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Effect of Cogen ash application on content and uptake of nutrients in paddy

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Abstract
Cogen ash, a by-product of sugar mills obtained during co-generation process to produce heat and electrical energy by burning bagasse and/or coal was used to study its effect on yield, nutrient content and uptake of paddy. The experiment was conducted in research block of Sri Chamundeshwari Sugars Ltd., K.M. Doddi, Mandya during *kharif* 2014 with 13 treatments replicated thrice using RCBD. Straw and grain yield was increased with increasing levels of cogen ash and further increased when applied along with recommended doses of FYM and chemical fertilizers. Data indicated that macro and micro nutrient content in paddy grain and straw was significantly higher in treatment T_9 which received RDF + RD FYM+ 15.0 t ha^{-1} cogen ash compared to all the other treatments, and in majority the same treatment showed significantly higher uptake of nutrients.

Keywords: cogen ash, crop yield, macro and micro nutrients, uptake, heavy metals

Introduction
Paddy (*Oryza sativa*) is one of the diverse crops grown in different agro-eco systems. It occupies prime place among the food crops cultivated around the world and is grown in an area of 147 m ha with a production of 525 m t. About 90 per cent of rice grown in the world is produced and consumed in Asia. Among rice growing countries, India has the largest area (41.91 m ha) with a production and productivity of 89.1 million tonnes and 2.12 t ha^{-1} respectively (Anon, 2012) [1].

Cogen ash is obtained when bagasse is burnt to produce heat and electricity during cogeneration. Coal is also burnt during the periods when bagasse is in short supply. Most of the research work has been done on characterization and utilization of coal fly ash and fewer attempts have been found in case of bagasse ash. Approach has to be developed to aim at high productivity and also sustain it in the long run. Development of such technologies will simultaneously answer the issue of disposal of cogen ash and also increasing productivity of agricultural land and nutrient content of crops.

Cogen ash can be used as a multi nutrient carrier material in agriculture in combination with any of organic manure like farm yard manure to supplement OC, N and P that may be present in cogen ash in trace amounts and to extract and chelate micronutrients present in it, also to improve the nutrient content of the crops. Ash can be effectively used in agriculture for crops such as paddy, for soil fertility improvement which otherwise may create nuisance and pollute the environment and may occupy vast areas of productive land in the present mode of disposal. Keeping these points in view, the present investigation was carried out with the objective to study the effect of varied levels of cogen ash on nutrient content and uptake of paddy.

Material and Methods
Study area
A field experiment was conducted to study the effect of cogen ash on nutrient content and uptake of paddy crop in two plots at the research block of M/s Sri Chamundeshwari Sugars Ltd., Bharathinagar, Maddur taluk, Mandya district located in Southern Dry Zone of Karnataka during the year 2014. The initial properties of the experimental site and the standard methods adopted for analysis are presented in table 1.

Table 1: Initial soil properties of experimental site

Parameters		Methods	References	Values
Physical properties				
Particle size distribution	Sand (%)			45.88
	Silt (%)			10.95
	Clay (%)			43.17
	Texture	International Pipette method	Piper, 1966 [2]	Sandy clay
Bulk density (Mg m^{-3})		Core sampler method	Piper, 1966 [2]	1.68
Maximum water holding capacity (%)		Keen Raczkowski Cup method	Piper, 1966 [2]	35.2
Chemical properties				
pH		Potentiometric method	Jackson, 1973 [3]	7.84
Electrical conductivity (dS m^{-1})		Conductometric method	Jackson, 1973 [3]	0.48
Organic carbon (%)		Wet oxidation method	Walkley and Black, 1934 [7]	0.83
CEC [c mol (p^+) kg^{-1}]		Sodium acetate leaching method	Jackson, 1973 [3]	25.64
Available Nitrogen (kg ha^{-1})		Alkaline potassium permanganate method	Subbiah and Asija, 1956 [4]	545.63
Available Phosphorus (kg ha^{-1})		Olsen's extractant method, Colorimetry	Jackson, 1973 [3]	48.34
Available Potassium (kg ha^{-1})		Ammonium acetate extractant method, Flame photometry	Jackson, 1973 [3]	332.90
Exchangeable Calcium [c mol (p^+) kg^{-1}]		Ammonium acetate extractant method, Versenate titration method	Jackson, 1973 [3]	15.80
Exchangeable Magnesium [c mol (p^+) kg^{-1}]		Ammonium acetate extractant method, Flame photometry	Jackson, 1973 [3]	3.70
Available Sulphur (mg kg^{-1})		$CaCl_2$extractant method, Turbidimetry	Black, 1965 [5]	9.72
DTPA-Iron (mg kg^{-1})		Atomic absorption spectrophotometry	Lindsay and Norvell, 1978 [6]	58.27
DTPA-Copper (mg kg^{-1})		Atomic absorption spectrophotometry	Lindsay and Norvell, 1978 [6]	6.38
DTPA-Manganese (mg kg^{-1})		Atomic absorption spectrophotometry	Lindsay and Norvell, 1978 [6]	4.70
DTPA-Zinc (mg kg^{-1})		Atomic absorption spectrophotometry	Lindsay and Norvell, 1978 [6]	1.60
Boron (mg kg^{-1})		Hot water extraction method and colorimetry using Azomethine-H reagent	John *et al.* 1975 [8]	0.77
DTPA-extractable heavy metals		Atomic absorption spectrophotometry	Lindsay and Norvell, 1978 [6]	Below detection limit

