Original Article

Improvement in rice crop productivity and soil fertility in field trial with magnetized fly ash soil conditioner

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Abstract

Field trial experiments were carried out on rice crop in 2010 using magnetized fly ash (*Biosil*) as soil conditioner along with recommended dose of fertilizer (RDF), keeping RDF and vermicompost (VC) as controls. Encouraging results on rice plant growth and productivity and soil fertility at very low concentrations (150 to 900 kg/ha) indicated the improved intrinsic soil conditioning power of fly ash. *Biosil* 900 kg/ha was observed to be the optimum dose for growth and yield parameters of rice. The maximum grain and straw yield of 47.7 and 77.4 q/ha were recorded under RDF+*Biosil* @ 900 kg/ha as compared to RDF alone (40.2 q/ha). The percentage improvements of soil parameters over initial status by *Biosil* optimum doses were 2.82% in pH, 2.69% in K, 5.50% in S, 20.83% in Zn, 6.45% in EC, 6.25% in OC, 0.80% in N, - 4.11% in BD and 3.73% in P. The general trend of improvement for growth of rice crop was *Biosil*+RDF > VC > RDF and for soil parameters was *Biosil*+RDF > RDF > VC. Thus it is suggested that integrated treatment would be the best for getting maximum benefits from *Biosil*.

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Introduction

Environmental and public health problems due to conventional land disposal of fly ash (FA) might be ameliorated by agricultural use of FA as soil conditioner. Fly-ash, having both the soil amending and nutrient-enriching properties, is helpful in improving crop growth and yield in low fertility soils. It has been shown that FA based soil conditioner not only improves the crop productivity and soil fertility but also mobilizes macro- and micronutrients in the soil [1]. Many researchers [2, 3, 4] have demonstrated that fly-ash increased the crop yield of various crops and improved the physical and chemical characteristics of the soil. However, limited work has been carried out on rice especially on Indian soils, some of them are related to control of P release from rice field and productivity[5]; integrated system [6]; fertilizers and organic manure [7]; and yield and nutrient composition [8].

Thus, there is need to improve the rice productivity by the application of novel methods. With this view, present work is aimed at to technologically modify the nature of FA to improve its intrinsic power of soil conditioning through magnetization and use of magnetized FA at low doses to improve the soil fertility and paddy productivity.

Materials and Methods

The FA was securely collected from the hopper of thermal power plant and was magnetized to produce novel soil conditioner *Biosil*. It was applied in July 2010 (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 PS-3 was selected as rice cultivar. A total of eight treatments in triplicates were arranged in a completely randomized design. The basal RDF dose which was applied into soil two days before rice transplanting was given as: nitrogen (50% dose), phosphorus (100% dose), and 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 [9]. 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 growth parameters. 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).

Effect on Rice Crop Growth and Productivity

Plant Height (PH)

PH was well correlated with the different doses of *Biosil*+RDF. The Correlation Coefficient varied from 0.87 to 0.96 before the maturity, while it was 0.90 on maturity (Table 1). The PH increase was extremely rapid in the first 60 days and then slightly slowed down during 60 day to 90 day. This is evident from the observation that the difference between PH at T1-150 and T6-900 was high on 30 DAT i.e. 9.6 cm and on 60 DAT i.e. 24.1 cm but was less on 90 DAT i.e. 7.1 cm. PH also increased with increasing *Biosil* doses. The slow rate of growth after 60 DAT may be due to prominence of reproductive growth over vegetative growth during this period. All the treatments T1-150 to T6-900 were observed to be more efficient than T7-RDF control throughout the experimental period, T6-900 showing maximum enhancement over T7-RDF of 38.52% on 60 DAT. The T3-450 to T6-900 treatments were better than T8-VC control, being best by 1.37% to 27.73% on 60 DAT. T8-VC control was better than T7-RDF and T1-150 by 8.44% and 5.48% respectively on 60 DAT. Thus, *Biosil* fortification played an important role in enhancing the PH, improving the effect of RDF by 38.52%, followed by VC control and lastly by RDF control.

Number of Leaves (NL)

The NL increased gradually on 30 DAT, 60 DAT and 90 DAT being significantly higher on 60 DAT and 90 DAT, followed by T8-VC and T7-RDF (Table 2). There was perfect correlation between *Biosil* doses in treatments and NL (R: 0.95 - 0.98). There is reduction in NL on maturity due to death, decay and leaf fall. *Biosil* fortifications, especially in T3-450 to T6-900 significantly improved the effect of T7- RDF.

