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Effect of Different Levels of Fly Ash on Biometric Parameters of Paddy

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A B S T R A C T

A field experiment was carried out at Agricultural and Horticultural Research Station (AHRS), Bhavikere, Tarikere taluk, Chikmagalur district, Karnataka state during summer season 2019. This experiment was carried out to study the effect of different levels of fly ash on paddy productivity. The experiment was laid out with ten treatment combinations with four levels of fly ash (10, 20, 30 and 40 t ha^{-1}) with and without PGPR and these were tried in an RCBD design with three replications. The study revealed that, the plant height (109. 80 cm), number of tillers per hill (22.08), number of panicles per hill (21.08) and the number of grains per panicle (97.15) were recorded maximum in T_9 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) which was followed by T_7 (T_1 + Fly ash @ 40 t ha^{-1}+ PGPR) over control where fly ash was not applied. Significantly higher grain (6054 kg ha^{-1}) and straw (7340 kg ha^{-1}) yield were obtained due to the combined application *i.e.*, T_1 + Fly ash @ 40 t ha^{-1} with PGPR (T_9) compared to only RDF application.

Introduction

Fly ash is produced as a result of coal combustion in thermal power plant. Now a day's fly ash disposal into the environment is one of the major concerns throughout the world mainly in the developing countries.

Fly ash sometimes used in buildings, production of bricks, construction of roads, embankment & cement industries. Its alkaline character and a high concentration of mineral substances have resulted in attempts in using it as fertilizer or amendment to enhance the Physico-chemical properties of soil.

Physically fly ash occurs as very fine particles, having an average diameter of < 10 mm, low to medium bulk density, high surface area and very light texture. Chemically the composition of fly ash varies depending on the quality of coal has used and operating conditions of thermal power stations. Approximately, on an average 95 to 99 percent of fly ash consists of oxides of Si, Al, Fe and Ca and the remainder of the ash composed of trace elements.

Fly ash amended soil showed significant improvement in soil quality and germination percentage of rice seeds. Rice growth parameters like shoot length, leaf area and pigment composition components (panicle length, seeds per panicle, seed weight and yield per plant) of rice increased with an increase in fly ash amendments. FA not only improved the physical properties of the soil but also contributed to better growth and yield (Sahu *et al.*, 2007). Fly ash treated plots produced significantly higher grain and straw yields over the control plot. The highest grain yield was obtained with fly ash at 25 t ha^{-1}. A similar trend was exhibited in the case of the straw yield of rice. The increase in yield under fly ash applied @ 25 t ha^{-1} might be due to an increase in nutrients available to the crops (Jawahar and Vaiyapuri, 2010)

Rice is the most important and extensively cultivated food crop which is a staple food for one-third world's population and occupies almost one fifth to the total land area covered under cereals. Worldwide, rice is grown in an area of 258.8 m ha with average productivity of 4660 kg ha^{-1}, out of which 90 per cent of the world's rice is produced in the Asian region including China, India, Bangladesh, Indonesia and Japan (Anon., 2016).

India is the second largest producer of rice in the world (106.57 m t) which covers an area of 43.97 m ha with a productivity of 2424 kg ha^{-1} (Anon., 2016a). In Karnataka, rice occupies 1.33 m ha producing 3.52 m t with a productivity of 2649 kg ha^{-1} (Anon., 2016b).

In combination with various organic manure, fly ash can enhance soil microbial activities, nutrient availability and plant productivity.

One of the ways of effective utilization of fly ash could be used as a soil amendment and as a source of plant nutrients. Hence the present investigation was undertaken to explore the feasibility of using fly ash as component of Integrated Plant Nutrient System for sustaining soil productivity and crop.

Materials and Methods

The present investigation entitled ‘Studies on influence of fly ash on rice crop in southern transition zone of Karnataka’ was carried out during 2019 at AHRS, Bavikere.

Location of the field experimental site

The experiment was conducted at Agricultural and Horticultural Research Station (AHRS), Bhavikere under UAHS, Shivamogga which is located on the north-western side of Tarikere, Chikmagalur district.

Experimental details

Field experimental details

The field experiment was planned with ten treatments consisting of four levels of fly ash at 10, 20, 30 and 40 t ha^{-1}. The farmyard manure (FYM) and recommended dose of fertilizer (RDF) were applied commonly to all the treatments.

