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Effect of Fly Ash Based Soil Conditioner (Biosil) and Recommen ded Dose of Fertilizer on Soil Properties, Growth and Yield of Wheat

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***Abstract*: -** Fly ash has been used in agriculture for improving the soil health and to increase the crop productivity with very high doses 10% to 80% of fly ash. In order to mitigate the impact of excess dose in terms of boron and heavy metal toxicity, present investigation was undertaken to process fly ash into improved soil conditioner "Biosil" through magnetization and to conduct field trials using wheat (*Triticum aestivum* L.) variety GW-273 with Biosil fortified by recommended dose of chemical fertilizers keeping Vermicompost and recommended dose of chemical fertilizers as control treatments. Very low Biosil doses resulted in improvement in soil quality, fertility, crop growth & productivity. The optimum concentration of Biosil dose was recorded to be in the range of 450 kg/ha to 900 kg/ha which were effective in reducing bulk density and improving organic carbon, phosphorus, potassium, sulphur and zinc which are generally deficient in Indian soils as per the results of national soil survey by Indian Council of Agricultural Research (ICAR). Vermicompost and chemical fertilizers were also effective in improving soil fertility. The Plant height, number of leaves/plant, length of earhead, number of grains/earhead, test weight, grain yield and straw yield showed improvement with the increasing Biosil doses. Vermicompost and chemical fertilizers were next to Biosil in improving the growth and yield of wheat. It is recommended that long term trials with Biosil fortified by chemical fertilizers and Vermicompost would be more beneficial for sustainable agriculture.

***Keywords:* -** *Chemical Fertilizer, Fly ash, Soil, Vermicompost, Wheat*

I. INTRODUCTION

The amount of fly ash produced annually in India was around 90 million tonnes during 1995 and is likely to cross the 140 million tonne barrier during 2020. Its disposal is a major concern. In India, most thermal power plants use bituminous coal as a fuel which contains a high amount of ash (up to 40%). Fly ash possesses unique physicochemical properties and has potential for its reuse in various sectors. There is also ample scope to process fly ash to make it a valuable product in different areas through applying suitable technology. Among all the recycling and reuse method for fly ash, agricultural utilization of fly ash as soil conditioner is now popular and can use huge quantity of fly ash produced in India.

In the past, various research studies evaluated the impact of fly ash on soil and crop productivity [1, 2, 3, 4, 5]. Trace elements in fly ash are found at concentrations which are higher than those in coal that act as source of micronutrients for healthy growth of plants, however the concentrations of biologically toxic elements such as B, Mo and Se greatly exceed their levels in soil [6]. To mitigate these problems, several techniques are being used like use of weathered fly ash or use of physically or chemically modified fly ash.

In order to mitigate the environmental problem, present study is proposed to study the effects of augmentation of soil with magnetized fly ash "Biosil" fortified with recommended dose of chemical fertilizers, keeping Vermicompost and chemical fertilizer as controls, on the growth and yield parameters of wheat and improvement of soil quality and fertility. The results of field trials will be used to optimize the dose of Biosil and its fortifications for improvement of wheat crops in the black soils of Jabalpur, Madhya Pradesh, India.

II. MATERIALS AND METHODS

The field experiments were conducted in an agricultural field near Jabalpur, Madhya Pradesh, India that comes under Kymore Plateau & Satpura Hills Agroclimatic Region of India. The main crops of the area are wheat, rice, pulses, oil seeds, and maize. Fly ash from Koradi Thermal Power Station at Koradi, District Nagpur, Maharashtra State, India was securely collected and processed to produce novel soil conditioner “Biosil” by the process of magnetization.

Field experiments were conducted during Rabi season (October to March) 2011-2012 using wheat (*Triticum aestivum* L.) variety GW-273. The different doses of soil conditioner “Biosil” ranging from 150 kg/ha to 900 kg/ha, fortified with recommended dose of fertilizers (RDF), was applied to the agricultural field to study the improvement in quality & fertility of soil and growth & yield of wheat crop. The results of (Biosil+RDF) were compared with those obtained from RDF control and Vermicompost (VC) control. Randomised Block Design was used with a total 32 number of plots and 4 replications. Gross and net plot sizes were 6m x 4m and 5.6m x 3.6m respectively. The distance between plots were kept at 1.5 m and the distance between replications was kept at 2 m. Soil samples collected from the test sites were analyzed for physical and chemical characteristics [7, 8]. Surface soil-samples (0-30 cm) collected from three areas, were analyzed and averaged for site characterization. The levels of “Biosil” addition (on an oven-dry basis) were selected on the basis of preliminary field trials conducted earlier.