Crop details
Paddy was taken up as a test crop with spacing 20 cm X 10 cm during *kharif* 2014 with 13 treatments replicated thrice under RCBD design. IR-30864 rice variety used in the experiment was developed by AICRP Centre at V.C. Farm, Mandya and released during 1991. It is a semi-dwarf, medium duration (maturing in 130-135 days) variety with long slender grains. It is mainly recommended for saline and alkaline soils in irrigated area of Southern Karnataka

Treatment details
T_1: RDF + RD of FYM
T_2: RDF + 2.5 t ha^{-1} CGA
T_3: RDF + 5.0 t ha^{-1} CGA
T_4: RDF + 10.0 t ha^{-1} CGA
T_5: RDF + 15 t ha^{-1} CGA
T_6: RDF + RD of FYM + 2.5 t ha^{-1} CGA
T_7: RDF + RD of FYM + 5.0 t ha^{-1} CGA
T_8: RDF + RD of FYM + 10.0 t ha^{-1} CGA
T_9: RDF + RD of FYM + 15.0 t ha^{-1} CGA
T_{10}: RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA
T_{11}: RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA
T_{12}: RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA
T_{13}: RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA

Note: RDF- recommended dose of fertilizers (100:50:50 kg N: P_2O_5: K_2O ha^{-1}).

RD of FYM- recommended dose of farm yard manure (10 t ha^{-1}) CGA- cogen ash.

Crop harvest and processing
The crop was harvested after attaining the physiological maturity. The identified and labeled plant samples (grain and straw) used for recording growth and yield observations were sampled and analyzed for nutrient content. The samples were dried in hot air oven at 65°C. The dried plant samples were powdered in a micro Willey mill. The samples were analyzed for different nutrients content by adopting standard chemical analytical methods as given in Table 2.

Table 2: Methods followed for the analysis of plant samples

Plant analysis		
Parameter	**Method**	**Reference**
Nitrogen (%)	Kjeldahl digestion and distillation method	Piper, 1966 [2]
Phosphorus (%)	Diacid digestion and colorimentry using vanadomolybdate reagent	Piper, 1966 [2]
Potassium (%)	Diacid digestion and Flame Photometer method	Piper, 1966 [2]
Calcium and Magnesium (%)	Diacid digestion and Versenate titration method	Piper, 1966 [2]
Sulphur (%)	Diacid digestion and Turbidometry method	Piper, 1966 [2]
Fe, Mn, Zn and Cu (mg kg^{-1})	Diacid digestion and Atomic Absorption Spectrophotometer method	Lindsay and Norvell, 1978 [6]

Boron (mg kg^{-1})	Diacid digestion and colorimetry using Azomethane-H reagent with continuous flow analyzer	Page *et al.* 1982 [9]
Heavy metals (mg kg^{-1})	Diacid digestion and Atomic Absorption Spectrophotometer method	Lindsay and Norvell, 1978 [6]

Crop nutrient analysis

Nutrient content of straw and grains was estimated by adopting standard chemical analytical methods and expressed in percentage. Nutrient uptake (kg ha^{-1}) by crop was calculated for each treatment separately using the following formula,

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)}}{100} \text{ X Biomass (kg ha}^{-1}\text{)}$$

Statistical analysis

The analyses and interpretation of the data was done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [10]. The level of significance used in 'F' and't' test was 5 % probability and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

Results and Discussion

Effect of varied levels of cogen ash on paddy grain and straw yield

Data on paddy grain and straw yield differed significantly due to varied levels of cogen ash application in both the plots (Table 3).

Straw and grain yield was increased with increasing levels of cogen ash and further increased when applied along with recommended doses of FYM and chemical fertilizers. Significantly higher grain and straw yield was recorded in T_9 (received recommended dose of chemical fertilizers + RD FYM + 15.0 t ha^{-1}cogen ash) (6.67 and 6.99 t ha^{-1}, respectively) followed by T_8 that received recommended dose of chemical fertilizers + RD FYM + 10.0 t ha^{-1} cogen ash. Lower grain and straw yield were obtained in T_2 (recommended dose of chemical fertilizers + 2.5 t ha^{-1}cogen ash) with 3.93t $ha^{-1}$of grain and 4.46 t ha^{-1} of straw yield.

