilization sources on germination PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 2)

Treatments	Germination %	
	PBW-343	HD-2967
Control	88.46	90.16
CF	92.36	94.33
FYM	90.46	92.26
FA	90.43	93.30
FA+CF	94.36	94.86
FA+FYM	91.46	94.23
CF+FYM	93.56	95.33
CF+FYM+FA	97.10	98.60
CD at 5 %	0.40*	0.44*

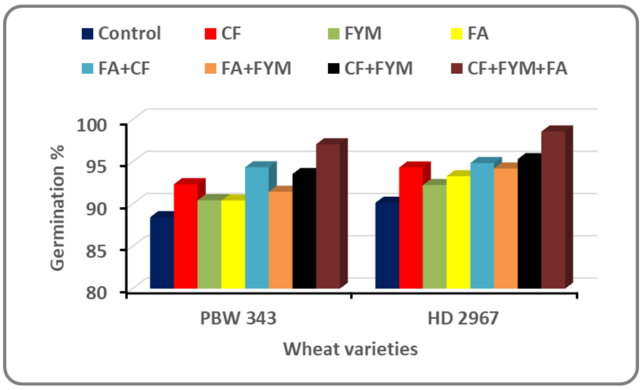

Fig. 1: Effect of different fertilization sources on germination % of wheat varieties (Trial 2)

The plant height in both trials followed the same pattern as observed for germination percentages. Table 3 and 4 showed that there was a significant increase across all the treatments as compared to the control.

Table 3: Effect of different fertilization sources on plant height of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 1)

Treatments	Plant Height (cm)					
	PBW-343			HD-2967		
	30th DAS	60th DAS	120th DAS	30th DAS	60th DAS	120th DAS
Control	27.09	70.52	99.78	29.25	73.30	102.08
CF	30.20	73.39	102.38	32.61	75.00	104.20
FYM	28.65	72.37	100.81	30.56	73.41	102.93
FA	28.25	72.25	100.33	30.20	72.88	102.45
FA+CF	31.61	74.21	103.50	32.68	75.41	104.86
FA+FYM	29.36	73.33	101.48	30.93	75.15	103.43
CF+FYM	31.36	74.35	103.15	33.01	75.89	104.77
CF+FYM+FA	32.73	75.16	106.21	34.11	76.68	106.48
CD at 5 %	0.54*	0.47*	0.66*	0.48*	0.9*	0.56*

In Trial 1, PBW-343 and HD-2967 experienced an increase of 0.5% and 0.3% respectively, while in Trial 2 the increments were more drastic with PBW-343 and HD-2967 reaching by 2.2% and 3.4%, respectively (Table 3, 4, Fig. 2). It's noteworthy that when fly ash was used with chemical fertilizer and farmyard manure, the greatest enhancement in plant height was recorded in both the trials.

Table 4: Effect of different fertilization sources on plant height of PBW-343 and HD-2967varieties of *Triticum aestivum* L. (Trial 2)

Treatments	Plant Height (cm)					
	PBW-343			HD-2967		
	30th DAS	60th DAS	120th DAS	30th DAS	60th DAS	120th DAS
Control	25.49	68.35	98.34	28.38	70.81	100.50
CF	29.35	71.49	101.42	31.21	73.42	102.58
FYM	27.46	69.66	100.21	29.95	71.55	101.12
FA	26.97	69.18	99.58	29.79	71.18	101.23
FA+CF	30.79	72.26	102.22	32.05	73.80	103.09
FA+FYM	28.10	70.41	101.11	31.33	72.37	101.98
CF+FYM	30.81	71.83	102.22	32.33	74.13	102.79
CF+FYM+FA	33.02	74.39	104.54	34.28	75.37	105.42
CD at 5 %	0.48*	0.66*	0.51*	0.42*	0.40*	0.64*

In comparison to the control, all treatments led to a marked increase in total chlorophyll levels. Particularly, when fly ash, chemical fertilizer and farmyard manure were applied together in Trials 1 and 2, PBW-343 and HD-2967 varieties showed an upsurge of 37.3 % and 42.2 % (Table 5) and 54.3% and 52.3% (Table 6 and Fig. 3) in total chlorophyll content, respectively.

