American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-06, pp-298-304
www.ajer.org

Research Paper Open Access

Application of magnetized fly ash based soil conditioner for the improvement of soil fertility and paddy productivity

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Abstract: **-** Use of fly ash as soil conditioner has been established as a safe method of recycle and reuse of enormous quantity of fly ash produced by thermal power plants. In this investigation, fly ash was magnetized and magnetized fly ash - *Biosil* - was tested for its potency in a field trial experiment on paddy crop. Recommended doses of fertilizers (RDF) were fortified by *Biosil* at different doses (kg/ha) namely 150, 300, 450, 600, 750 and 900, keeping RDF and vermicompost (VC) as controls. All doses of *Biosil*, especially 450 kg/ha to 900 kg/ha, improved the soil fertility and paddy productivity over and above RDF control and VC control as compared to conventional very high doses (10% to 100%) of fly ash used by other authors. Trend of improvement was in the order: *Biosil*+RDF>VC>RDF. *Biosil* fortification improved the effect of RDF on soil fertility and crop productivity to the best level in the treatments. Thus, it is evident that the magnetization has improved the potency of *Biosil* as Soil conditioner. VC showed better results than RDF. It is, thus, recommended that further field trials with the integrated treatment of *Biosil*, RDF and VC will be helpful in improving the paddy crop productivity and soil fertility on sustainable way.

Keywords: **-** *Fly ash, Magnetization, Soil conditioner, Paddy, Soil fertility*

I. INTRODUCTION

Amount of fly ash produced per year in India and elsewhere, where coal based thermal power plant is the principal source of energy, is enormous (Joshi and Lothia, 1997). India is the largest producer of FA followed by China, USA, W. Germany and UK. The dumping on land of accumulated fly ash has covered and deteriorated significant area of precious land resource in these countries. This has resulted in serious environmental pollution of air, water and soil apart from public health impacts (Carloon and Adriano, 1993).

The peculiar structure and richness of micronutrients has made the fly ash as reusable resource. The research on reuse of fly ash invented a potential large scale utilization in two fields namely construction sector for making cement and bricks and as soil conditioner in agriculture (Central Electricity Authority, New Delhi, December, 2011) for improvement of quality and fertility of soil and improvement of crop productivity and yield (Garg et al., 1996; Kalra et al., 1997; Gupta et al., 2002; Prem Kishor et al., 2010; Singh et al., 2011).

Lot of research is still needed to improve the agricultural use of fly ash soil conditioner, with respect to improvement of quality of fly ash, and its optimum use with respect to type of soil and crop. This investigation is aimed at improvement of fly ash soil conditioner through magnetization of fly ash and its use in improvement of paddy crop which is the staple crop of the majority of world population.

II. MATERIALS AND METHODS

The fly ash was securely collected from the hopper of thermal power plant and was magnetized to produce novel soil conditioner Biosil. It was applied in July 2011 (rainy season) to paddy fields at Jabalpur, India having black soil. Biosil at different doses (kg/ha) namely 150 (T1-150), 300 (T2-300), 450 (T3-450), 600 (T4-600), 750 (T5-750) and 900 (T6-900), each dose along with recommended dose of fertilizer (RDF) (120:60:40 kg NPK/ha), was added to different plots in the agricultural field before transplantation of paddy seedlings. The control plots of RDF control (T7-RDF) and vermicompost (VC) control (T8-VC) .were also maintained. Paddy variety WG132100 was selected as rice cultivar. The soil in the field was subjected to excessive dispersion during puddling, resulting into drastic change in their pore size distribution.

A total of eight treatments over 24 plots (8x3=24) were arranged in a completely randomized design and each treatment was carried out in three replications. The gross and net plot sizes were 6mx3.6 m and 5.6 m x 3.2 m respectively. The distance between plots was kept at 1.0 m and the distance between replications were kept at 1.5 m.

The powder form of Biosil was applied at the rates given above one week prior to flooding and mixed mechanically by ploughing within 15 cm depth of the surface soil. The basal RDF dose applied into soil two days before rice transplanting was given as: nitrogen (50% dose), phosphorus (100% dose), potash (100% dose). Each dose of top dressing fertilizer (nitrogen 25%) was added after one and two months of transplanting. Water level was controlled at around 5-7 cm depth during the cropping season and rice was harvested 150 days after transplantation.