The positive effect on yield and yield parameters due to combined use of cogen ash, chemical fertilizers and FYM might be due to improvement in the availability of plant nutrients and balanced supply of nutrients through organic manures and inorganic fertilizers that might have induced the cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency, increased nutrient absorption by increased root activity thus resulting in better growth and development of crop, increased fertile panicles, number of grains per panicle and test weight and this led to increased grain and straw yield of crop (Das *et al*. 2013) [11], which might be also due to favorable soil condition created by application of organic matter along with chemical fertilizers.

Table 3: Effect of varied levels of cogen ash on grain and straw yield (t ha^{-1}) of paddy

Treatments	Grain yield	Straw yield
T_1 : RDF + RD of FYM	4.27±0.33	4.95±0.41
T_2 RDF + 2.5 t ha^{-1} CGA	3.93±0.18	4.46±0.21
T_3 RDF + 5.0 t ha^{-1} CGA	4.44±0.12	5.04±0.14
T_4 RDF + 10.0 t ha^{-1} CGA	5.04±0.07	5.71±0.06
T_5 RDF + 15 t ha^{-1} CGA	5.39±0.14	6.16±0.02
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	5.48±0.07	6.08±0.24
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	5.73±0.22	6.22±0.08
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	6.46±0.22	6.66±0.20
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	6.67±0.13	6.99±0.18
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	5.37±0.14	5.83±0.05
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	5.67±0.29	6.07±0.27
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	5.92±0.20	6.26±0.20
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	6.03±0.20	6.34±0.20
S. Em±	0.077	0.099
C. D. at 5%	0.225	0.29

Effect of varied levels of cogen ash on macro nutrient content of paddy grain and straw

The concentration of nitrogen, phosphorus and potassium was found to be higher in paddy grain due to application of cogen ash at higher rates. Data indicated that nitrogen, phosphorus and potassium concentration in paddy grain was significantly higher (1.42%, 0.39%, 0.60%, respectively) in T_9 which received RDF + RD FYM+ 15.0 t ha^{-1} cogen ash compared to all the other treatments (Table 4). This was followed by T_{13} for grain nitrogen concentration. T_{13} was on par with T_9 in phosphorus and potassium concentration of grain. Nitrogen, phosphorus and potassium concentration in paddy straw (1.16, 0.26 and 1.87%, respectively) was significantly higher in the same treatment. However, lower nitrogen, phosphorus and potassium concentration was noticed in treatment T_2 receiving RDF + 2.5 t ha^{-1} of cogen ash (1.17%, 0.23 and 0.44%, respectively for grain and 0.86, 0.15 and 1.24%, respectively for straw). This may be due to decrease in the mineralisation of nutrients from cogen ash and their availability to the crop in the absence of FYM.

Increased P concentration in rice seedlings was also observed by Sistani *et al*. (1999) [12], upon application of rice hull ash. The probable root growth, supply of nutrient and conducive physical environment created on account of addition of fly ash in combination with FYM to the soil would have facilitated better absorption of N, P and K.

Concentration of calcium, magnesium and sulphur in paddy grain and straw at harvest varied significantly due to cogen ash treatments (Table 5).

Higher concentration of calcium, magnesium and sulphur in paddy grain and straw was recorded in treatment T_9 receiving RDF + RD FYM + 15.0 t ha^{-1} cogen ash (0.21, 0.15 and 0.39%, respectively for grain and 0.34, 0.13 and 0.24%, respectively for straw). Furr *et al*. (1976) [13] found higher concentrations of K, Ca and Mg in edible portions of millets and vegetables grown in pots upon application of fly ash compared to control. The material applied to soil *i.e.* the cogen ash, rich in nutrients especially K and Ca (1.19 and 0.79%). The increase in the concentration of Ca and Mg in paddy grain and straw with the increased rate of cogen ash application may be because of alkaline nature of the ash and sufficient concentration of Ca and Mg present in the material. Similar results were observed by Vishwanath (2004) [14] and the synergistic effect of P on Ca and Mg was reported by Mongia *et al*. (1998) [15].

Table 4: Effect of varied levels of cogen ash on nitrogen, phosphorus and potassium content (%) of paddy grain and straw