The treatments were imposed in RCBD design with three replications for each treatment. The rice variety Jyothi was taken as a test crop. The treatment details are as follows.

Treatment details

T_1: Control (RDF+ FYM)
T_2: Fly ash @ 10 t ha^{-1}
T_3: Fly ash @ 20 t ha^{-1}
T_4: Fly ash @ 30 t ha^{-1}
T_5: Fly ash @40 t ha^{-1}
T_6: Fly ash @10 t ha^{-1} + PGPR
T_7: Fly ash @ 20 t ha^{-1} + PGPR
T_8: Fly ash @ 30 t ha^{-1} + PGPR
T_9: Fly ash @ 40 t ha^{-1} + PGPR
T_{10}: T_1 + PGPR

Note: FYM: Farm yard manure (10 t ha^{-1})

RDF: Recommended dose of fertilizer (100:50:50 kg ha^{-1})

PGPR: Plant growth promoting rhizobacteria

Recommended dose of N: P_2O_5: K_2O (100:50:50) and FYM @ 10 t ha^{-1}were applied for all the treatments.

Land preparation and imposition of treatments

The experimental plot was ploughed with tractor-drawn cultivator and brought to a fine tilth by harrowing twice and weeds were removed from the experimental site. The experiment was laid out in flat beds and individual plots of 3.6 m × 3.0 m and small bunds of 30 cm were raised around each plot and levelled within the plots. A channel between replications was prepared and the same was used for irrigation. The fly ash and FYM were applied to the soil according to treatment details 30 days and 25 days before transplanting, respectively.

The recommended dose of phosphorus and potassium were applied as DAP and muriate of potash during the transplanting time and 50 per cent of recommended nitrogen was supplied through DAP and urea at the time of transplanting, remaining dose (50 %) at the tillering stage through urea was applied. The rice seedlings were transplanted in each plot with a spacing of 30 cm in between the rows and 10 cm in between the plants. Weeding and intercultural operation were taken up as per the package of practices.

Design : RCBD
Treatments : 10
Replication : 3
Gross plot size : 3.6 m × 3.0 m
Crop : Rice
Variety : Jyothi
Spacing : 30 cm ×10 cm
RDF : 100:50:50 kg N: P_2O_5: K_2O ha^{-1}

Growth parameters

Plant height

Plant height was measured by selecting the main shoot and recorded plant height from ground level to the base of the fully opened leaf. After the emergence of the panicle, the height was taken up to the base of the panicle. The mean plant height was worked out and expressed in centimetres (cm).

Number of tillers per plant

The number of tillers emerging directly from the main stem was counted and the average of the five plants was expressed as the number of tillers per plant.

Dry matter accumulation

Five plants were uprooted at random from each plot at harvest; the collected samples are washed with water and dried under shade, then kept in hot air oven at 70 ^{0}C for further drying. The total dry weight is computed and expressed in g plant^{-1}.

Yield and yield parameters

Number of panicles per hill

The panicles per hill were counted at harvest from each treatment from labelled five plants and the average was expressed as the number of panicles per hill.

Number of grains per panicle

The number of grains per panicle was carried out by counting the grains from the five panicles of labelled plants and the average was worked out.

Test weight

Grains were collected from the five labelled plants selected randomly and a thousand numbers counted manually, then the weight was recorded as grams.

Grain yield

After thorough drying, the plants along with panicles in each net plot were threshed; cleaned and seed weight in each plot was recorded in kilograms. Based on this, yield ha^{-1} was calculated and expressed in kg ha^{-1}

Straw yield

The dry straw yield from each net plot at harvest was recorded after separating the grains and complete sun drying was done for one week and dry straw yield ha^{-1} was calculated and expressed in kg ha^{-1}.

Results and Discussion

The results presented in Table 1 showed that the application of higher levels of fly ash with and without PGPR significantly increased all the biometric parameters of paddy Viz., plant height, a number of tillers per hill and dry matter accumulation at different growth stages of paddy as compared to control. There was a slight increase in biometric parameters of paddy and non-significant effect was found due to the application of fly ash with PGPR when compared to the application of fly ash alone.