Leaf Area (LA)

LA was found to be linearly increasing with increase in *Biosil* doses in all treatments with complete correlation (R: 0.93-0.98). LA increased significantly on 60 DAT and 90 DAT but reduced at maturity due to death and decay of old leaves (Table 3). The LA in treatments was higher than that in

T7-RDF, indicating stimulating effect of *Biosil* in treatments. LA in T8-VC was better than T7-RDF and T1-150 and is still better at maturity showing its longevity due to organic matter in T8-VC.

Leaf Area Index (LAI)

LAI of rice fields provides information on crop growth dynamics, and has the potential to be a good indicator of the status of paddy rice throughout the growing season [10] and is highly correlated with rice biomass and productivity [11]. Moreover, the LAI monitoring of paddy is crucial in outlining an efficient water management policy in dry areas because paddy is grown on flooded soils. LAI of paddy field ranged from 0.2 to 0.27 (30 DAT), 1.24 to 1.6 (60 DAT), 2.1 to 2.5 (90 DAT) and 1.6 to 2.0 (at maturity) (Table 4). The value is more than 1, indicating efficient water management and best photosynthetic capability of paddy crop. In general, LAI was found to be increasing with increase in doses of *Biosil*, with negative correlation at 30 DAT, but positively correlated on 60 DAT (R: 0.97), 90 DAT (R: 0.90) and at maturity (R: 0.73). The *Biosil* fortification to RDF considerably improved the LAI by 42.11% (T5-750, 30DAT), to 37.5% (T6-900 at maturity) over T7-RDF and 22.22% to 24.55% on 60 DAT to maturity by T6-900 over T8-VC Control. All the yield parameters were well correlated with the LAI (Table 5), R ranging from 0.94 to 0.98, showing indicator value of LAI for crop status, biomass and productivity.

Number of Tillers/m^2 (NT)

The *Biosil* doses were well correlated with the NT showing R as 0.95 on 30 DAT and from 0.83 to 0.86 from 30 DAT onwards to maturity (Table 6). The increase in NT was linear and the treatment T6-900 showed highest enhancement throughout the experimental period. The increase in NT after 90 days to maturity was much less as it was the period of grain development in paddy. T8-VC control was next in enhancement of development of tillers throughout the experimental period. T7-RDF control was the lowest among the treatments in enhancing the NT. At maturity, *Biosil*+RDF treatment showed 12.99% to 44.1% enhancement over T7-RDF; and T2-300 to T6-900 treatments showed 0.33% to 22.41% enhancement over T8-VC treatment, and T8-VC treatment was 17.72% better than T7-RDF Treatment.

Yield Attributes

The yield attributes are Number of Effective Tillers (NET), Length of Panicle (LP), Number of Grains/Panicle (NG) and Test Weight (TW) (Table 7). It was observed that all the yield parameters increased with the increase in the doses of *Biosil* in treatments, showing good correlation (R: 0.92 to 0.97). *Biosil* @900 kg/ha possessed average 152 NG, 30 cm LP, 306 NET, as well as TW (24.2 kg) which were significantly superior to other treatments. *Biosil* fortification to RDF in T2-300 to T6-900 showed considerable improvement in all yield parameters over T7-RDF control. T8-VC was superior to T7-RDF and T1-150.

Yield Parameters: Grain Yield (GY) and Straw Yield (SY)

The GY and SY significantly increased with increase in *Biosil* doses+RDF showing good correlation (R: 0.91) with SY and (R: 0.95) with GY (Table 8). It is reported that subsequent increase in doses of FA also increased GY significantly over control [12, 13]. Highest GY in T6-900 was 18.66% higher than T7-RDF control and 5.53% higher than T8-VC control. Similar observation [6] showed a yield increase of 23.3% and 32.4% in treatments over control which received FA @ 5 and 15 t/ha. T8-VC showed higher yield of both GY by 12.44% and SY by 36.06% over T7-RDF and lower doses of *Biosil* in T1-150 to T2-300 treatments. Similarly, highest rice yield (34.1 t/ha) was recorded [6] in treatments with 50% RDF + FYM 5 t/ha + FA 15 t/ha.

