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Influence of Cogen Ash Application on Soil Biology Under Paddy Cultivation

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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 soil properties, growth and yield of paddy. The experiment was conducted at research block of Sri Chamundeshwari Sugars Ltd., K.M. Doddi, Mandya during kharif 2014 with 13 treatments replicated thrice using RCBD. The cogen ash was applied at different levels along with chemical fertilizers to know its influence on soil biological properties. The bacteria and actinomycetes population were found to be significantly higher in the treatment T_9 which received RDF + RD of FYM + 15.0 t ha^{-1} CGA at 45, 90 DAT and at harvest. Lower was recorded in the treatment T_2 that received RDF + 2.5 t ha^{-1} CGA. Fungal population was higher in the treatment T_9 at 45 and 90 DAT whereas, treatment T_6 recorded highest value at the harvest of the crop. Significantly higher urease and dehydrogenase activity was observed in the treatment T_9 which received RDF + RD of FYM + 15.0 t ha^{-1} CGA at 45 and 90 DAT. However at harvest, urease activity was higher in the treatment T_6 that received RDF + RD of FYM + 12.5 t ha^{-1} CGA and dehydrogenase activity was higher in the treatment T_9. Lower urease and dehydrogenase activity was observed in the treatment T_2 that received RDF + 2.5 t ha^{-1} CGA.

Keywords- Cogen ash, enzyme activity, microbial population, soil biology

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INTRODUCTION

The sugar industry is India's second largest agro-based industry, next to cotton textiles, producing the larger amount of sugar in the world. Bagasse is an important agro-industrial waste, a by- product that is generally used as fuel in sugar industry. The use of bagasse in the boiler house for captive power and steam generation is an existing practice in sugar mills. Co-generation is the concept of producing two forms of energy from one fuel source. One of the forms of energy is heat and the other may be electrical or mechanical energy. The ash produced during this process is the cogen ash. Disposal of cogen ash has become a serious problem and large quantities of this ash are regularly disposed into rivers, ponds and open spaces thereby endangering the fragile ecosystems. 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. Along with chemical fertilizers, repeated application of organic manures is often recommended in order to maintain soil productivity. Cogen ash can be used as a soil amendment to improve the physical and chemical properties of soil, as a result it often provide a reasonably economic means of recycling this waste in an eco-friendly manner as it contains plant nutrients in appreciable amounts. It 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 raise the nutrient use efficiency of the crops. Ash can be effectively used in agriculture for crops such as paddy and others, for improvement of soil biology by providing nutrients to soil microbes and enhancing their enzymatic activities and also as amendment which otherwise may create nuisance and pollute the environment and may occupy vast areas of productive land given the present mode of disposal. Keeping these points in view, the investigation to study the effect of varied levels of cogen ash on physical, chemical and biological properties of soil was carried out.

MATERIAL AND METHODS

A field experiment was conducted to study the effect of cogen ash on soil biological properties under paddy cultivation at the research block of M/s Sri Chamundeshwari Sugars Ltd., Mandya district located in Southern Dry Zone of Karnataka during the year 2014. Composite soil samples were collected from 0-15 cm depth of soil from the experimental plot before taking up the crop and analyzed for physical, chemical and biological properties. Initial properties of the soil are given in Table 1.

Table 1: Initial soil properties of the experimental plot

Parameters	**Values**	**Reference**
Texture	Sandy clay	(1)
pH	7.84	(2)
Electrical conductivity (dS m^{-1})	0.48	(2)
Organic carbon (%)	0.83	(3)
Available Nitrogen (kg ha^{-1})	545.63	(4)
Available Phosphorus (kg ha^{-1})	48.34	(2)
Available Potassium (kg ha^{-1})	332.90	(2)
Exchangeable Calcium [c mol (p^+) kg^{-1}]	15.80	(2)
Exchangeable Magnesium [c mol (p^+) kg^{-1}]	3.70	(2)
Available Sulphur (mg kg^{-1})	9.72	(5)
DTPA-Iron (mg kg^{-1})	58.27	(6)
DTPA-Copper (mg kg^{-1})	6.38	(6)
DTPA-Manganese (mg kg^{-1})	4.70	(6)
DTPA-Zinc (mg kg^{-1})	1.60	(6)
Biological properties		
Urease activity (µg NH4 N g^{-1} soil h^{-1})	10.8	(7)
Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})	17.56	(8)
Microbial population		
Bacteria population (X 10^6cfu g^{-1} soil)	4.5	(8)
Fungi population (X 10^3cfu g^{-1} soil)	6.81	(8)
Actinomycetes population (X 10^3cfu g^{-1} soil)	2.56	(8)

EXPERIMENTAL DETAILS

Paddy was taken up as test crop with thirteen treatments replicated thrice laid out with RCBD design. Cogen ash was applied at different rate along with chemical fertilizers (the recommended dose of chemical fertilizers for paddy-:100:50:50 kg N: P_2O_5 : K_2O ha^{-1}), and FYM was applied at 10 t ha^{-1}

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. RD- recommended dose
CGA- cogen ash. FYM- farm yard manure.