Plant height

The data obtained on plant height as influenced by higher levels of fly ash with and without PGPR application at different crop growth stages are given in Table 1. The plant height of paddy was significantly influenced by the application of fly ash with PGPR as compared to control. At 30 and 60 DAT, application of T_1 + Fly ash @ 40 t ha^{-1} + PGPR (T_9) recorded significantly higher plant height (44.18 and 69.88 cm, respectively) which remained statistically on par with T_5 (T_1 + Fly ash @ 40 t ha^{-1}) which recorded 43.15 and 68.21 cm, respectively and followed by T_7 treatment (T_1 + Fly ash @ 20 t ha^{-1} + PGPR) 39.78 and 65.93 cm, respectively and significantly lower plant height were recorded in the control (31.19 and 54.26 cm, respectively) where only FYM and RDF were added.

Even at 90 DAT and at harvest stage, the results revealed that the application of fly ash along with PGPR significantly increased plant height over control treatment (T_1). However, treatment T_9 (Fly ash @ 40 t ha^{-1} + PGPR + Rec. RDF and FYM) recorded significantly higher plant height of 83.94 and 109.80 cm, respectively which found on par with T_5 (Fly ash @ 40 t ha^{-1} + 100 % RDF and FYM) which noticed 81.99 and 107.24 cm respectively, T_8 (Fly ash @ 30 t ha^{-1} + PGPR + 100 % RDF and FYM) with 81.24 and 106.27 cm, respectively and followed by T_7 (T_1 + Fly ash @ 20 t ha^{-1} + PGPR) with 75.58 and 98.86, respectively as compared to other treatments and significantly lower plant height were recorded in control treatment with 59.26 and 77.51 cm, respectively where no-fly ash was added.

Number of tillers per hill

Similarly, the number of tillers per hill was significantly increased (Table 1) in the treatments which received the combined application of fly ash with PGPR, RDF and FYM compared to the other treatments. At 30 and 60 DAT, the maximum number of tillers per hill was recorded due to application of T_1 + Fly ash @ 40 t ha^{-1} + PGPR (T_9) (11.94 and 16.72, respectively) which was on par with T_5 (Fly ash @ 40 t ha^{-1} + Rec. RDF and FYM) which registered 11.35 and 15.89, respectively and followed by T_7 (Fly ash @ 20 t ha^{-1} + PGPR + Rec. RDF and FYM) which recorded 10.01 and 14.01 respectively, over control (8.22 and 11.50, respectively)

The paddy crop supplied with fly ash in combination with PGPR, recommended dose of fertilizer and FYM recorded the maximum number of tillers per hill even at 90 DAT and harvest stage. However, T_9 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) recorded the higher number of tillers per hill with 20.23 and 22.26, had shown on par with T_5 (Fly ash @ 40 t ha^{-1} + Rec. RDF and FYM) which registered 19.22 and 21.15, respectively and followed by T_7 treatment (Fly ash @ 20 t ha^{-1} + PGPR + Rec. RDF and FYM) which recorded 16.95 and 18.65 respectively. The lower number of tillers per hill was recorded in the control treatment (13.92 and 15.31, respectively).

The significant increase in growth parameters like plant height and number of tillers per hill of paddy crops were recorded where fly ash was applied in combination with PGPR and FYM. This might be due to better root growth of the paddy and availability and supply of all the essential nutrients through the application of fly ash, PGPR, FYM. Further, there were so many factors contributing to the improvement of growth attributes of the crop with fly ash application. Indeed, a rise of soil pH decreased the fixation of P with Fe and Al, improved physical properties, the balanced release of nutrients and higher microbial activity which was influenced by the application of PGPR.

These factors can either work individually or simultaneously and would have contributed for the improvement of growth parameters of paddy in fly ash treated plots over control treatment. The results are in line with other studies reported by Kamakar *et al.,* (2010); Sahu *et al.,* (2007) and Murgan and Murugaianyan (2013). Similarly, a 20 per cent increased in the plant height of 30 day old rice plants was observed in response to PGPR application (Ashraffuzzaman *et al.,* 2009). Besides plant height, an increase in the number of tillers and number of panicles per hill was also reported in the rice plants treated with the plant growth-promoting rhizobacteria (Salamone *et al.,* 2012).

Dry matter accumulation

The data pertaining to the effect of fly ash along with PGPR, FYM and recommended dose of fertilizer on dry matter accumulation is presented in Table 1.