The maximum GY and SY of 47.7 and 77.4 q/ha were recorded under RDF+*Biosil* @ 900 kg/ha as compared to RDF alone (40.2 q/ha). Thus, all *Biosil* fortifications to RDF highly stimulated the GY and SY by 18.66% and 54.16% over T7-RDF control and were also better by 5.53% to 13.32% over T8-VC control.

Biosil Treatments and Plant Growth & Productivity

Application of different doses of *Biosil*+RDF as well as VC alone markedly influenced the rice crop growth and yield, showing the general trend of enhancement as *Biosil*+RDF > VC > RDF (Table 9). The optimum dose of *Biosil* in treatments was 900 kg/ha for all parameters except TW for which 750 kg/ha was the optimum dose. PH and NL attained maximum growth at 90 DAT while all other parameters attained maximum growth on maturity. *Biosil* improved tremendously the growth parameters and productivity (2.98% to 61.91%) over those obtained in RDF control.

Soil Quality of Experimental Field before Sowing

The soil of Jabalpur region is broadly classified as vertisol as per norms of US Classification of soil. It is clayey in texture, medium to deep in depth and black in colour. It swells by wetting and shrink when dries. Thus, it develops wide cracks on the surface during summer season. Black soils, in general have a high degree of fertility, though some of them, mainly in the upland, are of low productivity.

The soil was analyzed for particle size distribution and the composition was observed as sand 26.18%, silt 19.18% and clay 55.64%, thus the texture of the soil of experimental field was clayey (Table 10a).

The soil quality before sowing was assessed based on the guidelines for rating the soil fertility indicators in India (Table 11) and also given by Utah State University in cooperation with U.S. Department of Agriculture[14] (Table 12). The mean values of the surface soil data before sowing and the qualitative ratings of soil nutrients are presented in Table 10a and 10b, which reveals that the compositions of sand and silt in the soil were ideal (but very low) and clayey texture was acceptable, however, the clay content was unacceptable. The EC and pH were ideal. The OC content was medium, available N medium-low, available P low and available K medium in soil. The reason for medium-low N is the medium OC content of soil, which bind N in soil and retain it, and in presence of poor carbon, nitrogen is a very dynamic element, susceptible to leaching in high rainfall area; volatilization due to annual vegetal burning and high temperature of the tropical environment; and immobilization in organic pool. Soil OC is also beneficial in binding other nutrients in the soil for longer period.

Overall the soil is said to be of medium fertility with low available P. This is in conformity with the results of National Survey of Soils in India (Soil and Land Use Survey of India, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India**)**, which indicate that the productivity of Indian soils at present stands at a very low levels in comparison to world soils, due to cumulative effect of multiple factors like scarcity of moisture, deficiency of plant nutrients, and faulty management of soils [15]. It is also reported [16] that the N is universally low in the area, P usually medium, K is either medium or high in the soils and Jabalpur soils are deficient in micronutrients, high in copper, iron, while very low in case of zinc.

Effect on Soil Quality and Fertility after Harvest of Crop

Soil pH

Initial pH of soil before transplanting was 7.1 (Table 13). This value is near neutral and is within the range of 6.5 to 8.5, which is suitable for the growth of plants. Soil pH increased slightly due to application of different doses of *Biosil* and T7-RDF (Table 13). Soil pH changed from initial 7.1 to 7.3 in T3-450 to T6-900 treatments indicating positive impact of *Biosil* (2.82% increase over initial) even at very low doses as compared to high doses of FA given by other authors who recorded change in soil pH [17, 18] at FA application of 10 t/ha i.e. 10,000 kg/ha or more as compared to maximum 900 kg/ha *Biosil* in the present investigation. T3-450 was the optimum showing 2.82% increase over initial value and 2.81% increase over T8-VC. T7-RDF also had positive impact on soil pH showing increase in pH to 7.4 (4.23% over initial), however T8-VC did not show increase in soil pH. In VC control, pH remained unchanged at 7.1 due to decomposition of organic matter in VC, during which organic acids are produced. Similar observation [19] showed that soil pH is maintained or declined in all in Integrated Nutrient Management treatments as compared to the initial value.