Calculated quantity of cogen ash was mixed with FYM and broadcasted uniformly to each plot and incorporated into soil after the excess water was drained out a fortnight earlier to transplanting.

Recommended dose of fertilizers were applied to the plots just prior to transplanting. After transplanting, 2.5 cm depth of standing water was maintained in the field for the first 10 days, then gradually increased to 5 cm and was maintained throughout the crop growth period. The crop was irrigated with fresh water.

BIOLOGICAL PROPERTIES OF SOIL

The changes in the biological properties of soil *viz.* Bacteria, Fungi and Actinomycetes population, urease and dehydrogenase activity due to application of cogen ash were studied for the samples collected at different intervals (45 DAT, 90 DAT and at harvest) during the crop growth period following the standard procedures detailed below.

ESTIMATION OF SOIL MICROBIAL POPULATION

The general microbial population in different treatments of the experimental soil was estimated at different intervals of crop growth by serial dilution plate count technique. Soil samples from each treatment were collected separately and used for microbial population estimation following the procedure detailed below:

Ten grams of homogenized soil (treatment wise) was mixed in 90 ml sterile water blank to give 10^{-1} dilution. Subsequent dilutions upto 10^{-5} were made by transferring serially 1 ml of the dilution to 9 ml sterile water blanks. The populations of bacteria, fungi and actinomycetes were estimated by transferring 1ml of 10^3, 10^3 and 10^5 dilutions, respectively to a sterile petridish and approximately 20 ml of media *viz.*, Soil Extract Agar, Martins Rose Bengal Agar and Kusters Agar for soil bacteria, fungi and actinomycetes, respectively was poured into the plates. The plates were rotated twice in clockwise and anticlockwise direction for uniform mixing of the inoculum. After solidification of the media, plates were kept for incubation in an inverted position at 30 ± 1^0C for a week time and emerged colonies were counted (Tate, 1995).

ESTIMATION OF UREASE ACTIVITY:

The urease activity was determined by following the method outlined by Watts and crisp [7]. Two g of soil was taken in a 50 ml Erlenmeyer flask and treated with 0.2 ml of toluene and 9 ml of THAM buffer and flasks were swirled for few seconds to mix the contents. Then, 1ml of 0.2 M urea was added and the flasks were swirled for few seconds and placed in an incubator at 37^0C. After 2 h, the stoppers were removed and approximately 35 ml of KCl-Ag_2SO_4 solution was added. Then, the flasks were swirled again and allowed to stand until the contents have cooled to the room temperature. The volume was then made up to 50 ml by the addition of KCl-Ag_2SO_4. The NH_4-Nwas determined by steam distillation. Controls were performed in the same way, but 1ml of 0.2 M urea was added after the addition of 35 ml of KCl-Ag_2SO_4 solution.

ESTIMATION OF DEHYDROGENASE ACTIVITY:

The dehydrogenase activity was determined by the procedure as given by Casida *et al*. [8]. Two grams of air-dried soil (<2mm) was thoroughly mixed with 0.2 g of $CaCO_3$. To each sample tube 1ml of 3% aqueous solution of 2, 3, 5-triphenyl tetrazolium chloride (TTC) and 2.5 ml of distilled water were added. The contents of each tube were mixed with a glass rod and the tubes were stoppered and incubated at 37^0C. After 24 hours, the stopper was removed and 10 ml of methanol was added to the tube and shaken for 1min. Then, the suspension was filtered through a glass funnel plugged with absorbent cotton, into a 100 ml volumetric flask. The soil in the tube was washed repeatedly till the filtrate coming from the tip of the funnel was colorless. Then, the volume was made to 100 ml with methanol. The intensity of reddish color was read using spectrophotometer at a wavelength of 485 nm with methanol as the blank. The amount of TPF (2, 3, 5-triphenyl formazan) produced was calculated using a standard graph prepared by using different concentrations of TPF standards. For this, 10 ml of the TPF standard solution containing 1000 µg / ml was diluted to 100 ml with methanol (100 µg of TPF/ml). Aliquots of 5, 10, 15, and 20 ml were pipetted into 100 ml volumetric flasks (500, 1000, 1500 and 2000 µg of TPF/100ml). The volume was made to 100 ml with methanol and mixed thoroughly. Then, the intensity of red color of TPF was measured as described earlier.

STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

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 (9). 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

The analysis of the samples revealed that the cogen ash was alkaline (pH 8.43). Electrical conductivity was low (0.124 dS m^{-1}) with the total carbon content of 1.58%.The ash has trace quantity of nitrogen

(0.08 %),the total P, K, Na, Ca, Mg and sulphur contents were 0.82 %, 1.19 %, 0.09 %, 0.79 %, 0.31 % and 142.15 mg kg^{-1}, respectively. The total Fe, Mn, Cu, Zn and B contents were 10321.3, 353.0, 69.09, 135.44 and 174.93 mg kg^{-1}. It also contained some quantity of total heavy metals like Cr and Ni to an extent of 286.52 and 74.77 mg kg^{-1}, respectively, but Pb and Cd were not detected in the cogen ash samples.

INFLUENCE OF COGEN ASH APPLICATION ON SOIL BIOLOGICAL PROPERTIES

The effect of varied levels of cogen ash on soil microbial population and enzymes activities of soil during crop growth period and at harvest are presented in the Tables 2 to 6.

Influence of cogen ash application on soil microbial population

There was a significant difference in soil bacterial population at different days after paddy transplantation (Table 2). Bacterial population was higher (28.07, 28.63, 18.20 X 10^6 cfu g^{-1} soil at 45 DAT, 90 DAT and at harvest, respectively) in treatment T_9 which received RDF + 100 % RD FYM + 15.0 t ha^{-1}cogen ash and lower bacterial population (4.87, 6.60, 3.60 X 10^6 cfu g^{-1} soil at 45 DAT, 90 DAT and at harvest, respectively) was recorded in the treatment T_2 applied with RDF + 2.5 t ha^{-1}cogen ash.

Fungal population differed significantly at different days after paddy transplantation on application of cogen ash (Table 3). Treatment T_9 which received RDF + 100 % RD FYM + 15.0 t ha^{-1} cogen ash showed significantly higher fungal population (26.67, 31.33X 10^3 cfu g^{-1} soil at 45 and 90 DAT, respectively), whereas at harvest, treatment T_1 (RDF + RD FYM) recorded higher fungal population (12.0 X 10^3 cfu g^{-1} soil).

Actinomycetes population varied significantly with the application of cogen ash and higher population (14.5, 14.17 and 11.17 X 10^3 cfug^{-1} soil at 45 DAT, 90 DAT and at harvest, respectively)was recorded in the treatment T_9 which received RDF + 100 % RD FYM + 15.0 t ha^{-1}cogen ash and lower population(1.67, 3.33 and 1.17 X 10^3 cfug^{-1} soil at 45 DAT, 90 DAT and at harvest, respectively)was in the treatment T_2which received RDF + 2.5 t ha^{-1}cogen ash (Table 4).

The bacterial and fungal population showed an increase with increase in rates of cogen ash application and the increase was higher in the treatments of higher rates of cogen ash combined with 100 % RD FYM followed by 50 % RD FYM.

The microbial population in soil at all the stages of crop growth increased with increase in the rates of cogen ash and further increased with application of RD FYM followed by 50 % RD FYM as both are good source of nutrients and are organic in nature, that enhances growth and activity of micro organisms. Similar trend of results were reported by Rajakumar (10) and Pitchel and Hayes (11) on application of fly ash. Inhibition of microbes on application of fly ash containing traces of heavy metals even at very higher rates was less in sandy loam soils than in sandy soil (12).

The results are in accordance with Rautaray *et al*. (13) and Dee *et al*. (14) who found that organic matter also contributed nutrients in addition to N, P and K. Furthermore, improved soil reaction, due to addition of alkaline fly ash, and supply of substrates and nutrients through organic wastes and chemical fertilizers might have stimulated microbial activity (15; 13) leading to higher nutrient release and availability to rice plants.