It is apparent from the data presented in Table 1 that treatment T_9 (Fly ash @ 40 t ha^{-1}+ PGPR + Rec. RDF and FYM) recorded significantly higher total dry weight (69.88 g $hill^{-1}$) which found on par with T_5 (Fly ash @ 40 t ha^{-1} + Rec.RDF and FYM) and T_8 (Fly ash @ 30 t ha^{-1} + PGPR + 100 % RDF and FYM) recorded higher total dry weight with 68.21 and 67.07 g $hill^{-1}$, respectively and were significantly higher as compared to other treatments and followed by T_7 (Fly ash @ 20 t ha^{-1}+ PGPR + Rec. RDF and FYM) which registered 65.93 g $hill^{-1}$. Significantly a lower value of total dry weight in soil was recorded in T_1 treatment (54.27 g $hill^{-1}$).

The highest dry matter accumulation was recorded in the treatment which received higher levels of fly ash with PGPR and FYM. This might be due to the effect of fly ash and FYM by microorganisms, which helped to release more available nutrients in the soil and their continuous supply to plant which intern induced better root growth, vegetative growth and efficient photosynthesis and thus ultimately leads to higher dry matter accumulation. Similar findings were also reported by Sikka and Kansal (1995) and Padhy *et al.,* (2016).

Mitra *et al.,* (2003) recorded that combined application of FYM as an organic source, fly ash, or lime as a soil amendment and chemical fertilizer favourably improved dry matter production, yield and nutrient uptake of rice. Gaur and Singh (1982) observed that inoculation of *Bacillus polymyxa* increased the dry matter of rice plants and obtained an increased yield of rice by inoculation of seedling roots with *Bacillus polymyxa* along with the application of rock phosphate.

Effect of fly ash on yield attributes and yield of paddy crop

Yield parameters of paddy *viz.*, number of panicles per plant, number of grains per panicle, test weight, grain and straw yield as influenced by different levels of fly ash are presented in Table 2.

The results revealed that the application of different levels of fly ash with and without PGPR increased yield attributes of paddy over control treatment. Further, a higher number of panicles per hill, number of grains per panicle, 1000 grain weight (Test weight), grain and straw yields were recorded in the treatments which received a combined application of higher levels of fly ash with PGPR compared to the application of fly ash alone.

A significantly higher number of panicles per hill was found in the treatments, T_9 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) which recorded 21.08 which found on par with T_5 and T_8 (T_1 + Fly ash @ 40 t ha^{-1} and T_1 + Fly ash @ 30 t ha^{-1} + PGPR) treatments with 20.59 and 20.15, respectively and followed by T_7 (T_1 + Fly ash @ 20 t ha^{-1} + PGPR) which noticed 17.39. A significantly lower number of panicles per hill were found in the control treatment which recorded 12.79.

The number of grains per panicle was significantly enhanced under treatment which received T_1 + Fly ash @ 40 t ha^{-1} + PGPR (T_9) which recorded 97.15 but statistically on par with T_5 (T_1 + Fly ash @ 40 t ha^{-1}) with 94.75 and T_8 (T_1 + Fly ash @ 30 t ha^{-1} + PGPR) with 93.81 and followed by T_7 (T_1 + Fly ash @ 20 t ha^{-1} + PGPR) which noticed 88.27 were found significantly superior over control treatment (T_1) 72.24.

Results indicated that the effect of different treatments on test weight showed non-significant (Table 2). However, it ranged from 35.13 g in T_9treatment to 21.32 g in control.

It can be seen from the data presented above in accordance with the yield parameters of paddy *viz*. The number of panicles per hill and test weight were significantly influenced by the application of higher levels of fly ash along with FYM and PGPR (T_9). The higher number of panicles per hill was recorded in T_9 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) which showed the percentage efficiency of 64.81 per cent which was on par with T_5 (60.98 %) and followed by T_7 and T_3 as compared to control treatment (T_1).

This might be due to; application of fly ash along with PGPR improved the physical and chemical properties of soil by neutralizing the acid soil and increased solubility and availability of unavailable nutrients and thus enhanced more root development and resulted in better nutrient uptake by the crop and thereby it helped in increase of crop yield parameters like number of panicles per hill, number of grains per panicle and 1000 grain weight.

