Journal of Plant and Environmental Sciences

http://plantenvironment.org/

Research Article

Impact of Coal Fly Ash and Coarse Ash on the Growth and Yield of Wheat (*Triticum aestivum* L.)

Muhammad Usman Khan[1], Benish Ali[1], Imran Ashraf[1], Sardar Alam Cheema[1*]

[1] Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan.

***Correspondence:** sardaralam35@gmail.com

DOI:

Received: 14/04/2023 Accepted: 30/09/2023 Published: 15/03/2024

Abstract

Wheat (*Triticum aestivum* L.) is the primary cereal crop for the vast majority of the global population. Ashes (coal fly ash and coarse ash which) are heterogeneous sources of nutrients would play a vital role in agriculture production. This study was planned to evaluate the impact of coal fly ash and coarse ash (bottom ash) on the growth and yield of wheat at agronomic research area, University of Agriculture Faisalabad. A simple randomized complete block design (RCBD) was laid in triplicates under split-plot arrangement. The experiment was performed using two ashes (coal fly ash and coarse ash) with three application levels (0, 5 and 10 t ha^{-1}). Data regarding growth and physiological attributes were recorded during and after the completion of the experiment. Results show that application of ashes significantly improved the growth and yield of wheat. About 35.3%, 28.8%, 34%, 15.5%, 19.9%, 18.8%, 32.6% and 28.5% higher, grain weight per spike, no of spikelets per spike, no of grain per spike, 1000 grains weight, harvest index, grain yield and biological yield respectively were observed in treatment where 10% fly ash was applied compared to control. This study has shown that application of coal fly ash and course ash would be affective in improving growth and yield of wheat.

Keywords: Wheat; Coal fly ash; bottom ash; yield improvement

1. Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop and has been grown as the first domesticated food crop in many regions of the world for the last 8000 years (Charmet, 2011; Zhou *et al.,* 2020). It is a staple food for approximately 40% population of the globe and provides a significant number of fibers and carbohydrates that are necessary for strength as well as digestion (Giraldo *et al.,* 2019). It also contains 20% of the daily necessary protein and calories that a human body needs regularly (Petrie *et al.,* 2004). Wheat grain is also a major source of essential nutrients (Shewry, 2015; Sarwar *et al.,* 2013). In Pakistan wheat is the most significant cereal crop, planted over a 8.83 million hectares and providing about 25 million tons of edible grain per year at a productivity of roughly 2.8 t ha^{-1}. With 8.7 percent of value-added and 1.7 percent of Pakistan's GDP, wheat has a major role in the economy. According to Pakistan's census of 2017, our population is increasing at a faster pace of 2.0% per year (Census, 2017). Therefore, there is a current need to increase the area and yield of wheat to overcome food security issues.

The average farmer's wheat yield in Pakistan is 2.26 t ha^{-1} as compared to 6.80 t ha^{-1} gained by research institutes. This represents a difference of 67 percent between the theoretical yield. In addition, average wheat yield in Pakistan is 70% lower than the average wheat yield of major wheat producing countries (Aslam, 2016). There are many reasons of this low productivity; however, poor soil health is major one (Aslam, 2016). Application of coal fly ash and coarse (bottom) ash would improve soil health by replenishing the nutrients and improving soil conditions. Fly ash (main residual component of thermal power plants) plays a valuable role in agriculture because it is comprised of heterogeneous mixture of calcium, sodium, potassium, phosphorus, sulfur, magnesium, aluminum, silicon, iron and many other valuable nutrients (Mattigod *et al.,* 1990). Fly ash has also been employed for plant development over the last three decades due to the presence of important micro and macro-nutrients (Zacco *et al.,* 2014). At various degrees of incorporation, fly ash improves the biological and physicochemical features of the soil. Its use has increased significantly during the last three decades (Ram and Masto, 2010).