Soil was collected from the test field from 30 cm depth from three places before sowing and after harvest, air dried, sieved (<10mm) and analyzed for physico-chemical properties viz. pH, electrical conductivity (EC), bulk density (BD), available nitrogen (N), available phosphorus (P), available potassium (K), available sulphur (S) and available zinc (Zn) (Jackson, 1973). The results were averaged and presented. The observations on the crop were recorded at pre-harvest at 30, 60 90 days after transplantation (DAT) and at maturity in November 2011 on plant population - number/sq m, plant height (cm), number of tillers/sq m, number of leaves/sq m, and leaf area/sq m. Similarly post-harvest observations on the crop have been made on number of effective tillers/sq m, length of panicle (cm), no of grains/panicle, test weight (g), grain yield (kg/plot) and straw yield (kg/plot).

III. RESULTS AND DISCUSSION

Project site

Jabalpur from Madhya Pradesh, India has humid subtropical climate. Summer starts in late March and lasts up to June. May is the hottest month with average temperatures reaching upto and beyond 45 ^{0}C. Summer is followed by monsoon season, which lasts until early October, with a total precipitation of nearly 55 inches (1386 mm). Winter starts in late November and last until early March. They peak in January with average daily temperature near 15 ^{0}C.

Magnetized fly ash

Fly ash, upon being subjected to controlled magnetic field, exhibits remarkable magnetic movement. This magnetic movement causes nutrients in soil to be attracted to roots of plants, facilitating assimilation by the plants of the nutrients in the soil, to which magnetized fly ash is added. Particle size distribution showed dominance of small sized particles. The finer fractions (<0.25 mm) varied from 52.24% to 65.32%, as the magnetic properties are concentrated in small fraction of particles. Analysis of Biosil indicated 0.10-0.32% moisture content, 0.85-1.16 g/cubic cm bulk density, 40.1 to 55.6% water holding capacity, pH (7.3-7.9), electrical conductivity (0.27 to 0.36 dS/m), available macronutrients (ppm) (nitrogen 95-130;phosphorus 65-90; potash 72-98) and available micronutrients (ppm) (iron 10.2-22.2; zinc 0.8-3.2; manganese 1.5-4.2; boron 0.76-1.20; molybdenum 0.76-1.20; copper 40-109; zinc 47-136; and manganese 100-700). The major constituents of the fly ash were found to be silica (SiO_2) (60.1 to 68.8%) followed by total aluminium (20.6 to 27.5%) and total iron (4.3 to 8.7%). These characteristics of Biosil indicate that Biosil fortification to soil as soil conditioner will help in improving drainage and porosity of soil, pH of acidic soil, improvement of micronutrients in deficient soil, mitigating boron deficiency of soil.

Improvement of soil properties

The soil of experimental field before the transplantation of paddy seedlings was observed to be clayey in texture (Table I) (however with excess clay) and with ideal Electrical conductivity & pH; medium organic carbon & potassium; medium-low nitrogen and low phosphorus as per the guidelines for rating the soil fertility indicators in India (Table II) and also the guidelines given by Utah State University in cooperation with U.S. Department of Agriculture (Table III). This low content of P in the Jabalpur soil is in conformity with the report (Chandy, 2013) that medium black soils of semi-arid regions have a medium fertility level with respect to phosphorus. The reason for medium-low N is the medium organic carbon content of soil. Soil organic carbon has role in improving and maintaining soil fertility, structure, stability, nutrient retention & restricting soil erosion (Singh, 2008).

The initial soil quality and soil quality after harvest of paddy crop are shown in Table IV. Biosil+RDF treatments improved Initial pH of soil from initial 7.1 to 7.3 in T3-450 and higher treatments, electrical conductivity (EC) from 0.31 dS/m to 0.35 dS/m in T5-750 and higher treatments, organic carbon (OC) from 0.64% to 0.68% in T6-750 treatment onwards and effectively reduced the bulk density (BD) from 1.46 g/cc to