Thus synergistic effect from the integration of fly ash with organic and inorganic fertilizer in terms of nutrient supply system might have resulted in better nutrient uptake which produced more numbers of yield attributes. Similar results were reported by Padhy *et al.*, (2016); Karmarkar *et al.,* (2009) and Sahu *et al.*, (2007).

Table.1 Effect of different levels of fly ash on plant growth parameters at different growth stages of paddy

Treatment details	Plant height (cm)				Number of tillers hill^{-1}				Dry matter accumulation (g hill^{-1})
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest	
T_1: Control (RDF+ FYM)	31.19	54.27	59.26	77.51	8.22	11.50	13.92	15.31	54.27
T_2 : T_1 + Fly ash @ 10 t ha^{-1}	33.52	57.89	63.69	83.30	9.28	12.99	15.72	17.29	57.89
T_3 : T_1 + Fly ash @ 20 t ha^{-1}	37.54	65.33	71.33	93.29	9.82	13.75	16.64	18.30	65.33
T_4 : T_1 + Fly ash @ 30 t ha^{-1}	41.37	66.60	78.60	102.81	10.32	14.45	17.49	19.24	66.60
T_5 : T_1 + Fly ash @ 40 t ha^{-1}	43.15	68.21	81.99	107.24	11.35	15.89	19.22	21.15	68.21
T_6 : T_1 + Fly ash @ 10 t ha^{-1} + PGPR	35.43	59.43	67.32	88.05	9.54	13.36	16.16	17.78	59.43
T_7: T_1 + Fly ash @ 20 t ha^{-1} + PGPR	39.78	65.93	75.58	98.86	10.01	14.01	16.95	18.65	65.93
T_8: T_1 + Fly ash @ 30 t ha^{-1} + PGPR	42.76	67.07	81.24	106.27	10.92	15.29	18.50	20.35	67.07
T_9: T_1 + Fly ash @ 40 t ha^{-1} + PGPR	44.18	69.88	83.94	109.80	11.94	16.72	20.23	22.26	69.88
T_{10}: T_1 + PGPR	32.17	54.94	61.12	79.95	9.11	12.76	15.44	16.98	54.94
S. Em±	**0.91**	**1.06**	**1.73**	**2.25**	**0.53**	**0.74**	**0.89**	**0.98**	**1.06**
C. D. at 5%	**2.83**	**3.28**	**5.35**	**6.99**	**1.63**	**2.28**	**2.76**	**3.04**	**3.28**

RDF: Recommended dose of fertilizer, **PGPR:** Plant growth promoting rhizobacteria, **FYM:** Farm yard manure, **DAT:** Days after transplanting

Table.2 Effect of different levels of fly ash on yield parameters and yield of paddy

Treatment details	Number of panicles hill^{-1}	Number of grains panicle^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Control (RDF+ FYM)	12.79	72.24	21.32	5114	6361
T_2 : T_1 + Fly ash @ 10 t ha^{-1}	14.02	78.16	23.36	5360	6638
T_3 : T_1 + Fly ash @ 20 t ha^{-1}	16.85	85.48	28.09	5561	6757
T_4 : T_1 + Fly ash @ 30 t ha^{-1}	19.11	90.61	31.85	5799	6918
T_5 : T_1 + Fly ash @ 40 t ha^{-1}	20.59	94.75	34.31	5915	7259
T_6 : T_1 + Fly ash @ 10 t ha^{-1} + PGPR	14.97	80.64	24.95	5429	6497
T_7: T_1 + Fly ash @ 20 t ha^{-1} + PGPR	17.39	88.27	28.98	5612	6885
T_8: T_1 + Fly ash @ 30 t ha^{-1} + PGPR	20.15	93.81	33.58	5891	7198
T_9: T_1 + Fly ash @ 40 t ha^{-1} + PGPR	21.08	97.15	35.13	6054	7340
T_{10}: T_1 + PGPR	13.51	75.59	22.51	5216	6560
S. Em±	**0.67**	**2.58**	**1.11**	**97.98**	**144.45**
C. D. at 5%	**1.98**	**7.67**	**NS**	**291**	**429**

RDF: Recommended dose of fertilizer, **PGPR:** Plant growth promoting rhizobacteria, **FYM:** Farm yard manure