Bulk Density (BD)

Proper BD is important for retention and transport of water and nutrients. Ideal BD for clayey soil as that of Jabalpur is <1.10 g/cc, however, the initial BD of the soil of experimental field was 1.46 g/cc which was higher than ideal bulk density. BD recorded at harvest of crop significantly decreased (1.46 to1.40 g/cc) (4.11% decrease) by application of 900 kg/ha of *Biosil* in T6-900 treatment, which was better than initial BD (Table 13). Additions of *Biosil* contributed to the silt content to the soil and made the soil porous which recorded the less mass per unit volume of soil. BD was negatively correlated with doses of *Biosil* (R: -0.96). Moreover, response in VC control was more pronounced with BD 1.36 (6.85% decrease) because it added comparatively more organic matter hence decreased the soil mass in a given volume of soil. Similar observations [20] have been recorded, wherein FA addition in soil resulted in lower BD, although the differences compared with control plots were not significant. Application of FA at 0, 5, 10 and 15% by weight in clay soil significantly reduced the BD and improved the soil structure, which in turn improves porosity, workability, root penetration and moisture-retention capacity of the soil [21].

Electrical Conductivity (EC)

The initial EC of soil of experimental field was 0.31 dS/m which was under acceptable level i.e. <3dS/m (Table 12). It increased linearly with the increase in doses of *Biosil* with highest level of EC 0.35 dS/m in T6-900 and was well correlated with doses of

Biosil (R: 0.96) (Table 13). This low level of increase in EC was due to very low application of *Biosil* to the soil. However, the change in EC indicates positive impact of *Biosil* application to the soil under one cycle of cropping, which might be significantly improved under long term application of *Biocil* in agricultural field. Other workers [22] also observed that the EC of soil increases with FA application and so does the metal content. Similarly Tekade *et al*. [18] observed gradual increase in EC of soil, being highest at 75% FA to soil. Other authors [23] observed the gradual increases in soil pH, EC, available P, and OC with increased application rate of FA. Sarkar *et al*. [24] observed that under the treatment of RDF and FA (0 to 20%), the alkalinity, conductivity, and water holding capacity of the soil in experimental fields increased with higher FA application. T7-RDF control and T8-VC control also showed marginal increase over initial value in EC as 0.33 dS/m and 0.32 dS/m respectively. The optimum treatment T5-750 increased EC by 6.45% over initial value, 3.13% over T8-VC and 0% over T7-RDF.

Macronutrients

Primary important macronutrients in soil are OC, available N, P and K and secondary important nutrient is S. S is also now important limiting element after adoption of modern agricultural techniques. Although each of these fertilizer elements has multiple roles, in general OC stores the nutrients in the soil, N encourages strong leaf growth, P encourages flowering and budding, and K encourages stronger root growth.

Organic Carbon (OC)

Initial OC content of soil was 0.64% (medium) which significantly improved due to various treatments of *Biosil+RDF* and VC over T7-RDF control. In *Biosil* treatments the OC increases linearly with good correlation (R: 0.92) (Table 13). T5-750 treatment showed 6.25% increase in OC over initial and T7-RDF control. T8-VC showed highest increase in OC as 0.72%, which was higher by 5.88% over T6-900 and by 12.5% over initial and T7-RDF control. Therefore, there is need to utilize (*Biosil* + RDF) along with VC in order to get highest benefit with respect to soil fertility and crop productivity.

Available Nitrogen (N)

Application of *Biosil* resulted in increase in available N content, though marginally, from initial 372 kg/ha to 375 kg/ha (T5-750 to T6-900), with strong positive correlation (R: 0.92). T7-RDF showed increase of an equivalent amount of N of 375 kg/ha, while T8-VC showed further decrease in N content of soil (Table 13). The minimum optimum treatment for N mobilization is T5-750, which was 33.93% higher than T8-VC.

Available Potassium (K)

Initial K of the soil of experimental field was 297 kg/ha (medium). Low *Biosil* doses T1-150 and T2-300 did not change the K content of soil. Higher doses increased the K content from 303 kg/ha (T3-450) to 310 kg/ha (T6-900). Next better treatment was of T8-VC showing 302 kg/ha of K, while T7-RDF showed only marginal increase in K up to 299 kg/ha (Table 13). The optimum T6-900 treatment increased K content by 4.38% over initial value, 1.64% over T8-VC controls and 3.68% increase over T7-RDF control. The rating of K in soil changed from Medium to High due to *Biosil* doses (T6-900) and T8-VC treatment as per Soil Fertility Classification [25] (Table 11).