Table 5: Effect of different fertilization sources on growth parameters of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 1)

Treatments	Growth Parameters									
	PBW-343					HD-2967				
	Total Chlorophyll (mg/g)	No. of Tillers	No. of Ears	Days to 50% Flowering	Days to Maturity	Total Chlorophyll (mg/g)	No. of Tillers	No. of Ears	Days to 50% Flowering	Days to Maturity
Control	1.44	4.26	4.13	75.00	112.00	1.33	3.96	3.80	76.00	113.00
CF	1.69	4.80	4.60	71.00	105. 00	1.58	4.53	4.33	69.00	105.00
FYM	1.59	4.36	4.20	73.00	108.00	1.42	4.16	4.00	72.00	108.00
FA	1.53	4.20	3.96	74.00	111.00	1.40	4.06	3.93	74.00	110.00
FA+CF	1.75	5.06	4.93	70.00	105.00	1.69	4.73	4.60	68.00	104.00
FA+FYM	1.60	4.66	4.46	72.00	107.00	1.50	4.43	4.33	70.00	107.00
CF+FYM	1.88	5.03	4.90	68.00	103.00	1.75	4.76	4.63	67.00	103.00
CF+FYM+FA	1.98	5.33	5.06	67.00	102.00	1.89	5.36	5.06	66.00	101.00
CD at 5 %	0.03*	0.23*	0.17*	NS	NS	0.05*	0.16*	0.14*	NS	NS

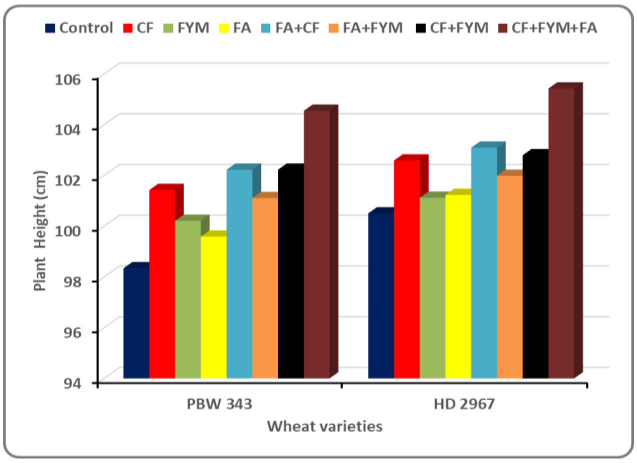

Fig. 2: Effect of different fertilization sources on plant height (120 DAS) of wheat varieties (Trial 2)

On the other hand, with just farmyard manure as the sole amendment for both trials, the increase in total chlorophyll content was slight (Table 5, 6). Similarly, Trial 2 recorded slightly lesser yet still noteworthy increases in the number of tillers with increments of 16.8% and 15.1%, respectively (Table 6 and Fig. 4). Data depicted in both these tables showed that the least increment was recorded when farmyard manure was used alone in both trials.

The number of ears for PBW-343 and HD-2967 varieties showed a consistent increase as compared to the control in both Trial 1 and 2, with the maximum percentage increase being 22.5% and 33.1% respectively in trial 1, when fly ash, chemical fertilizer and farmyard manure were used as soil amendments (Table 5). In the second trial, a slightly lesser yet significant increase was also observed (18.7% and 14.6%), as evidenced by Table 6 and Fig. 5. The minimum increase was recorded when farmyard manure was used alone in both the trials (Table 5 and 6).

Table 6: Effect of different fertilization sources on growth parameters of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 2)

Treatments	Growth Parameters									
	PBW-343					HD-2967				
	Total Chlorophyll (mg/g)	No. of Tillers	No. of Ears	Days to 50% Flowering	Days to Maturity	Total Chlorophyll (mg/g)	No. of Tillers	No. of Ears	Days to 50% Flowering	Days to Maturity
Control	1.27	4.50	4.26	77.00	111.00	1.26	4.63	4.50	75.00	109.00
CF	1.53	4.83	4.66	71.00	106.00	1.45	4.83	4.66	70.00	105.00
FYM	1.39	4.66	4.53	73.00	108.00	1.32	4.70	4.56	73.00	109.00
FA	1.35	4.63	4.46	73.00	108.00	1.35	4.63	4.53	73.00	109.00
FA+CF	1.63	4.96	4.83	68.00	104.00	1.52	4.96	4.73	68.00	104.00
FA+FYM	1.57	4.76	4.63	72.00	107.00	1.45	4.83	4.66	71.00	108.00
CF+FYM	1.62	4.96	4.83	68.00	105.00	1.62	4.96	4.83	67.00	103.00
CF+FYM+FA	1.96	5.26	5.06	65.00	100.00	1.92	5.33	5.16	65.00	99.00
CD at 5 %	0.70*	0.10*	0.11*	NS	NS	0.06*	0.10*	0.09*	NS	NS