	Grain			Straw		
Treatments	**N**	**P**	**K**	**N**	**P**	**K**
T_1 : RDF + RD of FYM	1.33±0.05	0.32±0.04	0.57±0.06	1.03±0.02	0.16±0.01	1.62±0.05
T_2 RDF + 2.5 t ha^{-1} CGA	1.17±0.03	0.23±0.17	0.44±0.02	0.86±0.01	0.15±0.02	1.24±0.013
T_3 RDF + 5.0 t ha^{-1} CGA	1.19±0.02	0.28±0.02	0.47±0.05	0.90±0.02	0.16±0.05	1.26±0.03
T_4 RDF + 10.0 t ha^{-1} CGA	1.27±0.1	0.34±0.03	0.52±0.04	0.99±0.02	0.17±0.04	1.43±0.11
T_5 RDF + 15 t ha^{-1} CGA	1.33±0.03	0.37±0.11	0.54±0.04	1.01±0.03	0.19±0.03	1.64±0.07
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	1.20±0.06	0.28±0.07	0.54±0.05	0.97±0.01	0.18±0.01	1.59±0.24
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	1.27±0.03	0.36±0.03	0.55±0.03	1.05±0.03	0.19±0.01	1.65±0.02
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	1.33±0.04	0.36±0.01	0.60±0.02	1.09±0.03	0.22±0.03	1.75±0.27
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	1.42±0.06	0.39±0.02	0.60±0.01	1.16±0.02	0.26±0.05	1.87±0.04
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	1.24±0.03	0.33±0.01	0.53±0.02	0.93±0.04	0.15±0.02	1.59±0.17
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	1.26±0.05	0.34±0.01	0.54±0.06	0.95±0.01	0.17±0.03	1.61±0.19
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	1.31±0.01	0.35±0.02	0.58±0.05	1.02±0.01	0.18±0.03	1.71±0.24
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	1.34±0.09	0.39±0.04	0.60±0.01	1.11±0.03	0.25±0.01	1.77±0.09
S. Em±	0.03	0.04	0.017	0.01	0.02	0.09
C. D. at 5%	0.09	0.12	0.05	0.03	0.05	0.26

Table 5: Effect of varied levels of cogen ash on calcium, magnesium and sulphur content (%) of paddy grain and straw

Treatments	Grain			Straw		
	Ca	**Mg**	**S**	**Ca**	**Mg**	**S**
T_1 : RDF + RD of FYM	0.13±0.01	0.07±0.01	0.38±0.02	0.30±0.08	0.09±0.01	0.16±0.01
T_2 RDF + 2.5 t ha^{-1} CGA	0.11±0.01	0.04±0.01	0.23±0.11	0.22±0.01	0.06±0.01	0.12±0.01
T_3 RDF + 5.0 t ha^{-1} CGA	0.12±0.01	0.06±0.01	0.27±0.09	0.30±0.02	0.06±0.02	0.13±0.02
T_4 RDF + 10.0 t ha^{-1} CGA	0.14±0.02	0.08±0.01	0.29±0.04	0.30±0.01	0.07±0.01	0.14±0.01
T_5 RDF + 15 t ha^{-1} CGA	0.15±0.02	0.10±0.03	0.32±0.02	0.29±0.01	0.08±0.01	0.18±0.04
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	0.16±0.02	0.11±0.01	0.33±0.01	0.27±0.05	0.10±0.03	0.16±0.03
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	0.18±0.02	0.12±0.02	0.34±0.05	0.30±0.03	0.10±0.02	0.15±0.02
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	0.19±0.02	0.13±0.02	0.37±0.04	0.33±0.09	0.12±0.01	0.22±0.06
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	0.21±0.02	0.15±0.02	0.39±0.02	0.34±0.04	0.13±0.02	0.24±0.05
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	0.14±0.02	0.10±0.01	0.27±0.03	0.27±0.05	0.07±0.01	0.16±0.07
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	0.15±0.01	0.12±0.01	0.29±0.08	0.30±0.08	0.10±0.02	0.17±0.02
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	0.16±0.02	0.12±0.02	0.35±0.03	0.32±0.06	0.10±0.01	0.17±0.04
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	0.17±0.02	0.12±0.01	0.37±0.02	0.33±0.05	0.11±0.01	0.21±0.06
S. Em±	0.001	0.004	0.03	0.03	0.004	0.02
C. D. at 5%	0.005	0.011	0.09	0.06	0.01	0.05

Effect of varied levels of cogen ash on micronutrients and heavy metal content of paddy grain and straw

The concentrations of all the micronutrients in paddy grain (Fe, Mn, Cu, Zn and B) were significantly higher in treatment T_9 that received RDF + RD FYM+ 15.0 t ha^{-1} cogen ash (640.23, 126.99, 16.68, 23.05 and 12.67 mg kg^{-1}, respectively) as compared to all the other treatments (Fig 1 and 2). Significantly higher concentration of Fe, Mn, Cu, Zn and B (874.01, 268.69, 20.39, 39.08 and 10.00 mg kg^{-1}, respectively) in paddy straw was recorded in the same treatment. However, lower Fe, Zn and B content (155.75, 12.75 and 7.80 mg kg^{-1}, respectively) in grain was recorded in treatment T_2. Lower Mn and Cu content (58.67 and 9.00 mg kg^{-1}, respectively) was recorded in T_1. Heavy metal content *viz*. Pb, Ni, Cd and Cr were below detection limits in the paddy grain samples. The findings were similar with that of Furr *et al*. (1976) [13].