Available Phosphorus (P)

Initial P content of soil was 17.45 kg/ha (low). *Biosil* doses in T2-300 to T6-900 were found to improve the status of P in soil, showing increase in available P from 17.4 kg/ha (T2-300) to 18.1 kg/ha (T6-900), showing good correlation (R: 0.83). All the treatments were found to mobilize P from soil significantly. Next better treatment was of T7-RDF control with 18.1 kg/ha P, followed by T8-VC with 17.8 kg/ha P (Table 13). The optimum treatment was T6-900 which showed 3.73% increase in P content over initial content, 1.69% increase over T7-RDF and 0.56% increase over T8-VC. P solubilisation in *Biosil* treatment is explained by the results of experiment [26] wherein P solubilising bacteria showed good adaptability in FA amended soils and better survival compared to free-living nitrogen fixing bacteria, exhibiting 36.5% to 86.1% P solubilisation. The population of P solubilising bacteria in FA amended soils mixed with chemical fertilizers was higher in the presence of FA, a level as high as 12%. In another experiment [27], soil samples were mixed with FA at rates of 0, 1.5 and 3.0 t/ha and incubated for a month at field capacity. Soil reaction (pH) was slightly increased in granite and sandstone soils but decreased in limestone soil from 6.1 to 5.9 with FA addition. The concentrations of available P and exchangeable Na were increased.

Available Sulphur (S)

S deficiency was extremely uncommon in soil. However, it has been on the increase from earlier localized areas to now much larger areas, since the adoption of new high yielding varieties and concentrated nitrogenous, phosphatic and potashic fertilizers. Soils in Jabalpur district have been found to be deficient in S [28].

The S content (9.1 kg/ha) of present soil is below the critical level of 10 ppm (Table 14). Significant improvement was observed due to application of *Biosil* doses to 9.5 kg/ha (T1-150 to T3-450) and 9.6 kg/ha (T4-600 to T6-900), with positive strong correlation (R: 0.88). Next better treatment was of T8-VC with 9.5 kg/ha S, followed by T7-RDF with 9.4 kg/ha S (Table 13). The optimum treatment T6-900 increased soil S content by 7.69% over initial status, 3.16% over T8-VC control and 4.26% over T7-RDF control. This indicates that the *Biosil* has capacity to mobilize S from the soil and make it available to the growing crop. Similar observations have been recorded by other authors with higher doses of FA [27], who recorded increase in the concentrations of N, P, K, S, in FA treated soil. FA was also used for correction of sulphur and boron deficiency in acid soils [29].

Micronutrient: Available Zinc (Zn)

Zn was taken as the representative of micronutrients in the soil as it is more common and is required in comparatively large quantity by the crop. Zn is essential micronutrient which acts as activator of enzymes in many enzymatic actions in the plant metabolism. The soil of experimental field is near neutral which is suitable for maintaining micronutrient content of Zn; as the micronutrients become less available as the soil becomes more alkaline. Initial level of Zn in soil was 1.20 kg/ha (0.421 mg/kg), which was below the critical level of 0.60 mg/kg (Table 14) [30]. The Jabalpur is in the belt of low Zn in Madhya Pradesh [30]. This is in conformity with the observation that micronutrient deficiencies also started becoming critical beginning with the intensification of agriculture and using high chemical fertilizers [28]. Low organic matter soils usually have less available copper, iron, manganese and zinc than soils with moderate amounts of organic matter.

Zn content in soil was observed to be increasing with increase in *Biosil* doses from 1.40 kg/ha (T1-150), to 1.8 (T6-900). The optimum treatment T6-900 showed 25.0% increase over initial value, 22.45% increase over T7-RDF and 24.14% increase over T8-VC control. The correlation coefficient with *Biosil* doses was R: 0.79. *Biosil* treatment was followed by T7-RDF with 1.47 kg/ha zinc and T8-VC with 1.45 kg/ha zinc. This shows that *Biosil* and RDF are capable of mobilizing the zinc in the soil and make it available to the plants.

Similar observations of FA application from 0 to 20% [24] and from 0 to 100 t/ha [31] along with RDF on soil nutrients have been observed. Micronutrients (Fe, Cu, Zn, Mn and Mo) and heavy metals (Cr, Co) were observed to occur within permissible limits in soil as a result of FA addition [24, 26].