1.40 g/cc which is optimum for black soil (USDA-NRCS Soil Quality Test Kit Guide). Thus, Biosil treatments improved the physical quality of soil with respect to pH, EC, bulk density and organic carbon, an essential macronutrient, in the soil. The vermicompost (VC) and recommended dose of fertilizers (RDF) also improved the soil nutrients. Vermicompost improved the nitrogen content of soil from 372 to 378.25 kg/ha (1.68% increase), phosphorus content from 17.45 to 17.93 kg/ha (2.75% increase), potassium content from 297 to 303 kg/ha (2.02% increase), sulphur from 9.1 to 9.5 kg/ha (4.4% increase), and zinc from 1.3 to 1.45 kg/ha (11.54% increase). Similarly, RDF improved the nitrogen content of soil by 372 to 372.5 (0.13% increase0, potassium content by 297 to 297.25 kg/ha (0.08% increase), sulphur content from 9.1 to 9.13 kg/ha (0.33% increase) and zinc from 1.30 to 1.38 kg/ha (6.15% increase). Percent Increase/Decrease in Soil Parameters in Optimum Dose of Biosil at 90 DAT over initial value, RDF control and VC control are shown in Figure 1. The trend of improvement was RDF > Biosil+RDF for pH and EC and VC > Biosil+RDF for OC and BD.

In vermicompost control, pH remained unchanged at 7.1. Similar observation is made by Sharma et al., 2013 who observed soil pH maintained or declined in all in Integrated Nutrient Management Treatments as compared to the initial value, which may be ascribed to the formation of organic acids due to the decomposition of organic manure and crop residues.

Similar improvement in soil quality have been observed by other authors but with very high doses of fly ash such as change in soil pH at 10 t/ha fly ash application (Gautam et al., 2012; Tekade et al., 2013), Reduction in bulk density (Kalra et al., 1998; Kene et al., 1991), increase in electrical conductivity (Tekade et al., 2013; Matsi and Keramidas, 1999,), and improvement in soil pH, conductivity, available phosphorus, organic carbon and organic matter with increased application rate of fly ash (Sarkar et al., 2012; Sarangi et al., 2001).

Biosil Treatment with RDF showed improvements in macronutrients over initial value namely nitrogen from 372 to 376 kg/ha (1.28% increase), phosphorus from 17.45 to 17.85 kg/ha (2.29% increase), potassium from 297 to 301 kg/ha (1.35% increase), sulphate from 9.1 to 9.48 kg/ha (4.18% increase) and zinc from 1.30 1.45 kg/ha (11.54% increase). Vermicompost and RDF also improved the soil nutrients (Table IV) with the trend of improvement as Biosil+RDF > VC > RDF. This indicates that Biosil fortification to RDF improved the results of RDF on soil fertility to the best level in all the treatments. Thus, vermicompost and Biosil were effective in improving the soil fertility and were capable of optimizing bulk density, and mobilizing organic carbon, nitrogen, phosphorus, potassium, sulphur and zinc. Biosil doses ranging from 600 kg/ha to 900 kg/ha were found to be suitable as soil conditioner (Table V). Better results were recorded by some authors with higher doses of fly ash. Jala (2005) observed a distinct increase in the concentrations of N, P, K, S, in soil plus fly ash mixtures after trial with concomitant increase in fly ash percentage. RDF was more effective in improving EC and pH of soil, while Biosil+RDF and vermicompost were effective in improving other soil parameters.

Improvement of paddy growth and productivity

The results on paddy growth and productivity are summarized in Table VI. The treatment T6-900 i.e. Biosil 900 kg/ha along with RDF was observed to be optimum for all the plant growth and productivity parameters. 90 DAT was sufficient for full development of plant height and leaf area/m^2. Number of leaves increased rapidly in first 30 days and then shows gradual decline. Yield attributes and yield components were maximally developed at maturity. The trend of enhancement was similar for all the parameters that is Biosil+RDF followed by vermicompost and then by RDF. Therefore, it is recommended that the combined treatment of Biosil, RDF and vermicompost would be beneficial in improving the paddy growth and productivity. The T6-900 treatment gave maximum values of different parameters such as 47.40 q/ha grain yield, 97.47 q/ha straw yield, 19.33 g test weight, 173 grains per panicle, 32.7 cm length of panicle, 273 number of effective tillers/m^2, and leaf area index of 5.49.

All the doses of Biosil along with RDF showed significant superiority with respect to all plant growth and productivity parameters over RDF alone except lower dose of 150 kg/ha Biosil with RDF. Percent increases in all parameters in T6-900 treatment over T7-RDF control and T8-VC control on 90 DAT are shown in Figure 2. The growth and productivity parameters increased by 8.66% to 34.97% over RDF control (showing enhancement of the effect of RDF due to Biosil fortification) and by 4.15% to 25.26% over VC control in T-900 treatment. On the other hand, addition of vermicompost alone proved to be equally good to 100% RDF alone and lower dose of Biosil (150 kg/ha) with RDF.