Table 2: Influence of cogen ash application on soil bacterial population (X10^6 cfug^{-1} soil)

	45 DAT	90 DAT	At harvest
T_1 : RDF + RD of FYM	8.00	9.00	3.63
T_2 RDF + 2.5 t ha^{-1} CGA	4.87	6.60	3.60
T_3 RDF + 5.0 t ha^{-1} CGA	5.00	7.10	3.90
T_4 RDF + 10.0 t ha^{-1} CGA	8.93	7.70	5.87
T_5 RDF + 15 t ha^{-1} CGA	9.97	11.23	6.83
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	7.00	9.97	7.83
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	10.57	12.77	8.77
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	18.90	20.33	16.97
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	28.07	28.63	18.20
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	5.40	9.53	6.57
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	10.17	12.00	8.40
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	14.37	15.20	9.10
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	14.50	16.33	11.47
S. Em±	**1.19**	**0.89**	**0.78**
C. D. at 5%	**3.48**	**2.6**	**2.26**

Note:
RDF-recommended dose of fertilizers. RD- recommended dose CGA- cogen ash. FYM-farm yard manure

Table 3: Influence of cogen ash application on soil fungal population (X10^6 cfug^{-1} soil)

Treatments	45 DAT	90 DAT	At harvest
T_1 : RDF + RD of FYM	5.00	6.33	12.00
T_2 RDF + 2.5 t ha^{-1} CGA	4.67	5.00	10.00
T_3 RDF + 5.0 t ha^{-1} CGA	4.00	5.67	9.00
T_4 RDF + 10.0 t ha^{-1} CGA	2.33	6.00	3.67
T_5 RDF + 15 t ha^{-1} CGA	2.33	12.33	2.00
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	10.33	9.67	10.33
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	14.67	16.67	9.33
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	22.33	25.33	4.67
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	26.67	31.33	2.33
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	6.00	7.67	8.33
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	12.00	14.67	6.33
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	15.00	17.33	4.00
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	17.33	20.00	2.00
S. Em±	**1.25**	**1.44**	**1.07**
C. D. at 5%	**3.65**	**4.2**	**3.12**

Note:
RDF-recommended dose of fertilizers.
RD- recommended dose
CGA- cogen ash.
FYM-farm yard manure

Table 4: Influence of cogen ash application on soil actinomycetes population (X10^6 cfug^{-1} soil)

Treatments	45 DAT	90 DAT	At harvest
T_1 : RDF + RD of FYM	4.33	2.67	1.67
T_2 RDF + 2.5 t ha^{-1} CGA	1.67	2.00	1.00
T_3 RDF + 5.0 t ha^{-1} CGA	2.33	2.33	1.33
T_4 RDF + 10.0 t ha^{-1} CGA	4.33	2.67	1.67
T_5 RDF + 15 t ha^{-1} CGA	5.00	5.33	3.00
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	3.67	3.33	2.67
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	7.00	7.33	4.33
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	8.67	11.00	6.67
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	11.33	12.33	8.33
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	2.33	3.33	2.33
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	6.00	7.00	3.67
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	8.33	7.67	5.67
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	8.33	10.33	6.33
S. Em±	**0.61**	**0.85**	**0.48**
C. D. at 5%	**1.78**	**2.48**	**1.40**

Note:
RDF-recommended dose of fertilizers.
RD- recommended dose
CGA- cogen ash.
FYM-farm yard manure

Influence of cogen ash application on soil enzymes activities

The changes in the urease and dehydrogenase activity of soil at different days after paddy transplantation due to application of varied levels of cogen ash are presented in Table 5 and 6.

There was a significant difference in the enzyme activities among the treatments. Significantly higher urease activity (30.54 µg NH_4-N g^{-1} soil h^{-1} and32.47 µg NH_4-N g^{-1} soil h^{-1}at 45DAT and 90 DAT) was observed in the treatment T_9which received RDF + 100 % RD FYM + 15.0 t ha^{-1} cogen ash. At harvest higher urease activity was observed in the treatment T_6 which received RDF + 100 % RD FYM + 2.50 t ha^{-1} cogen compared to other treatments (25.37 µg NH_4-N g^{-1} soil h^{-1}). Lower urease activity (19.0, 21.49µg NH_4-N g^{-1} soil h^{-1} at 45DAT and 90 DAT, respectively) was observed in the treatment T_2 which received RDF + 2.5 t ha^{-1}cogen ash, at harvest the same treatment recorded lower urease activity.

There exists significant variation in the urease and dehydrogenase activity of soil at different days after paddy transplantation due to cogen ash application. There was an increase in urease and dehydrogenase activity of soil due to cogen ash application with RD FYM and RDF compared to without FYM application.