Further, lower concentration of iron manganese and copper (354.07, 152.62 5.83 mg kg^{-1}, respectively) in paddy straw were observed in the treatment T_1 receiving RDF + RD FYM. Treatment T_2 recorded significantly lower concentration of zinc and boron (17.0, 5.30 mg kg^{-1}, respectively) (Fig 1and 2).

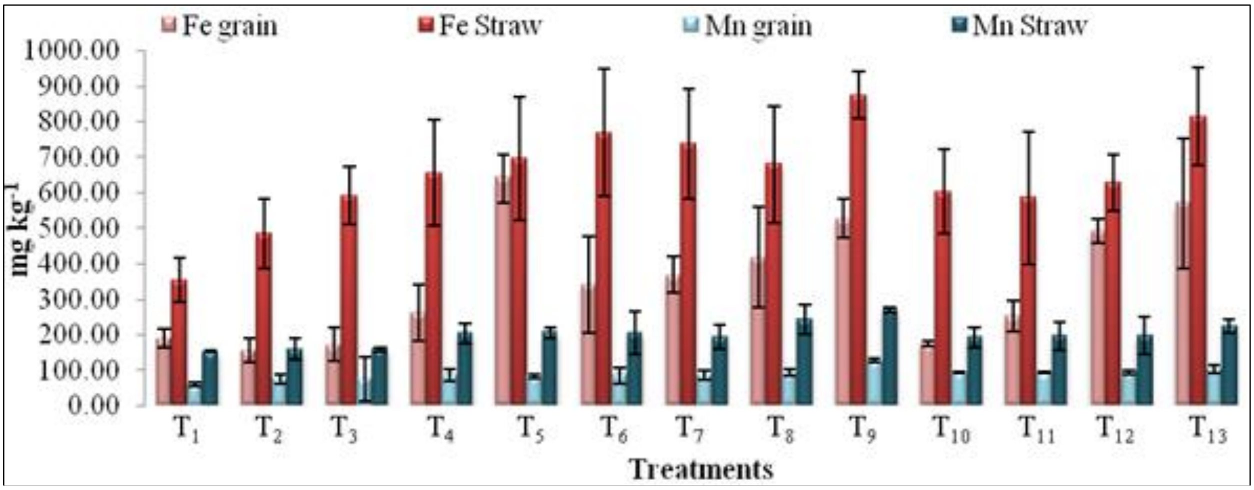

Fig 1: Effect of varied levels of cogen ash on iron and manganese content (ppm) of paddy grain and straw

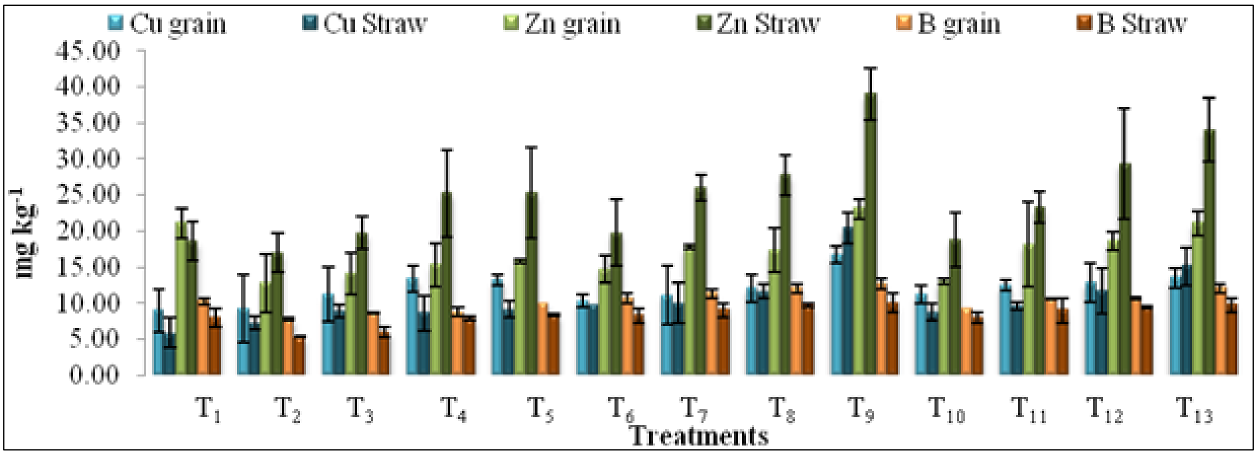

Fig 2: Effect of varied levels of cogen ash on copper, zinc and boron content (ppm) of paddy grain and straw

Effect of varied levels of cogen ash on macro nutrient uptake by paddy grain and straw

The nitrogen, phosphorus and potassium uptake by paddy increased with the levels of cogen ash. Significantly higher nitrogen, phosphorus and potassium uptake by paddy grain and straw was recorded in the treatment with RDF + RD FYM + 15.0 t ha^{-1} cogen ash (T_9) (94.94, 26.21, 39.56 kg ha^{-1} and 81.12, 15.94, 130.83 kg ha^{-1} respectively) (Table 6). Favourable interaction exists between N and P and this might have increased the uptake of N by the crop (Singh *et al*. 1998) [16].