IV. CONCLUSION

It is thus concluded that the magnetization of fly ash has increased tremendously the inherent power of fly ash and showed improvement in soil quality and fertility as well as in crop growth and productivity at a very low concentration of 900 kg/ha Biosil as compared to conventional higher rate of applications of fly ash i.e. 10% to 100% to the soil. These improvements have been achieved by higher mobilization of nutrients and making them more available to the paddy under the influence of Biosil. Biosil fortification to RDF also improved the individual impact of RDF on soil fertility and crop growth and productivity (Figure 1 and 2). Considering the better results of vermicompost over RDF, it is recommended that the integrated treatment of Bioslil with RDF and vermicompost will be highly beneficial to improvement of crop productivity and for maintenance of soil fertility for longer period.

V. ACKNOWLEDGMENT

The authors wish to thank the Principal, Sevadal Mahila Mahavidyalaya & Research Academy, Nagpur for providing necessary facilities to conduct above investigation.

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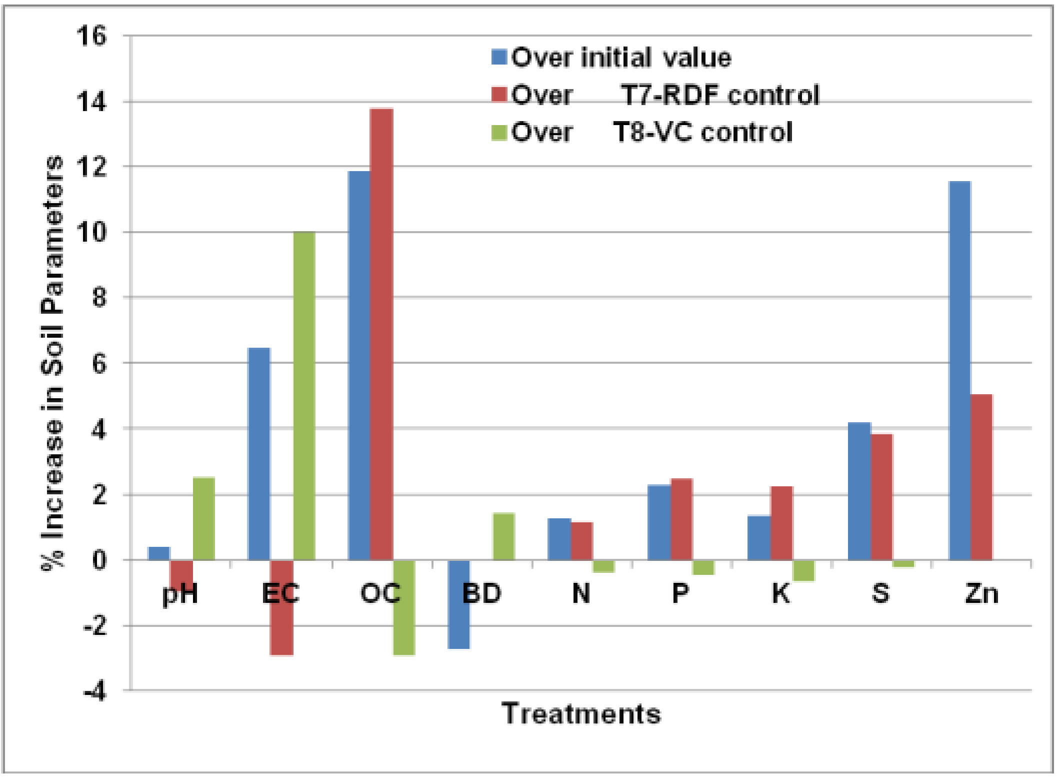
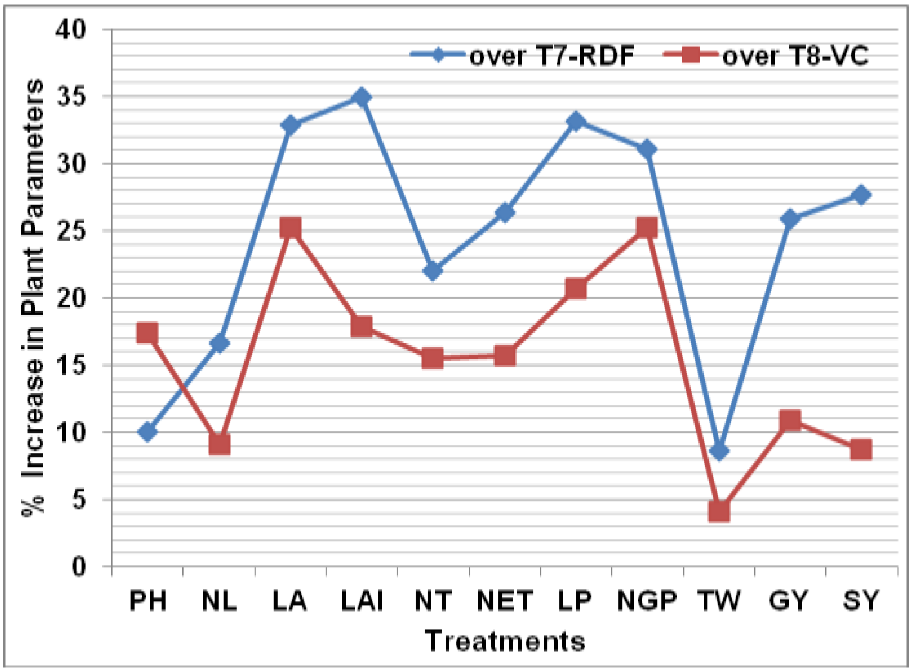