Coarse ash has particle sizes ranging from 0.1 to 10 mm and an apparent dark grey color (Theis and Gardner 1990; Ahmaruzzaman, 2010). The coarse ash is a granular and bristly material as compared to the fly ash (Mukhtar *et al.,* 2003). It was observed that clayey soils combined with coarse ash can improve tilth by decreasing crust development and increasing clayey soil friability. Coarse ash mixed with soil exhibits high air content and water holding capability and also contains several mineral elements that are beneficial for plant growth. The coarse ash may improve water infiltration and soil structure which generally improves soil

To cite this paper: Khan, M.U.; Ali, B.; Ashraf, I.; Cheema, S.A.. Impact of Coal Fly Ash and Coarse Ash on the Growth and Yield of Wheat (*Triticum aestivum* L.). J. Plant Environ. Sci. 2023, 01, JPES08.

productivity (Sell *et al.,* 1989. Some of the coarse ash mineral nutrients may have a revitalizing impact when applied to agricultural or forest soils.

To the best of our knowledge, literature is very sketchy about the usage of fly ash and coarse ash in agriculture in Pakistan. Therefore, this study was planned to check the effect of coal fly ash and coarse ash on wheat growth and yield.

2. Materials and Methods

2.1 Experiment and treatment description

The experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (Pakistan), in winter season 2020-21. The research was carried out on sandy clay loam soil. The soil of the experimental site was fertile with fine texture and uniform soil particles. Soil samples were taken from each experimental plot from 0-30 cm depth using an auger to determine soil physicochemical properties. Wheat was sown by using recommended production technology in each experimental plot. The experiment was laid out in randomized complete block design (RCBD) with simple plot arrangements. The experiment was comprised of the following treatments, control, Fly-ash @ 5 t ha^{-1}, Fly-ash @ 10 t ha^{-1}, coarse-ash @ 5 t ha^{-1}, coarse-ash @ 10 t ha^{-1}. The experiment was replicated three times with gross plot size of 1.8 m × 5 m in three replications.

2.2 Crop husbandry

Pre-sowing irrigation (Rouni) was applied in the field. When the moisture was at field capacity (Wattar) seedbed was prepared with the cultivator and then with a tractor-mounted rotavator followed by the planking. For this experiment wheat genotype, Anaj-2017 was taken from Agronomic Research Farm University of Agriculture Faisalabad. Seed (@ 125 kg ha^{-1} was sewn by hand drill method. Recommended dose of NPK (120 kg ha^{-1}, 100 kg ha^{-1} and 60 kg ha^{-1} respectively) were applied using urea, diammonium phosphate (DAP) and sulfate of potash (SOP) fertilizers respectively. DAP and SOP were applied as basal fertilizer while urea was applied with first irrigation. All other recommended agronomic practices were kept constant for all the treatments.

2.3 Yield and Yield Components

With the use of a measuring tape, the height of ten randomly selected mature plants from each plot was taken. After that, the average plant height in cm was computed. Then five wheat spikelets were picked from each plot to count spikelets per spike and also calculated the number of grains per spike. The average 1000 seed weight grams was calculated by obtaining three representative samples of seeds from each treatment and weighing them on an electrical balance. At crop maturity, the entire plot was harvested and threshed manually using mini thresher and economic yield calculated. Each plot's biological yield was measured in kilograms, then converted into tons per hectare (t ha^{-1}). The harvest index (HI) was calculated by dividing grain yield on biological yield and then represented as a percentage.

2.4 Statistical Analysis

Fisher's analysis of variance was used to statistically interpret the results of all parameters. The means of the treatments were compared using the computer software Statics 8.1 and the Least Significant Difference (LSD) test at the 5% probability value (Steel *et al*., 1997).

.

3. Results

3.1. Growth related traits

Results show that plant height was significantly affected by the use of fly ash and coarse ash in the soil (Table 1). All ash treatments except course ash at higher rate (10 t ha^{-1}) significantly improved the plant height at maturity. Maximum plant height 94.47 cm was noted in treatment where fly ash mixed with soil at the rate of 10 t ha^{-1} followed by Fly-ash @ 5 t ha^{-1}. However, minimum plant height was observed in control treatment.

Results also show that SPAD value was significantly affected by the use of fly and coarse ashes in soil (Table 1). Maximum SPAD value 54.00 was recorded in the treatment where fly ash mixed with soil at the rate of 10 t ha^{-1}; however, minimum was noted in control treatment. Among the ash treatments, soil application of coarse ash at the rate of 10 t ha^{-1} was shown minimum SPAD value i.e. 45.46, however it was non-significant to control treatment wherein fly ash or coarse ash was not applied.