However, lower nitrogen, phosphorus and potassium uptake by paddy grain was recorded in the treatment T_2 (46.06, 9.20 and 17.41 kg ha^{-1} kg ha^{-1}, respectively). Lopez *et al*. (2009) [17] found that high P uptake may be due to a relatively high solubility of P in sugarcane ash. Similar observation was reported by Talashilkar and Chavan (1996) [18] who found an increase in rice grain yield as well as P uptake with the application of rice hull ash. However, lower uptake of nitrogen, phosphorus and potassium by straw (38.25, 6.88 and 55.69 kg ha^{-1}, respectively) was recorded in the treatment T_2.

Uptake of calcium, magnesium and sulphur by paddy grain was found to be higher in the treatment T_9 receiving RDF + RD FYM + 15.0 t ha^{-1}cogen ash (14.02, 10.04, 25.96 kg ha^{-1}, respectively). This was followed by treatment T_8 receiving RDF + RD FYM+ 10.0 t ha^{-1} cogen ash (12.31, 8.40, 24.18 kg ha^{-1}, respectively) However, lower uptake of calcium, magnesium and sulphur (4.48, 1.59, 9.13 kg ha^{-1}, respectively) was recorded in the treatment T_2 (RDF+ 2.5 t ha^{-1} cogen ash) (Table 7).

Treatment T_9 receiving RDF+ RD FYM + 15.0 t ha^{-1}cogen ash recorded higher uptake of calcium, magnesium and sulphur by paddy straw (23.50, 9.08, 17.29 kg ha^{-1}, respectively) (Table 7). However, lower uptake of calcium, magnesium and sulphur (9.82, 2.53 and 5.46 kg ha^{-1}) was recorded in the treatment T_2. Treatments T_1 and T_2 were on par. The calcium and magnesium replaces the sodium on the exchange complex which in turn improves the chemical properties of soil for better uptake of plant nutrients.

Increased content of P, K, Ca, Mg and S in soils treated with recommended dose of fertilizers + recommended dose of FYM + 15.0 t ha^{-1}cogen ash resulted in higher concentration in both paddy grain and straw and in turn better growth of crop and higher yields has resulted in higher nutrient uptake. Yankaraddi Honnalli (2008) [19] also gave similar reasons for higher uptake of nutrients.

Table 6: Effect of varied levels of cogen ash on nitrogen, phosphorus and potassium uptake (kg ha^{-1}) by paddy grain and straw

Treatments	Grain			Straw		
	N	P	K	N	P	K
T_1 : RDF + RD of FYM	56.67±5.98	13.66±2.58	24.22±3.41	50.84±4.63	8.17±1.93	80.31±5.36
T_2 RDF + 2.5 t ha^{-1} CGA	46.06±3.02	9.20±7.31	17.41±0.21	38.25±2.50	6.88±1.91	55.69±8.54
T_3 RDF + 5.0 t ha^{-1} CGA	53.02±1.34	12.41±1.11	20.89±2.31	45.41±1.98	8.73±4.26	63.53±2.74

T_4 RDF + 10.0 t ha^{-1} CGA	64.01±5.15	17.37±1.53	26.19±2.21	56.37±0.32	9.66±0.72	81.96±6.33
T_5 RDF + 15 t ha^{-1} CGA	71.48±0.95	20.09±5.63	29.07±1.51	62.37±0.82	11.74±0.55	101.11±4.13
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	65.56±3.79	15.57±3.83	29.41±2.79	58.94±1.37	9.29±0.82	96.86±4.14
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	72.47±1.13	20.73±2.21	31.50±2.32	65.50±2.12	11.09±0.94	102.37±2.38
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	86.16±3.24	23.55±0.84	38.82±3.02	72.44±3.72	13.28±1.60	116.69±8.75
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	94.94±5.77	26.21±1.96	39.56±0.31	81.12±3.19	15.94±0.97	130.83±5.86
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	66.42±1.96	17.60±1.10	28.27±0.40	54.06±1.44	9.32±1.47	92.63±10.24
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	71.31±6.31	19.52±0.95	30.82±3.73	57.69±2.18	9.83±2.04	97.46±8.89
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	77.53±2.06	20.73±0.70	34.38±3.75	63.82±2.48	10.60±2.07	106.64±6.48
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	80.75±7.59	23.51±1.85	36.22±1.77	70.35±3.60	15.02±0.98	112.55±9.38
S. Em±	0.03	0.04	0.02	1.05	1.06	5.61
C. D. at 5%	0.09	0.11	0.05	3.06	4.00	16.39