The details of treatment are given in TABLE I. Wheat cultivar GW-273 was sown with six levels of Biosil along with RDF (120:69:40 kg NPK/ha). Biosil was applied to the soil at the time of sowing. Nitrogen (50% dose), phosphorus (100% dose) and potash (100% dose) were applied as basal dose. Two Nitrogen (25%) doses were applied as top dressing after one and two months. Statistical analyses were carried out to establish the effects of fly ash addition on soil characteristics and crop yields.

Soil samples from the experimental field were analyzed before sowing and after harvest of crop for the parameters namely pH, electrical conductivity (EC), bulk density (BD), nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and zinc (Zn). In case of crops, pre-harvest observations at maturity were recorded on plant population (Number of plants/m2), plant height (cm), and number of leaves/plant, while post-harvest observations were made on number of effective tillers/m2, length of earhead (cm), number of grains/earhead, test weight (g), grain yield (q/ha) and straw yield (q/ha).

III. RESULTS AND DISCUSSION

3.1 Climate and Meteorological Status

Jabalpur has a humid subtropical climate, typical of North-Central India (Madhya Pradesh and Southern Uttar Pradesh). Summer starts in late March and last up to June. May is the hottest month. The total annual precipitation is nearly 55 inches (1386 mm). Jabalpur gets moderate rainfall of 35 inches (889 mm) during July-September due to the southwest monsoon. Winter starts in late November and last until early March. They peak in January. The annual average meteorological status of 3 years is given in TABLE II. The annual average temperature ranged from 25.1 ^{0}C to 26.2 ^{0}C with maximum temperature from 31.5 ^{0}C to 32.5 ^{0}C and minimum temperature from 19.6 ^{0}C to 20.6 ^{0}C. Total annual precipitation ranged from 1375.40 mm with 62 to 86 days with rain, 17 to 33 days with thunderstorm, with fog from 0 to 5 days and with hail from 0 to 1 day. The annual average wind speed ranged from 2.9 to 3.0 km/h.

3.2 Preparation of ‘Biosil’ Soil Conditioner

Refined magnetized fly ash ‘Biosil’, imparting magnetic activity and adding economic value to fly ash for use as a soil conditioner was used in present investigation. Biosil was prepared by passing it through a magnetizer under controlled conditions.

3.3 Quality of Soil of Experimental Field before Sowing

A field experiment was conducted during Rabi 2011-12. The soil of Jabalpur region is broadly classified as Vertisol as per norms of US classification of soil. It is 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.

The mean values of the surface soil data before sowing are presented in TABLE III. The soil of experimental field showed particulate composition as sand 25.18%, silt 19.18% and clay 55.64% and thus the texture is clayey. The soil pH is 7.1 which is neutral and is in the range 7.0 to 8.5 which is favorable for most crops and most of the essential nutrients are available within this pH range (Table IV; Fig.1). The EC is 0.31 dS/m which is below the desirable level for black soils for most plants (TABLE V). The Bulk Density of Soil is 1.46, which is much higher than the ideal Bulk Density of 1.10 for clayey soils (TABLE VI).

The soil fertility was assessed based on the guidelines for rating the soil fertility indicators (TABLE VII). The qualitative ratings of soil, arising from the comparison between soil data and the indicator's stratification are presented in TABLE VIII that reveals that the organic carbon content was medium, available N medium-low, available P low, and available K medium in soil before sowing. The low to medium nutrient status is due to medium content of organic carbon which plays an important role in binding nitrogen and other nutrients in the soil protecting them from leaching out. Under low organic carbon content in soil, 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. Therefore widespread nitrogen deficiency is not surprising.

Overall, the soil of experimental field 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 by ICAR. 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 [9].

3.4 Effect of Treatments on Soil Properties

The initial soil quality before sowing and the final soil quality after harvest in different treatments are presented in TABLE IX.