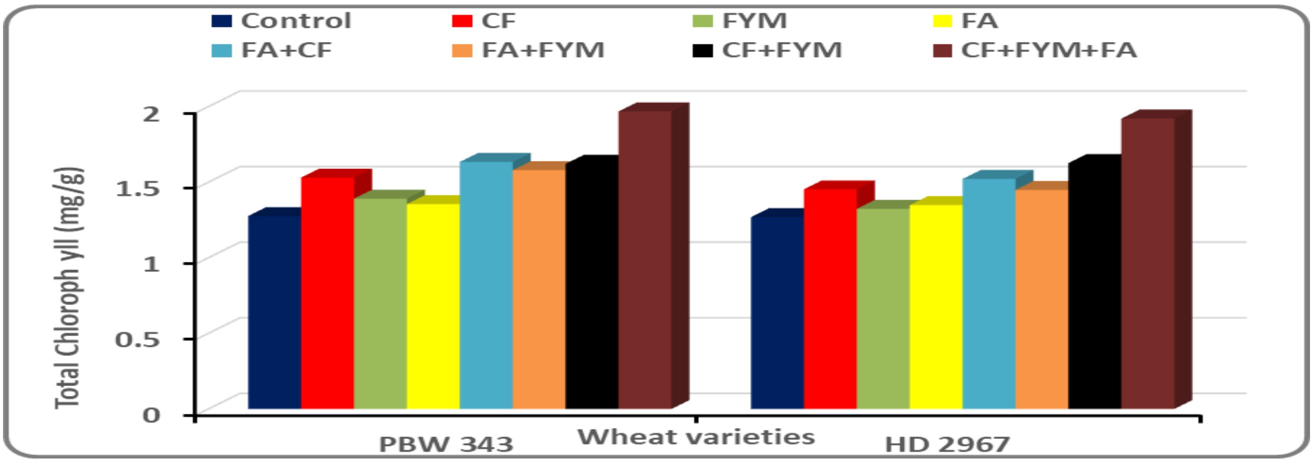

Fig. 3: Effect of different fertilization sources on total chlorophyll content of wheat varieties (Trial 2)

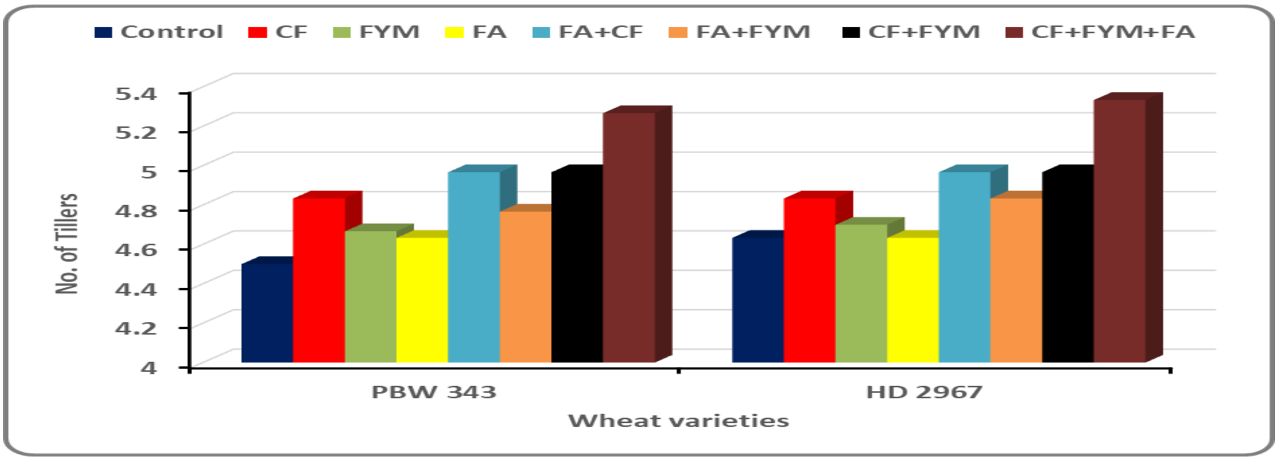

Fig. 4: Effect of different fertilization sources on no. of tillers of wheat varieties (Trial 2**)**