Table 7: Effect of varied levels of cogen ash on calcium, magnesium and sulphur uptake (kg ha^{-1}) by paddy grain and straw

Treatments	Grain			Straw		
	Ca	**Mg**	**S**	**Ca**	**Mg**	**S**
T_1 : RDF + RD of FYM	5.58±1.09	2.99±0.63	16.03±0.59	14.94±4.45	4.11±0.18	7.92±0.42
T_2 RDF + 2.5 t ha^{-1} CGA	4.48±0.71	1.59±0.30	9.13±4.26	9.82±0.47	2.53±0.27	5.64±0.88
T_3 RDF + 5.0 t ha^{-1} CGA	5.44±0.77	2.67±0.43	12.15±3.78	15.13±0.42	3.02±0.46	6.42±0.67
T_4 RDF + 10.0 t ha^{-1} CGA	6.82±0.82	4.03±0.56	14.59±2.20	17.14±0.17	4.00±0.61	8.01±1.26
T_5 RDF + 15 t ha^{-1} CGA	7.81±0.81	5.32±1.39	17.12±1.37	18.06±0.75	4.72±0.36	11.04±2.72
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	8.74±0.97	6.02±0.75	17.96±0.26	16.65±3.16	6.08±0.24	9.32±1.58
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	10.35±1.51	6.89±1.08	19.30±2.81	18.65±0.24	6.42±0.94	9.29±0.87
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	12.31±1.81	8.40±1.32	24.18±2.03	21.71±5.95	7.98±0.47	14.71±4.01
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	14.02±1.90	10.04±1.43	25.96±2.17	23.50±2.37	9.08±0.57	17.29±4.64
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	7.60±1.05	5.51±0.81	14.45±1.82	15.94±2.63	4.28±0.36	9.62±4.08
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	8.50±1.39	6.53±0.61	16.14±3.86	18.12±4.39	5.87±0.93	10.49±1.82
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	9.33±1.29	6.89±0.58	20.82±0.84	20.29±0.73	6.46±0.16	10.92±2.74
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	10.27±1.49	7.23±0.69	22.55±1.88	20.70±3.03	6.96±0.41	13.50±4.07
S. Em±	0.24	0.22	1.45	1.64	0.21	1.16
C. D. at 5%	0.69	0.65	4.42	4.77	0.62	3.40

Effect of varied levels of cogen ash on micro nutrient uptake by paddy grain and straw

The amount of micronutrients (Fe, Mn, Cu, Zn and B) taken up by paddy grain and straw was higher compared to all the other treatments in treatment T_9 on application of RDF + RD FYM + 15.0 t ha^{-1} cogen ash (3500.38, 846.40, 111.28, 154.22, 84.42 g ha^{-1} and 6114.59, 1878.07, 142.74, 272.94, 69.81 g ha^{-1}, respectively) (Fig 3 and 4).

However, lower uptake of Fe, Cu, Zn and B (611.13, 36.33, 50.35 and 20.64 g ha^{-1}, respectively) was observed in the treatment T_2. Lower Mn content in paddy grain (249.86 g ha^{-1}) was recorded with T_1.

However, lower uptake of Fe, Cu in paddy straw (1763.27, 28.71 g ha^{-1}) was recorded in the treatment T_1, lower Mn, Zn and B uptake was observed in T_2 (703.40, 75.60 and 23.65 g ha^{-1}).

In the present study, the crop exhibited maximum uptake of nutrients in the treatment that received recommended dose of NPK + recommended dose of FYM + 15 t ha^{-1}cogen ash in both the plots. Nutrient uptake is influenced by productive capacity of soil, nutrient concentration of plant and plant biomass. As the crop yields are higher in the treatments applied with higher rates of cogen ash along with FYM and chemical fertilizers, it is obvious that uptake was also higher. The cogen ash treated plots along with FYM and chemical fertilizers nutrients that promoted greater microbial and enzyme activities in soil which in turn facilitated higher rate of mineralization leading to enhanced nutrients level in soil. The application might have improved the soil physical conditions, favouring better root and shoot growth and nutrient uptake.

These findings fall in line with those of Rautaray *et al*. (2003) [20] who reported that combined application of fly ash and chemical fertilizers resulted in higher uptake of P, Ca and Zn than application of only chemical fertilizers. Uptake of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu was higher in integrated nutrient treatments involving fly ash at 10 Mg ha^{-1}, organic wastes and chemical fertilizers than application of only chemical fertilizers. The higher nutrient uptake under these treatments was responsible for the higher yield of rice.

There was no uptake of heavy metals by paddy grain and straw. It is apparent from the study of Rautaray *et al*. (2003) [20] that use of organic wastes and chemical fertilizers was effective in lowering Cd and Ni in rice grain and straw as compared to chemical fertilizers alone.