The activities were higher at 90 DAT, followed by 45 DAT and at harvest in all the treatments. This increase in soil enzyme activity was attributed to increase in the population of different groups of enzyme-producing microorganisms in soil. These results are in line with the findings of Nwaugo *et al.* (16) and Janeesh (17) who recorded increased urease activity on addition of organics with chemical fertilizers by Chakrabarti *et al*. (18) and Shylla (19). Higher N content in soil stimulated heterotrophic microbial activity and resulted in higher activity of hydrolytic enzymes in turn, urease activity was enhanced (20).

The lower enzyme activities in treatment T_2 : RDF + 2.5 t ha^{-1}cogen ash may be due to accumulation of soluble salts and sodium which have negative impact on enzyme activities and also because FYM was not added and there was less substrate for the growth of micro organisms, cogen ash alone did not provide much carbon and hence the enzyme activity was low. Urease activity reduced in treatment T_9 at harvest indicating the low availability of nitrogen in soils. Available N stimulates urease activity (21).

The dehydrogenase activity gives an indication of total microbial activity (19) Hence the activity was higher when microbial population was high. Application of balanced nutrients at higher level in combination with organics and inorganics improved the organic status of soil which in turn enhanced dehydrogenase activity (22).

In the present study microbial population and the enzyme activity was higher in treatments of FYM, cogen ash and chemical fertilizers, this could be due to enrichment of soil by both organic and inorganic sources that not only supplied plant nutrients but also numerous micro organisms and intensify biological activity thereby improve soil health leading to higher crop yields. Therefore the increase in grain and straw yield of paddy can also be attributed to improvement in soil health. Similar observations were made by Cunderlik (23) and Shylla (19) in ragi.

Table 5: Influence of cogen ash application on soil urease activity (µg NH_4-N g^{-1} soil h^{-1})

Treatments	45 DAT	90 DAT	At harvest
T_1 : RDF + RD of FYM	23.00	25.30	21.31
T_2 RDF + 2.5 t ha^{-1} CGA	19.00	21.49	13.39
T_3 RDF + 5.0 t ha^{-1} CGA	21.33	23.63	16.66
T_4 RDF + 10.0 t ha^{-1} CGA	24.00	27.97	17.65
T_5 RDF + 15 t ha^{-1} CGA	26.67	28.01	21.16
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	25.93	26.60	25.37
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	28.80	30.87	24.72
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	30.27	32.36	23.54
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	30.54	32.47	19.50
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	24.53	26.57	24.53
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	25.93	28.95	21.85
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	28.52	30.87	19.78
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	29.35	30.95	17.48
S. Em±	**1.55**	**1.54**	**1.50**
C. D. at 5%	**4.54**	**4.52**	**4.37**

Note:
RDF-recommended dose of fertilizers.
RD- recommended dose
CGA- cogen ash.
FYM-farm yard manure

Table 6: Influence of cogen ash application on soil dehydrogenase activity (µg TPF g^{-1} soil h^{-1})

Treatments	45 DAT	90 DAT	At harvest
T_1 : RDF + RD of FYM	35.26	35.97	33.54
T_2 RDF + 2.5 t ha^{-1} CGA	11.39	12.72	8.21
T_3 RDF + 5.0 t ha^{-1} CGA	41.86	42.97	40.25
T_4 RDF + 10.0 t ha^{-1} CGA	49.02	50.97	33.53
T_5 RDF + 15 t ha^{-1} CGA	49.59	50.01	46.03
T_6 RDF + RD of FYM + 2.5 t ha^{-1} CGA	11.91	13.19	9.60
T_7 RDF + RD of FYM + 5.0 t ha^{-1} CGA	26.40	27.65	24.65
T_8 RDF + RD of FYM + 10.0 t ha^{-1} CGA	39.85	41.64	38.36
T_9 RDF + RD of FYM + 15.0 t ha^{-1} CGA	58.56	59.88	56.21
T_{10} RDF + 50% of RD of FYM + 2.5 t ha^{-1} CGA	9.82	11.25	9.47
T_{11} RDF + 50% of RD of FYM + 5.0 t ha^{-1} CGA	12.03	13.28	10.51
T_{12} RDF + 50% of RD of FYM + 10.0 t ha^{-1} CGA	35.82	36.69	33.78
T_{13} RDF + 50% of RD of FYM + 15.0 t ha^{-1} CGA	53.41	54.29	50.21
S. Em±	**4.09**	**4.20**	**5.89**
C. D. at 5%	**11.95**	**12.27**	**17.2**

Note:
RDF-recommended dose of fertilizers.
RD- recommended dose
CGA- cogen ash.
FYM-farm yard manure

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