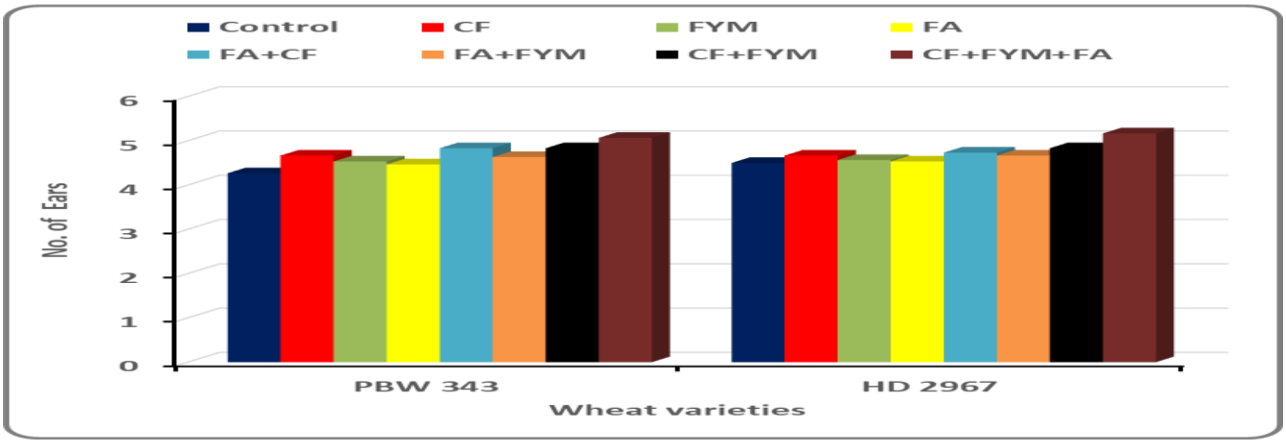

Fig. 5: Effect of various fertilization sources on number of ears of wheat varieties (Trial 2)

The application of fly ash, farmyard manure and chemical fertilizer in different combination triggered a substantial advance in the onset of flowering for both the wheat varieties (PBW-343 and HD-2967), inducing it by 10.7% and 15.6% earlier than the control in Trial 1 and 13.2% and 13.4% earlier in Trial 2, respectively (Table 5, 6 and Fig. 6).