Biosil Treatments and Soil Quality

Biosil+RDF treatments were observed to be beneficial for improving physicochemical quality and fertility of soil. *Biosil* doses reduced the BD of soil and were capable to mobilize the nutrients in soil namely available N, P, K, S, & Zn, and EC while RDF was mainly responsible for improvement of pH of soil and VC improved OC and BD of soil. However, all the three conditioners had some or other role in improving the quality and fertility of soil. The *Biosil* doses improved the soil parameters over initial values and over and above VC control and upgraded the beneficial impact of RDF (Table 15). Optimum *Biosil* doses improved initial status of soil with respect to pH (2.82% increase); K (2.69% increase), S (5.50% increase), and Zn (20.83% increase); EC (6.45% increase), OC (6.25% increase), N (0.80% increase), BD (- 4.11% decrease) and P (3.73% increase). *Biosil* treatments showed 0.0% to 33.93% better results than VC except OC and 0.0% to 6.25% better results than RDF except pH, BD, N and Zn.

Conclusion

It is concluded from the present study that addition of soil conditioner *Biosil* improved the soil health and thus increased the growth and yield components which gave higher yield. Other workers [6, 12] also observed increased uptake of N, P and K by rice plant due to application of FA. Increasing levels of *Biosil* increased the yield of paddy and *Biosil* @900 kg/ha with RDF gave highest yield of paddy. It is expected that long term application of *Biosil* might result in improving EC of soil significantly.

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Competing Interests

None declared.

Table 1: Effect of Different Treatments on Plant Height (cm)

Treatments	30 DAT	60 DAT	90 DAT	At Maturity
T1-150	43.5	69.4	94.4	98.9
T2-300	44.6	73.8	95.2	103.1
T3-450	47.4	74.2	96.3	103.3
T4-600	48.4	75.8	96.4	104.7
T5-750	48.4	78.8	96.8	104.8
T6-900	53.1	93.5	101.5	105.9
T7-RDF	43.1	67.5	93.5	101.2
T8-VC	45.5	73.2	94.9	103.1
SEm ±	0.90	3.58	0.75	0.28
CD at 5%	2.65	10.49	2.21	0.83
CD (R^2)	0.9	0.76	0.76	0.81
CC (R)	0.95	0.87	0.87	0.90

DAT: Days after transplantation; CD: Coefficient of Determination; CC: Correlation Coefficient

Table 2: Effect of Different Treatments on Number of Leaves/m^2

Treatments	30 DAT	60 DAT	90 DAT	At Maturity
T1-150	129	567	764	606
T2-300	137	575	790	629
T3-450	140	590	796	630
T4-600	142	596	802	652
T5-750	158	602	822	658
T6-900	167	639	826	675
T7-RDF	110	543	734	600
T8-VC	135	573	765	618
SEm ±	4.44	17.66	8.53	15.02
CD at 5%	13.02	51.71	24.99	43.97
CD (R^2)	0.92	0.90	0.94	0.96
CC (R)	0.96	0.95	0.97	0.98

DAT: Days after transplantation; CD: Coefficient of Determination; CC: Correlation Coefficient

Table 3: Effect of Different Treatments on Leaf Area/m^2

Treatments	30 DAT	60 DAT	90 DAT	At Maturity
T1-150	1972.7	12471.8	21682	16280
T2-300	2406.3	13861.6	24109	18082
T3-450	2466.5	14857.0	24929.2	18738.9
T4-600	2438.0	15125	24991	19048.5
T5-750	2773.3	15772	25719	20642.7
T6-900	2808.9	15871	27429.7	21649.2
T7-RDF	1923.1	12140.5	20930.5	13528.2
T8-VC	2255.1	12838.2	21956.5	17542.0
SEm ±	147.49	373.04	518.65	1694.54
CD at 5%	431.77	1092.07	1518.32	4960.65
CD (R^2)	0.86	0.90	0.90	0.96
CC (R)	0.93	0.95	0.95	0.98

DAT: Days after transplantation; CD: Coefficient of Determination; CC: Correlation Coefficient

Table 4: Effect of Different Treatments on Leaf Area Index (LAI)

Treatments	30 DAT	60 DAT	90 DAT	At Maturity
T1-150	0.20	1.24	2.10	1.75
T2-300	0.30	1.30	2.40	1.60
T3-450	0.24	1.30	2.50	1.60
T4-600	0.24	1.40	2.50	1.60
T5-750	0.27	1.50	2.50	2.00
T6-900	0.28	1.60	2.74	2.20
T7-RDF	0.19	1.20	2.00	1.60
T8-VC	0.20	1.30	2.20	1.80
SEm ±	0.01	0.03	0.04	0.05
CD at 5%	0.04	0.10	0.14	0.16
CD (R^2)	0.01	0.94	0.81	0.53
CC (R)	-0.12	0.97	0.9	0.73