3.2. Yield Components

Impact of ashes on the yield contributing traits and yield of wheat is shown in table 2. Results show that application of ashes, significantly affected the yield and related traits. Overall, fly ash exhibited better response in terms of yield contributing traits and yield compared to the corresponding course ash treatments. Application of fly ash at the higher rate i.e. 10 ton ha^{-1} exhibited the highest no of spikelet per spike (19.67); however, minimum were found in control treatment. Similarly, the number of grains per spike was also highest in treatment where fly ash was applied at the rate of 10 t ha^{-1}. It is also evident from the results that 1000 grain weight was highest i.e. 46.37 g in treatment where fly ash was applied at the rate of 10 t ha whereas minimum was found in control i.e. 37.10 g.

3.3. Biological yield, grain yield and harvest index

Results show that application of fly ash at higher rate (10 t ha^{-1}) produced highest yield i.e. 3.49 t ha^{-1} followed by the fly ash at the rate of 5 t ha^{-1} and there is a statistically significant yield difference with course ash treatments whereas minimum yield was found in control treatment. Similarly, highest biological yield was found in treatment where flay ash was applied at 10 t ha^{-1} followed by the treatment where fly ash was applied at

Table 1. Impact of Coal fly ash and Course ash on SPAD value and plant height.

Treatments	SPAD value	Plant Height
Control *	35.76B	70.33C
Fly-ash @ 5 t ha^{-1}	51.58A	83.20B
Fly-ash @ 10 t ha^{-1}	54.00A	94.47A
Coarse-ash @ 5 t ha^{-1}	51.30A	83.15B
Coarse-ash @ 10 t ha^{-1}	45.46AB	74.43C

Table 2: Impact of Coal fly ash and Course ash on number (No). of spikelets per spike, number of grains per spike, grain weight per spike, thousand grain weight, grain yield, biological yield and harvest index of wheat

Treatments	No. of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	1000 grains weight (g)	Harvest Index(%)
Control *	14.00B	45.47B	1.88C	37.10C	31.47B
Fly-ash @ 5 t ha^{-1}	18.67A	53.53A	2.33B	43.53AB	34.78AB
Fly-ash @ 10 t ha^{-1}	19.67A	53.87A	2.91A	46.37A	38.77A
Coarse-ash @ 5 t ha^{-1}	18.66A	53.33A	2.18BC	43.13AB	34.71AB
Coarse-ash @ 10 t ha^{-1}	17.33AB	51.00AB	2.17BC	38.93BC	32.87B

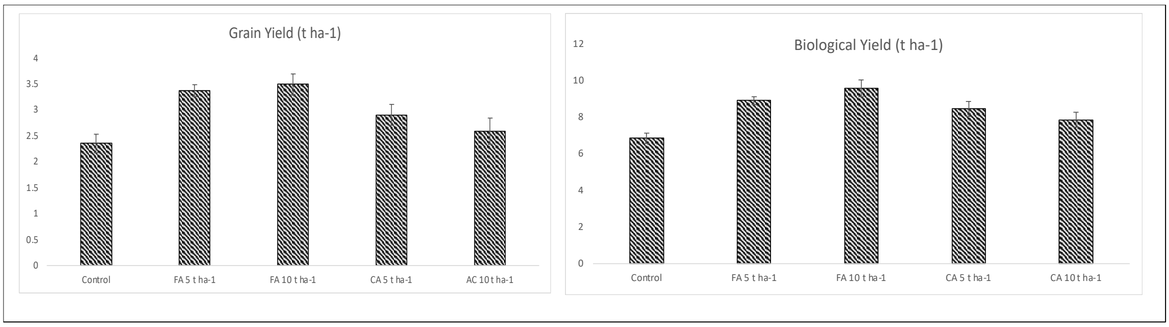

Figure 1. Impact of Coal fly ash (FA) and Course ash (CA) on grain yield and biological yield of wheat. Column show the mean of three replicates whereas bars show the standard error.

the rate of 5 t ha^{-1}. Results also show that highest harvest index (38.77) was found in treatment where fly ash was applied at higher rate; however, minimum was found in control treatment i.e. 31.47.