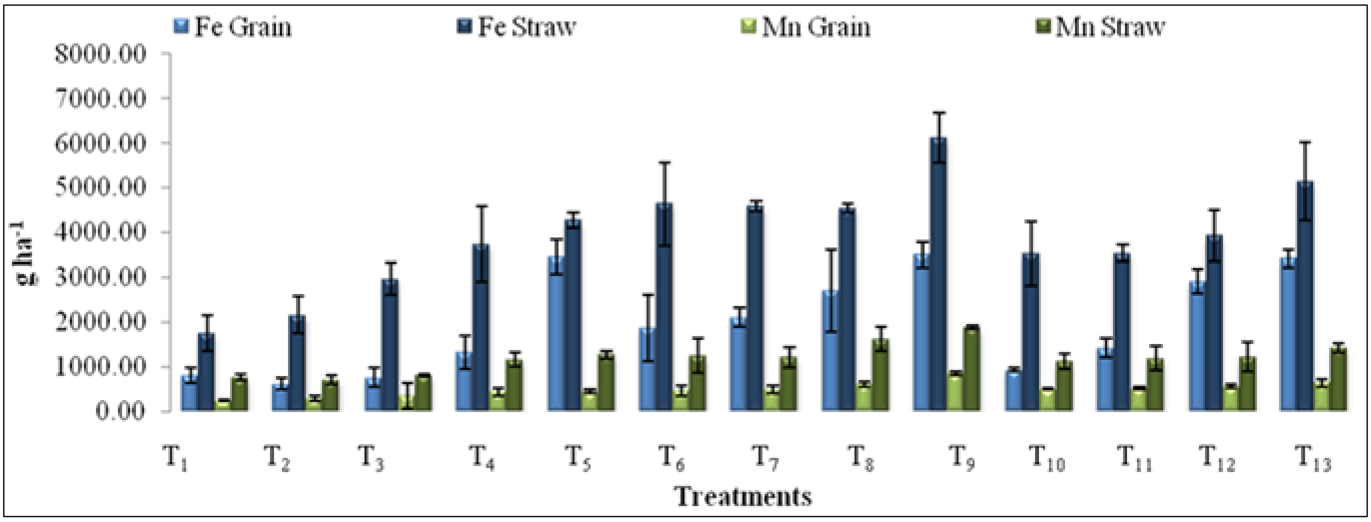

Fig 3: Effect of varied levels of cogen ash on iron and manganese uptake (kg ha^{-1}) by paddy grain and straw

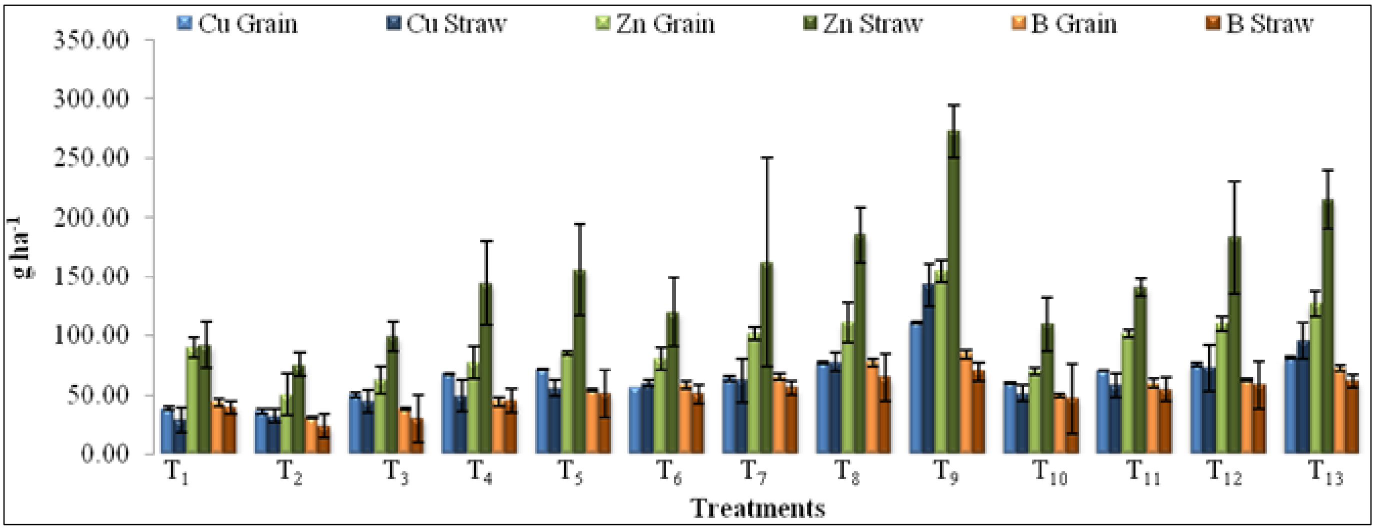

Fig 4: Effect of varied levels of cogen ash on copper, zinc and boron uptake (kg ha^{-1}) by paddy grain and straw

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