(EC: electrical conductivity; OC: organic carbon; BD: bulk density)

Figure 1: Percent Increase/Decrease in Soil Parameters in Optimum Dose of *Biosil* at 90 DAT



[PH: plant height; NL: number of leaves/sq m; LA: leaf area; LAI: leaf area index; NT: number of tillers/sq m; NET: number of effective tillers/sq m; LP: length of panicle (cm); NGP: number of grains per panicle; TW: test weight (g); GY: grain yield (q/ha); SY: straw yield (q/ha)]

Figure 2: Percentage Increase in Plant Parameters at Optimum *Biosil* Dose at 90 DAT

Table I: Qualitative ratings of soil nutrients in experimental fields before transplantation

Description	*Sand %*	*Silt %*	*Clay %*	*Texture*	*EC dS/m*	*pH*	*OC (%)*	*Available plant nutrients (kg / ha)*		
								N	P	K
Nutrient Content	25.18	19.18	55.64	Clayey	0.31	7.1	0.59	372	17.45	297
Quality ratings	Ideal	Ideal	Unacceptable	Acceptable	Ideal	Ideal	Medium	Medium low	Low	Medium

EC: electrical conductivity; OC: organic carbon; N: available nitrogen; P: available phosphorus; K: available potassium

Table II: Soil fertility classification followed in Maharashtra & some other states

Soil fertility level	***Organic carbon (%)***	***Available N (kg/ha)***	***Available P_2O_5 (kg/ha)***	***Available K_2O (kg/ha)***
Very High	>1.00	>700	>80.0	>360
High	0.81-1.00	561-700	64-80	301-360
Medium	0.61-0.80	421-560	48-64	241-300
Medium Low	0.41-0.60	281-420	32-48	181-240
Low	0.21-0.40	141-280	16-32	121-180
Very Low	<0.20	<140	<16.0	<120

Source: Tandon (2005)

Table III: Guidelines category of soil parameters for the growth of crops

Category	*Soluble Salts (EC) (dS/m or mmho/cm)*	*pH*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Texture Class**	*Organic Matter (%)*	*% Coarse fragments (>2 mm in diameter)***	*Sodium Adsorption Ratio (SAR)**
Ideal	<3	5.5 to 7.5	<70	<70	<30	L, SiL	≥2.0	≤ 2	<3 for any texture
Acceptable	<4	5.0 to 8.2	<70	<70	<30	SCL, SL, CL, SiCL	≥1.0	2.1 to 5.0	3 to 7 (SiL, SiCL, CL) 3 to 10 (SCL, SL, L)
Un-acceptable	>4	<5.0 or >8.3	>70	>70	>30	LS, SC, SiC, S, Si, C	<1.0	➢ 5.0	➢ 10 for any texture

Source: Utah State University Cooperation with the U.S. Department of Agriculture under Cooperative Extension Work (AG/SO-02, 2002) [S: Sand; Si: Silty; C: Clay; L: Loam; LS: Loamy Sand; SL: Sandy Loam; SCL: Sandy Clay Loam; CL: Clay Loam; SiCL: Silty Clay Loam; SC: Sandy Clay; SC: Silty Clay; SiC: Silty clay; SiL: Silty loam]