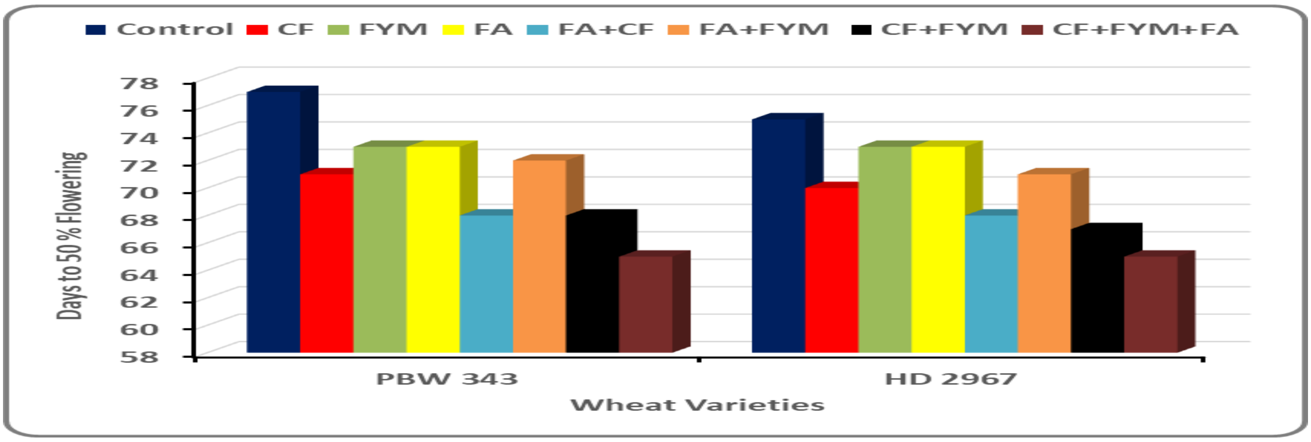

Fig. 6: Effect of various fertilization sources on days to 50 % flowering of wheat varieties (Trial 2)

In both the trials, PBW-343 and HD-2967 wheat varieties gets matured earlier with different fertilizing sources as compared to the control. In Trial 1, the number of days for maturity decreased by 0.9% and 2.7% for PBW-343 and HD-2967 respectively. For Trial 2, PBW-343 showed a reduction of 2.8% over control, while HD-2967 stayed at 0% (Table 5, 6 and Fig. 7).

Yield Parameters

The results of both the trials shown in Table 7 and 8 and Fig. 8 indicate a significant increase in the number of seeds per plant across all treatments as compared to the control. The maximum increase was recorded under integrated nutrient supply system; a rise of 42.9% and 37.2% for PBW-343 and 35.3% and 49.5% for HD-2967 varieties over the control in Trial 1 and Trial 2, respectively. When chemical fertilizer was used as the sole soil treatment, there was also an appreciable increase of 24.3% and 20.8% for PBW-343 and 21.6% and 25.8% for HD-2967 varieties over the control in Trial 1 and Trial 2, respectively.

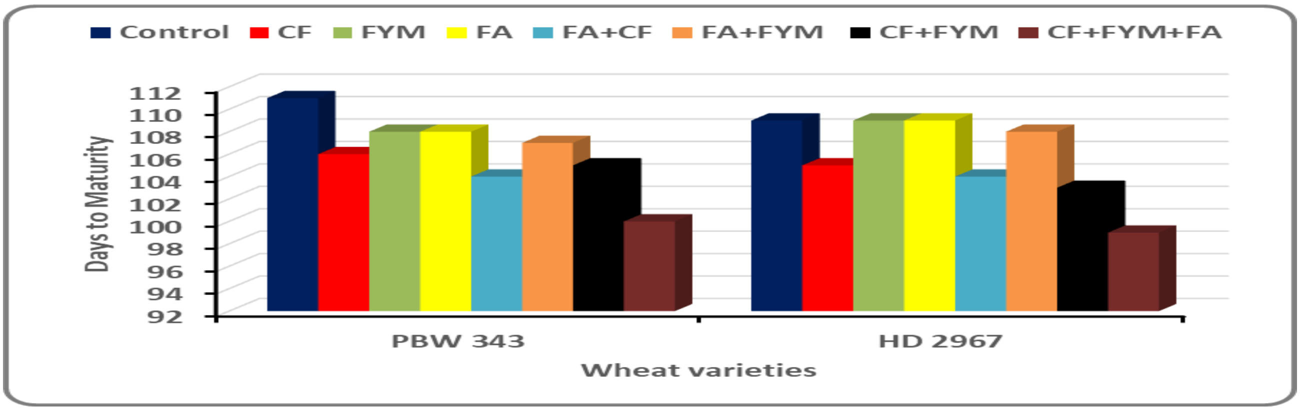

Fig. 7: Effect of various fertilization sources on days to maturity of wheat varieties (Trial 2)

Table 7: Effect of various fertilization sources on yield parameters of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 1)

Treatments	Yield Parameters							
	PBW-343				HD-2967			
	Seed/Plant (gm)	1000 seeds weight (gm)	Biological Yield (gm)	Harvest Index (%)	Seed/Plant (gm)	1000 seeds weight (gm)	Biological Yield (gm)	Harvest Index (%)
Control	6.32	40.45	16.62	38.05	7.18	42.35	17.55	40.98
CF	7.85	43.51	18.75	41.88	8.74	44.66	19.55	44.66
FYM	6.89	42.36	17.22	40.03	7.71	43.45	18.18	42.40
FA	6.73	41.98	17.05	39.50	7.23	42.99	18.34	39.40
FA+CF	8.09	44.12	18.99	42.60	8.95	45.23	20.36	43.94
FA+FYM	7.36	43.24	18.18	40.49	8.19	43.49	18.38	44.56
CF+FYM	7.94	44.13	19.16	41.44	9.05	46.23	21.01	43.00
CF+FYM+FA	9.03	47.67	21.49	42.05	9.72	50.31	22.50	43.19
CD at 5%	0.22*	0.29*	0.18*		0.22*	0.34*	1.09*	