4. Discussion

Our results show that application of ashes significantly improved the plant height and chlorophyll content of wheat. Our results concur the findings of Durgude *et al.* (2018), who reported an increase in chlorophyll content when fly ash was added in soil. Improvement in the chlorophyll and plant height might be due to the presence of macro and micronutrients present in the ashes. Singh and Yunus (2000) reported that plant growth can be increased by coarse ash and fly ash because these contain essential elements such as Ca, Fe, Zn, Na, K, and Mg, Rai *et al.*, (2000) suggested that the concentration of the fly ash and coarse ash present in the plant tissue is easily available to the plant for use in the metabolic process. In addition, it would also be due to positive effects of ashes on the soil biochemical properties (Babu *et al.*, 2011). Chang *et al.*, (1977) reported that use of fly ash increased the soil's ability to store water and essential plant nutrients and soil properties which would help plant growth. When fly ash and coarse ash are incorporated into the soil, they can fix hazardous heavy metals in the soil, improve soil aeration and water holding capacity, which ultimately enhance the growth of plants (Su and Wong, 2004). They can also stimulate the soil microbiota by providing them with excessive carbon and other nutrients, which has a valuable role in plant growth (Ramme et al., 2013).

Application of ashes significantly improved the yield and contributing traits of wheat. Thind *et al.* (2012)

conducted a 3.5-year field experiment to study the feasibility of application of fly ash to increase the productivity of the paddy and wheat systems in various eco-zones. The treatments consisted of fly ash @ 15 and 30 Mg ha^{-1}. They observed that the application of fly ash on wheat produce much better results. They suggested that application of the fly ash on wheat and rice improved physiological, physical and yield attributes.

It is also found that application of ash on wheat increased the biological and grain yield of grain by 25%. The grain yield is the combined effect of all individual parameters of yield components under the particular set of ecological conditions. The results are in the same trend of the results of growth and yield contributing traits. This would be due to the direct impact of the ashes on the soil nutrient status and indirect effects in terms of improving soil health. Our results are in line with the studies of Wearing *et al.* (2004) who conducted field experiment for assessment of effects of coarse ash on yield and growth of peanut and also investigate the effect of the coarse ash on the physical properties of the soil. They found that addition of coarse ash increased the yield of large sized peanuts, the larger kernels percentage was increased 9.5 mm from 63 percent to 78 percent. In addition, they concluded that application of coarse ash enhanced the quality and yield of peanuts and also improved the soil physical and chemical properties. It is also evident from our results that at higher level of course ash application, the yield slightly declined. It would be due to some negative impacts of course ash on soil properties. In literature, some negative impacts of application of fly ash have also been reported. The high pH of ash may damage the microbial activities and for many other critical plant growth activities. Application of ash may delay the nodulation in the plants that show reduction in nodules (Martensson and Witter 1990).

5. Conclusion

This study has proved the hypothesis that application of coal fly ash and course ash would be effective in improving growth and yield of wheat. It was found that the soil amendment of fly ash at rate of 5 and 10 t ha^{-1} and course ash at the rate of 5 t ha^{-1} significantly improved the growth and yield of wheat. However, the addition of higher rate of course ash slightly reduced the yield. To further recommend the application of fly ash and course ash for crop production, more studies should be done to check the impact of ashes on the physicochemical properties of different soil types.

References

Abbas, M., A.D. Sheikh, H.M. Sabir and S. Nighat. 2005. Factors responsible for low wheat productivity in Central Punjab. Pak. J. Agric. Sci. 42:3-4.

Ahmad, M., M. Afzal, A. Ahmad, A. Ahmad and M. Azeem. 2013. Role of organic and inorganic nutrient sources in improving wheat crop production. Agron. Res. Moldavia. 46:15-21.

Aslam, M. 2016. Agricultural productivity current scenario, constraints and future prospects in Pakistan. Sarhad J. Agric. 32:289-303.

Babu, A. G., and M. S. Reddy. 2011. Dual inoculation of arbuscular mycorrhizal and phosphate solubilizing fungi contributes in sustainable maintenance of plant health in fly ash ponds. Water. Air. Soil. Pollut. 219:3-10.