Table IV: Effect of different treatments on soil properties along with initial status of soil

Treatment	Soil pH	E.C. (dS/m)	Organic Carbon (%)	Bulk Density (g/cc)	Available Plant Nutrients (kg/ha)				
					N	P	K	S	Zn
Initial Status	7.30	0.31	0.59	1.46	372.00	17.45	297.00	9.1	1.30
T1-150	7.30	0.33	0.64	1.45	373.25	17.40	296.25	9.1	1.40
T2-300	7.30	0.33	0.64	1.44	373.00	17.45	296.50	9.1	1.40
T3-450	7.30	0.33	0.65	1.44	374.75	17.50	297.50	9.28	1.43
T4-600	7.30	0.33	0.66	1.43	374.00	17.60	299.00	9.30	1.43
T5-750	7.33	0.33	0.66	1.42	375.5	17.83	299.50	9.43	1.45
T6-900	7.33	0.33	0.66	1.42	376.75	17.85	301.00	9.48	1.45
T7-RDF	7.40	0.34	0.58	1.42	372.50	17.45	297.25	9.13	1.38
T8-VC	7.15	0.30	0.68	1.40	378.25	17.93	303.00	9.50	1.45
SEm ±	0.07	0.01	0.03	0.02	21.52	0.95	4.89	0.47	0.09
Coefficient of Determination (R^2)	0.69	0.38	0.85	0.94	0.83	0.86	0.96	0.94	0.90
Correlation Coefficient (R)	0.83	0.61	0.92	- 0.97	0.91	0.93	0.98	0.97	0.95

SEm: Standard Error around mean; CD: Critical Difference; EC: electrical conductivity

Table V: Summary of the results on effects of treatments on soil characteristics

Parameters	*Optimum Treatments*	*Trend of enhancement*	*Correlation Coefficient*	*% Increase over initial value*	*% increase over T7-RDF control*	*% increase over T8-VC control*
pH	T5-750	RDF>BS+RDF	0.83	0.41	-0.95	2.52
EC	T1-150	RDF>BS+RDF	NaN	6.45	-2.94	10.00
OC	T4-600	VC>BS+RDF	0.92	11.86	13.79	-2.94
BD	T5-750	VC>(BS+RDF)=RDF	-0.97	-2.74	0.0	1.43
N	T6-900	VC>BS+RDF>RDF	0.91	1.28	1.14	-0.40
P	T6-900	VC>BS+RDF	0.93	2.29	2.47	-0.45
K	T6-900	VC>BS+RDF	0.98	1.35	2.25	-0.66
S	T6-900	VC>BS+RDF>RDF	0.97	4.18	3.83	-0.21
Zn	T5-750	VC=BS+RDF>RDF	0.95	11.54	5.07	0.0

BS: *Biosil*; RDF: recommended dose of fertilizers; VC: vermicompost; EC: electrical conductivity; OC: organic carbon; BD: bulk density

Table VI: Optimum dose of Biosil with RDF and comparison of the results of treatments on plant growth and productivity

Parameters	*Optimum treatment*	*DAT for maximum development*	*Trend of Enhancement*	*Maximum Value*
Plant height	T6-900	90 DAT	BS+RDF>VC>RDF	82.33 cm
Number of leaves	T6-900	Rapid in 30 DAT then taper gradually	BS+RDF>VC>RDF	793 leaves/m2
Leaf area/m2	T6-900	90 DAT	BS+RDF>VC>RDF	27444/m2
Leaf Area Index	T6-900	60 DAT	BS+RDF>VC>RDF	5.49
Number of Tillers/m2	T6-900	60 DAT	BS+RDF>VC>RDF	287 tillers/m2
Number of Effective tillers	T6-900	Maturity	BS+RDF>VC>RDF	273/m2
Length of panicle	T6-900	Maturity	BS+RDF>VC>RDF	32.70 cm
Number of grains per panicle	T6-900	Maturity	BS+RDF>VC>RDF	173 grains/ panicle
Test weight	T6-900	Maturity	BS+RDF>VC>RDF	19.33 g
Grain yield	T6-900	Maturity	BS+RDF>VC>RDF	47.40 q/ha
Straw yield	T6-900	Maturity	BS+RDF>VC>RDF	97.47 q/ha

DAT: days after transplantation; BS: *Biosil*; RDF: recommended dose of fertilizers; VC: vermicompost