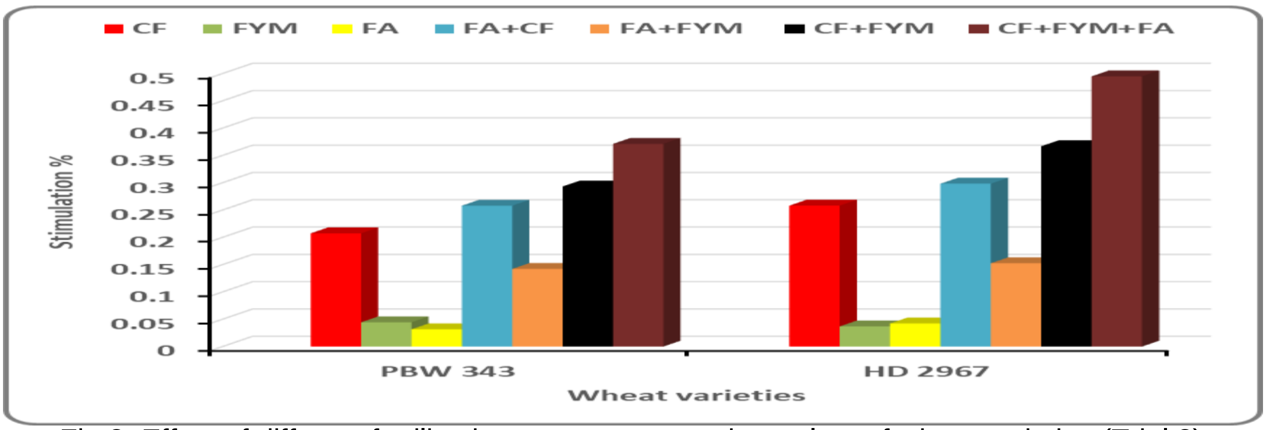

Fig 8: Effect of different fertilization sources on seed per plant of wheat varieties (Trial 2)

Table 8: Effect of various fertilization sources on yield parameters of PBW-343 and HD-2967 varieties of *Triticum aestivum* L. (Trial 2)

Treatments	Yield Parameters							
	PBW-343				HD-2967			
	Seed/Plant (gm)	1000 seeds weight (gm)	Biological Yield (gm)	Harvest Index (%)	Seed/Plant (gm)	1000 seeds weight (gm)	Biological Yield (gm)	Harvest Index (%)
Control	6.44	41.34	17.30	37.22	6.22	43.38	17.36	35.80
CF	7.78	44.43	20.45	38.04	7.83	45.49	20.49	38.21
FYM	6.73	42.24	18.53	36.31	6.45	44.22	18.47	34.92
FA	6.65	42.45	18.38	36.18	6.48	44.17	18.24	35.52
FA+CF	8.11	45.45	20.79	39.00	8.08	45.95	21.12	38.25
FA+FYM	7.36	43.38	19.49	37.76	7.17	45.16	19.48	36.80
CF+FYM	8.33	45.32	21.10	39.47	8.50	46.47	21.64	39.27
CF+FYM+FA	8.84	48.40	22.19	39.83	9.30	49.63	22.57	41.20
CD at 5 %	0.31*	0.34*	0.32*		0.19*	0.30*	0.27*	