DAT: Days after transplantation; CD: Coefficient of Determination; CC: Correlation Coefficient

Table 5: Correlation Coefficients between LAI and Yield Parameters of Rice

	Number of effective tillers	Length of panicle	Number of grains	Test weight	Grain yield	Straw yield
Correlation Coeffieient (R)	0.95	0.98	0.98	0.73	0.94	0.98
Coefficient of Determination (R^2)	0.91	0.97	0.96	0.53	0.88	0.96

Table 6: Effect of Different Treatments on Number of Tillers/m^2

Treatments	30 DAT	60 DAT	90 DAT	At Maturity
T1-150	171	233	281	287
T2-300	183	235	283	300
T3-450	190	236	285	305
T4-600	191	252	285	307
T5-750	208	260	308	312
T6-900	233	312	352	366
T7-RDF	162	212	260	254
T8-VC	171	235.	283	299
SEm ±	12.13	8.60	9.76	24.81
CD at 5%	35.51	12.17	28.58	72.63
CD (R^2)	0.9	0.74	0.69	0.71
CC (R)	0.95	0.86	0.83	0.84

DAT: Days after transplantation; CD: Coefficient of Determination; CC: Correlation Coefficient

Table 7: Effect of Different Treatments on Yield Attributes

Treatments	No of Effective Tillers/m-2	Length of Panicle (cm)	No. of Grains/ Panicle	Test Weight (g)
T1-150	192	26.2	143	23.4
T2-300	231	28	146	23.6
T3-450	235	28.3	148	23.7
T4-600	242	28.7	149	23.8
T5-750	252	29	149	24.2
T6-900	306	30	152	24.2
T7-RDF	189	25.5	142	23.4
T8-VC	217	26.3	145	23.5
SEm ±	30.14	0.32	0.99	0.11
CD at 5%	88.25	0.96	2.92	0.32
CD (R^2)	0.85	0.9	0.92	0.94
CC (R)	0.92	0.95	0.96	0.97

CD: Coefficient of Determination; CC: Correlation Coefficient

Table 8: Effect of Different Treatments on Grain Yield and Straw Yield

Treatments	Grain Yield (q/ha)	Straw Yield (q/ha)
T1-150	41.5	58.3
T2-300	44.5	68.1
T3-450	45.3	71.9
T4-600	45.8	73
T5-750	47.3	73.6
T6-900	47.7	77.4
T7-RDF	40.2	50.2
T8-VC	45.2	68.3
SEm ±	1.6	6.3
CD at 5%	4.8	18.5
CD (R^2)	0.9	0.83
CC (R)	0.95	0.91

Table 9: Optimum Dose of *Biosil* in Treatments and Comparison of the Results of Treatments on Plant Growth and Productivity

Parameters of Plant Growth & Yield	Optimum Dose of *Biosil* with RDF (kg/ha)`	Period for Maximum Value	Trend of Positive Impact	% Increase over T7-RDF Control
Plant Height	T6-900	90 DAT	BS+RDF>VC>RDF	38.52
Number of Leaves	T6-900	90 DAT	BS+RDF>VC>RDF	12.53
Leaf Area	T6-900	At maturity	BS+RDF>VC>RDF	60.03
Leaf Area Index	T6-900	At maturity	BS+RDF>VC>RDF	37.50
Number of Tillers /m^2	T6-900	At maturity	BS+RDF>VC>RDF	44.10
Number of Effective Tillers	T6-900	At maturity	BS+RDF>VC>RDF	61.91
Length of Panicle	T6-900	At maturity	BS+RDF>VC>RDF	17.65
Number of Grains/ Panicle	T6-900	At maturity	BS+RDF>VC>RDF	7.04
Test weight	T6-750	At maturity	BS+RDF>VC>RDF	2.98
Grain Yield	T6-900	At maturity	BS+RDF>VC>RDF	18.66
Straw Yield	T6-900	At maturity	BS+RDF>VC>RDF	54.18

Biosil: BS

Table 10a: Physicochemical Characteristics of Soil of Experimental Fields before Sowing

Description	Particle Size Analysis			Texture
	Sand	Silt	Clay	
Parameter value	26.18	19.18	55.64	Clayey
Quality ratings	ideal	ideal	Unacceptable	Acceptable