Bashir, A., M.A. Mahmood, A.D. Sheikh and M. Kashif. 2006. Causes of wheat yield decline in the irrigated Punjab. J. Agric. Res. 44:71-83.

Chang, A.C., L.J. Lund, A.L. Page and J.E. Warneke. 1977. Physical properties of fly ash‐amended soils. J. Environ. Qual. 6:267-270.

Government of Pakistan. 2003. Economic survey of Pakistan, Ministry of Finance and Revenue, Finance Division, Islamabad. 24-43.

Government of Pakistan. 2019-120. Economic Survey, government of Pakistan economic advisory wing, finance Division Islamabad, Pakistan. 14-32.

Giraldo, J.P., H. Wu, G.M. Newkirk and S. Kruss. 2019. Nano biotechnology approaches for engineering smart plant sensors. Nat. Nanotech. 14:541-55.

Martensson, A.M., and E. Witter. 1990. Influence of various soil amendments on nitrogen fixing soil microorganisms in a long term field experiment, with special reference to sewage sludge. Soil Bio. Biochem. 22:977–982

Mattigod, S.V., D. Rai, L.E. Eary and C.C. Ainsworth. 1990. Geochemical factors controlling the mobilization of inorganic constituents from fossil fuel combustion residues: I. Review of the major elements. J. Environ. Qual. 19:188-201.

Mukhtar, S., A.L. Kenimer, S.S Sadaka and J.G. Mathis. 2003. Evaluation of bottom ash and composted manure blends as a soil amendment material. Bioresour. Technol. 89:217–228.

Mussgnug, F., M. Becker, T. Son, R. Buresh and P. Vlek. 2006. Yield gaps and nutrient balances in intensive, rice-based cropping systems on degraded soils in the red river delta of Vietnam. Field Crops Res. 98:127-140.

Olanders, B., and B. Steenari. 1995. Characterization of ashes from wood and straw. Biomass Bioenergy.

Petrie, H.J., E.A. Stover and C.A. Horswill. 2004. Nutritional concerns for the child and adolescent competitor. Nutri. 20:620-631.

Phan, N.T., T. Sengsingkham, P. Tiyayon and K. Maneeintr. 2019. Utilization of bottom ash for degraded soil improvement for sustainable technology. In IOP Conference Series: Earth Environ. Sci. 268:12-43.

Ramme and Tharaniyil. 2013. Coal Combustion Products Utilization Handbook (Wisconsin: We Energies Publication). 5:6-209.

Ram, L.C., and R.E. Masto. 2010. An appraisal of the potential use of fly ash for reclaiming coal mine spoil. J. Environ. Manag. 91:603-617

Sarwar, M.H., M. F. Sarwar, M. Sarwar, N.A. Qadri and S. Moghal. 2013. The importance of cereals (Poaceae: Gramineae) nutrition in human health: A review. J. Cereals Oilseeds. 4: 32–35.

Sell, N., T. McIntosh, C. Severance and A. Peterson. 1989. The agronomic land spreading of coal bottom ash: using a regulated solid waste as a resource. Resour. Conserv. Recycl. 2:119–129.

Shewry, P.R., and S.J. Hey. 2015. The contribution of wheat to human diet and health. Food energy secure. 4:178-202.

Singh, N. and M. Yunus. 2000. Environmental impacts of fly ash. J. Environ. Hazard. 5:60-79.

Zacco, A., L. Borgese, A. Gianoncelli, R. P. Struis, L. E. Depero and E. Bontempi. 2014. Review of fly ash inertisation treatments and recycling. Environ. Chem. Lett. 12:153-175.

Wang, J., Z. Yang, S. Qin, B. Panchal, Y. Sun and H. Niu. 2019. Distribution characteristics and migration patterns of hazardous trace elements in coal combustion products of power plants Fuel. 258: 116062.

Whiteside, M., and J. M. Herndon. 2018. Aerosolized coal fly ash: Risk factor for COPD and respiratory disease. J. Adv. Med. Res. 1-13.

Zhou, X., J. Yu, R. N. Spengler, H. Shen, K. Zhao, J. Ge, ... and X. Li. 2020. 5,200-year-old cereal grains from the eastern Altai Mountains redate the trans-Eurasian crop exchange. Nat. Plants. 6:78-87.