With intensification of farming and utilization of chemical fertilizers, the significance of supplementary and complementary organic materials is being important for retaining or regaining productivity of soil (Modgal and Singh, 1990; Karmakar *et al.,* 2009). Thus integrated or combined nutrient management by utilizing different chemical fertilizers, organic sources and some soil amendments is needed for sustaining high yield of crop. Among many, some industrial heavy wastes like fly ash and paper factory sludge are sufficiently potent of enhancing soil pH besides being very rich sources of various plant nutrients (Mesa, 1991; Sims *et al.,* 1993; Guerini *et al.,* 1994). Utilization of chemical fertilizers, industrial wastes and agricultural animal wastes in a combined form may attribute differences in the decomposition process of organic materials and so are likely to alter the nutrient release manner of the soil (Mittra *et al.,* 2003). Fly ash had a transformative impact on the soil, resulting in several notable changes. It significantly modified the soil texture, reducing bulk density while enhancing water holding capacity, soil porosity, pH levels, electrical conductivity and organic carbon content (Tejasvi and Kumar, 2012).

Varshney *et al.* 2023 observed that the addition of 40% FA to the soil produced a remarkable improvement in marigold plant growth and metal tolerance compared to those grown in the control soil. There are several factors that collectively represent a satisfactory plant growth performance, such as height, biomass accumulation, leaf area and vitality. These parameters showed marked improvement in plants grown on FA-amended soil suggesting its positive effect on plant development. Furthermore, the metal tolerance index (MTI) was also found to be elevated when the soil was enriched with FA. This was suggested that plants grown in this medium were hardier and more capable of tolerating metals without having any adverse effects on their health or growth. The findings revealed that FA-amended soils have the potential to enhance plant growth and increase tolerance to metals, offering insights into strategies to improve crop performance in regions with elevated metal concentrations.

CONCLUSION

In conclusion, this study was designed to explore the potential of fly ash as a valuable resource in agricultural practices via field experiments that incorporated it as soil amendment. The experiments compared its performance to more traditional inputs such as farmyard manure and chemical fertilizers within an integrated nutrient supply system and were conducted in slightly acidic sandy loam soil. Particular emphasis was placed on investigating their impact on crop yield and soil productivity. In both the wheat varieties tested, we observed a significant increase in growth and yield when fly ash was applied in different fertilization combinations. Fly ash was most effective for enriching soils and enhancing crop production when combined with chemical fertilizer and farmyard manure. This shows how these inputs can work synergistically. A significant positive correlation was also found between grain yield and nutrient uptake, specifically nitrogen (N), phosphorus (P) and potassium (K), which are essential nutrients. Fly ash has been shown to improve crop yield as well as nutrient absorption by plants, contributing to the nutritional value of crops overall when introduced into agricultural practices. As a result of our research, we found that utilizing combined fertilizer sources, including fly ash, improve nutrient utilization efficiency. This approach not only helps improve crop yields but also mitigates the reliance on costly chemical fertilizers, which are often economically burdensome for farmers. By integrating fly ash into the agricultural landscape, we can work towards more sustainable and cost-effective farming practices, promoting both environmental and economic benefits.

REFERENCES

Aggarwal, S., Singh, G.R. and Yadav, B.R. (2009) Utilization of fly ash for crop production: Effect on the growth of wheat and sorghum crops and soil properties. *Journal of Agricultural Physics,* **9:** 20-23.

Chandrakar, T., Jena, D., Dash, A.K., Jena, S.N., Panda, N. and Monica, M. (2015) Soil microbial activity as influenced by application of fly ash and soil amendments to maize crop in acidic alfisols, *International Research Journal of Agricultural Science and Soil Science,* **5** (4) **:** 120-128.

Guerini, I.A., Villas Boas, R.L., Bull, L.T., Eira, A.F., Penatti, A., Toledo, C.M., Matsumoto, K., Machado, R.W., Mello, S.L. and De, M. (1994) Effect of cellulose residue and ash from a cellulose and paper mill on some physical, chemical and biological properties of soil in pot experiment. *Cientifica,* **22:** 43-51.

Karmakar, S., Mittra, B.N. and Ghosh, B.C. (2009) Influence of Indian soil waste on soil- plant interaction in rice under acid lateritic soil. World of Coal Ash (WOCA) Conference May 4-7 in Lexington, KY, USA (http://www.flyash.info).

Krishnamoorthy, R. (2000) Ash utilization in India- Prospects and problems, In Barrier and utilization of fly ash in India. Central Board of Irrigation and Power, New Delhi. pp.15-27.