Grain and Stover yield of paddy

Application of the different levels of fly ash along with FYM and PGPR showed significant differences in the grain and straw yield of paddy (Table 2). Higher grain yield was obtained in the T_9 which recorded significantly higher grain yield with 6054 kg ha^{-1} and was on par with T_5 (T_1 + Fly ash @ 40 t ha^{-1}) with 5915 kg ha^{-1}, T_8 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) (5891 kg ha^{-1}) and followed by T_7 with T_1 + Fly ash @ 20 t ha^{-1} + PGPR (5612 kg ha^{-1}) and T_3 with T_1 + Fly ash @ 20 t ha^{-1} (5561 kg ha^{-1}). Significantly lower grain yield (5114 kg ha^{-1}) was noticed in the control treatment.

The trend of straw yield was followed a similar pattern as that of grain yield (Table 2). The straw yield was differed significantly due to higher levels of fly ash application along with and without PGPR. Among different treatments, treatment T_9 recorded significantly higher straw yield with 7340 kg ha^{-1} and found on par with T_5 (T_1 + Fly ash @ 40 t ha^{-1}) which recorded 7259 kg ha^{-1}, T_8 (T_1 + Fly ash @ 40 t ha^{-1} + PGPR) which recorded 7198 kg ha^{-1} and followed by T_1 + Fly ash @ 20 t ha^{-1} + PGPR (T_7: 6885 kg ha^{-1}) and T_3 with T_1 + Fly ash @ 20 t ha^{-1} (6757 kg $ha^{-1)}$ and significantly lower straw yield (6361 kg ha^{-1}) was noticed in the control treatment.

A significant increase in grain and straw yields were recorded with the combined application of fly ash (40 t ha^{-1}) and FYM (10 t ha^{-1}) along with PGPR treatments. Among different treatments, T_9 (Fly ash @ 40 t ha^{-1} + PGPR) recorded significantly higher grain yield (6054 kg ha^{-1}) as compared to control which showed the percentage efficiency of 18.38 per cent increased in grain yield which was on par with T_5 (15.66 %) and this was followed by $T_7$and T_2 treatment as compared to control treatment (T_1).This might be due to the combined application of fly ash, PGPR and FYM which improved the soil physical, chemical and biological properties of soil, they are a good source of nutrients for micro-organisms which in turn increased the mineralization rate of fly ash and decomposition of FYM by the influence of PGPR and PGPR also helped in a solubilizing organic form of nutrients to inorganic form. This has resulted in increased availability of nutrients and thus helped in supply and uptake of nutrients by plants which ultimately resulted in a higher number of grains per panicle and consequently higher grain and straw yield of paddy. The increased yield largely brought about by the advantage gained due to a higher number of tillers, panicles per hill, grain filling and increasing grain weight due to better translocation of photosynthesis.

Similar findings were reported by Yong *et al.*, (2002). In addition, to provide macro and micronutrients to the plants, PGPR also protects them from pathogens. They suppress the activity of pathogens by producing numerous antifungal metabolites like siderophores and antibiotics (Chowdhury *et al.*, 2015).

Therefore, they helped in better growth and development of crop and hence may ensure sustainable agriculture production. The use of efficient plant growth-promoting rhizobacteria (PGPR) would be another sustainable route to better performance, in terms of soil properties and crop yield.

Higher grain and straw yields in paddy could also be attributed to better total uptake of essential nutrients and its translocation to economic parts as well as improvement in yield attributing characters Viz., the number of panicles per hill, number of grains per hill and 1000 seeds grain weight. Similar results were reported by Mulla *et al.,* (2000). Selvakumari *et al.*, (2000) also reported the highest yield in rice when fly ash was applied in combination with compost, fertilizer and *Azospirillum.* Matte and Kene (1995) evaluated that application of fly ash helps in better aeration, root activity and nutrient absorption and the consequent complementary effect would have resulted in higher grain and straw yield in rice.

Application of Fly ash @ 40 t ha^{-1} along with PGPR significantly influenced morphological characters of paddy crop like plant height, number of tillers per hill at all crop growth stages which found on par with (T_5). The number of panicles per hill, number of grains per panicle, grain yield and straw yield were also recorded maximum in the treatment T_9. Fly ash in combination with various organic manure enhance the nutrient availability and plant productivity. Hence fly ash could be used as a source of plant nutrients.

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