Table 10b: Physicochemical Characteristics of Soil of Experimental Fields before Sowing

pH	E.C. (dS/m)	Organic Carbon (%)	Bulk Density (g/cc)	Available Plant Nutrients (kg/ha)				
				N	P	K	S	Zn
7.1	0.31	0.64	1.46	372	17.45	297	9.1	1.20
Ideal	Ideal	Medium	--	Medium low	Low	Medium	--	--

Table 11: Soil Fertility Classification Followed in Maharashtra & Some Other States

Soil fertility level	Organic carbon (%)	Available N (kg/ha)	Available P2O5 (kg/ha)	Available K2O (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 [34]

Table 12: 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 [21]

[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 13: Effect of Different Treatments on Soil Properties after Harvest of Paddy Crop

Treatment	Soil pH	E.C. (dS/m)	Organic Carbon (%)	Bulk Density (g/cc)	Soil nutrients				
					N	P	K	S	Zn
Initial Status	7.1	0.31	0.64	1.46	372	17.45	297	9.1	1.20
T1-150	7.2	0.33	0.64	1.45	373	16.9	297	9.5	1.40
T2-300	7.25	0.33	0.66	1.44	374	17.4	297	9.5	1.42
T3-450	7.3	0.34	0.67	1.44	374	17.5	303	9.5	1.45
T4-600	7.3	0.34	0.67	1.43	374	17.6	305	9.6	1.45
T5-750	7.3	0.35	0.68	1.41	375	17.7	308	9.6	1.49
T6-900	7.3	0.35	0.68	1.40	375	18.1	310	9.8	1.80
T7-RDF (Control)	7.4	0.33	0.64	1.50	375	18.0	299	9.4	1.47
T8-VC (Control)	7.1	0.32	0.72	1.36	280	17.8	302	9.5	1.45
SEm ±	0.04	0.005	0.006	0.01	32.9	0.3	2.98	0.12	0.08
CD (at 5%)	0.92	0.01	0.01	0.04	98.4	0.8	8.7	0.37	0.25
CoD (R^2)	0.0	0.91	0.85	0.92	0.85	0.69	0.19	0.77	0.63
CC (R)	0.05	0.96	0.92	- 0.96	0.92	0.83	0.43	0.88	0.79

(SEm: Standard Error around mean; CD: Critical Difference; CoD: Coefficient of Determination; CC: Correlation Coefficient); T1-150 to T6-900 *Biosil* treatments from 150 kg/ha to 900 kg//ha + RDF; RDF: recommended dose of fertilizers; VC:vermicompost

Table 14: Critical Levels of Secondary Nutrient Sulphur and Micronutrient Zinc in the Soil

Elements	Critical level in soil
Sulphur	10 ppm
Zinc	0.6 ppm

Source: Singh [16]

Table 15: Comparison of Results of Different Treatments and Controls

Parameters	% Increase in optimum treatment over Initial value	Optimum Treatment	Trend of Improvement over Initial Value	% Increase/ decrease in optimum treatment over T8-VC	% Increase/ decrease in optimum treatment over T7-RDF
pH	2.82	T3-450	RDF>(BS+RDF)	2.82	-1.35
EC	6.45	T5-750	(BS+RDF)>RDF>VC	3.13	0.0
OC	6.25	T5-750	VC>(BS+RDF)	-5.56	6.25
BD	-4.11	T6-900	VC>(BS+RDF)	2.94	-6.67
Available N	0.80	T5-750	(BS+RDF)=RDF>VC	33.93	0.0
Available P	3.73	T6-900	(BS+RDF)=RDF>VC	1.69	0.56
Available K	2.69	T4-600	(BS+RDF)>VC>RDF	0.0	2.01
Available S	5.50	T4-600	(BS+RDF)>VC>RDF	1.05	2.13
Available Zn	20.83	T4-600	(BS+RDF)>RDF>VC	-1.36	0.0

Abbreviations and Symbols

BD: bulk density;

EC: electrical conductivity;

LA: leaf area;

NT: number of tillers/m2;

OC: organic carbon/matter;

SY: straw yield;

BS: Biosil;

FA: fly ash

LAI: leaf area index;

NG: number of grains/panicle;

PH: plant height;

TW: test weight;

DAT: days after transplantation;

GY: grain yield;

LP: length of panicle;

NET: number of effective tillers/m2;

RDF: recommended dose of fertilizers;

VC: vermicompost.

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