Kumar, V. and Jha, G.K. (2014) Use of fly ash in agriculture: Indian Scenario, WACAU-2014, Israel International Workshop on Agricultural Coal Ash Uses. pp 1-10.

Mesa, L.J. (1991) Effects of the application of rice husk ash on the chemical and mineral composition of two Oxosols in Colombia, **8:** 322-335.

Mittra, B.N., Karmakar, S., Swain, D.K. and Ghosh, B.C. (2003) Fly ash – a potential source of soil amendment and a component of integrated plant nutrient supply system. International ash utilization symposium, Centre of applied energy research, University of Kentucky (http://www.flyash.info).

Modgal, S.C. and Singh, C.M. (1990) Crop residue management. In Agronomic Research towards sustainable agriculture (Eds. K.N. Singh and R.P. Singh). *Indian Soc. Agron.,*IARI, New Delhi, pp. 7-23.

Naik, T.R. and Tyson, S.S. (2000) "Environmental benefits from the use of coal combustion products (CCP)", Verma, C.V.J., Rao, S.V., Kumar, V. and Krishnamoorthy, R. (Eds), Proceddings of the second international Conference on Fly ash disposal utilization, pp 4-43.

Raj, S. and Mohan, S. (2014) Approach for improved plant growth using fly ash amended soil, *International Journal of Emerging Technology and Advanced Engineering,* **4** (6): 709-715.

Raj, S. and Mohan, S. (2016) Effect of low concentration of fly ash on the plant growth performance: A review, Special Issue on International Journal of Recent Advances in Engineering and Technology (IJRAET) **4** (I-1) For National Conference on Recent Innovations in Science, Technology and Management (NCRISTM) ISSN (Online): pp 2347-2812, Gurgaon Institute of Technology and Management, Gurgaon.

Sharma, S., Kumar, V. and Yadav, K.K. (2016) Effect of fly ash deposition on biochemical parameters of different crop plants around Parichcha Thermal Power Plant, Jhansi, India. *Int. J. Curr.* NISHANT

Microbiol. App. Sci., **5** (8)**:** 873-877.

Sims, J.T., Vasilas, B.L. and Ghodrati, M. (1993) Effect of coal fly ash and co-composted sewage waste on emergence and early growth of clover crop. *Communications in Soil Science and Plant Analysis*, **24**: 503–512.

Skousen, J., Yang, J. E., Lee, J. S. and Ziemkiewicz, P. (2013) Review of fly ash as a soil amendment. *Geosystem Engineering*, 16 (3): 249-256.

Tejasvi, A. (2017) Response of pea crop in fly ash amended soil. *Annals of Horticulture*, **10** (1): 25-30.

Tejasvi, A. (2020) Response of Azad P1 cultivar of pea in fly ash amended soil. *Plant Archives*, **20** (1): 1959-1962.

Tejasvi, A. (2021) Response of Arkel cultivar of garden pea in fly ash amended soil. *Plant Archives*, **21** (1): 841-844.

Tejasvi, A. and Kumar, S. (2012) Impact of Fly Ash on Soil Properties. *National Academy Science Letters*, **35** (1): 13-16.

Vasistha, V. (2014) Effects of pollutants produced by thermal power plant on environment: A review, IJMERR, **3** (2): 202-207.

Vashistha, N. and Tejasvi, A. (2021) Effect of fly ash extract on early growth of wheat. *International Journal of Botany Studies*, **6** (4): 204-206.

Vashistha, N. and Tejasvi, A. (2022) Impact of fly ash on growth parameters of wheat through pot culture studies. *Journal of Science and Technological Researches (JSTR)*, **4**(3): 17-19.

Vashistha, N. and Tejasvi, A. (2023) Response of pea cultivar (PBW-343) to fly ash amended soil. *Ecology, Environment and Conservation*, **29**(2): 726-729.

Varshney, A., Dahiya, P. and Mohan, S. (2023) Growth, biochemical, and antioxidant response of pot marigold (*Calendula officinalis* L.) grown in fly ash amended soil. *Int. J. Phytoremidiation,* 25 (1): 115-124.

Vitekari, H.N., Ashish, P., Talele, R.G., Mane, V.S., Gaik, J.V. and Shah, J. V. (2012). Fly ash-based bio-pesticides: A comprehensive review, IJPBS, **2**(1): 76-82.