3.4.1 Soil pH

Soil pH was recorded before sowing as well as after harvest of crop. It did not change significantly neither with the application of Biosil in combination with RDF nor due to the addition of VC or RDF (TABLE IX). Soil pH increased to 7.2 in T3-300 to T4-600 treatments. Indian fly ashes are alkaline due to presence of low sulphur and appreciable content of oxides of Ca, Mg etc. in coals and an increase in the pH of mine spoil after lignite fly ash amendments during field study has been reported [10]. This low response of soil may be due very low application of Biosil as compared to conventional doses given from 10% to 80% of fly ash:soil mixture, where change in pH is reported [11,12,13]. Another reason is that this is first year of application of Biosil and long term treatments are expected to give more desirable results.

3.4.2 Electrical Conductivity

Electrical conductivity of soil was correlated (R: 0.5; R2: 0.25) with Biosil+RDF doses (Table IX, Fig. 2). T2-300 treatment showed maximum 6.45% increase in electricity conductivity of soil, showing Biosil (300kg/ha) as optimum dose for improving electrical conductivity (TABLE XA and XI). RDF also showed equivalent increase in electrical conductivity by 6.45%. Vermicompost was lowest among them with 3.23% increase in electricity conductivity over initial, showing trend as given below, RDF+Biosil>RDF>VC (TABLE XI). Similarly, gradual increases in soil pH and conductivity [13, 14, 15, 16] has been observed with increased application rate of fly ash.

3.4.3 Bulk Density

The initial bulk density of soil 1.46 g/cc decreased due to application of Biosil+RDF in the range of 1.41 g/cc to 1.44 g/cc that is by 1.37% to 3.43% and negatively correlated with Biosil+RDF doses (R: -0.93; R2: 0.86) (TABLE IX; Fig. 2). The reduction was more pronounced due to addition of Vermicompost which had significantly lowest value of bulk density (1.37 g/cc) showing -12.33% reduction. Bulk density did not decrease in RDF treatment (TABLE XA). The Vermicompost (8t/ha) treatment proved superior over the lowest doses of Biosil i.e. 150, 300, and 450 kg/ha and RDF control also. This shows that the application of Biosil @600 kg/ha (T4-600) and vermicomppost @8t/ha are sufficient to keep the soil porous. However, the bulk density is required to be reduced to 1.10 g/cm3 which is ideal for clayey soils (TABLE VI). These changes in soil properties might have been due to modification in macro- and micro-pore size distribution in black soils of Jabalpur and which may have also contributed to the increased crop yield. Reduction of bulk density in these soils is also advantageous for reduced hydraulic conductivity and improved moisture retention at field capacity and wilting point.

Similar observations have been recorded [17] that fly ash addition in soil resulted in lower bulk density, although the differences compared with control plots were not significant. Application of fly ash at 0, 5, 10 and 15% by weight in clay soil significantly reduced the bulk density and improved the soil structure, which in turn improves porosity, workability, root penetration and moisture-retention capacity of the soil [18]. Fly ash treated plots tended to have lower bulk density of surface soil (0-30 cm) by 5.9 percent under 20 t/ha fly ash treatment, though the differences over control were non-significant for both sorghum and wheat crop [19].

3.4.4 Soil Organic Carbon

Organic carbon of soil recorded after harvest of crop showed improvement in Biosil+RDF treatments by 1.56% in T1-150 (0.65% organic carbon) to 7.81% in T4-600 (0.69% organic carbon) over initial value (0.64% organic carbon) as well as over RDF control (0.64% organic carbon). The highest organic carbon (0.73%) (Increase by 14.06%) was noted in the plots receiving Vermicompost @ 8t/ha and it was found at par to higher doses of Biosil (T4-600,T5-750 and T6-900) (Table IX, XA; Fig. 2). These organic carbon levels (0.69% in Biosil+RDF and 0.73% in Vermicompost) are medium as compared to soil fertility classification and are in optimum range for the crops (TABLE VII). Similar observation have been reported [13]wherein increase in organic carbon and electrical conductivity was observed after application of fly ash at 50t/ha in wheat field. Biosil dose of 600kg/ha was optimum for improving organic carbon and the trend was VC>Biosil+RDF>RDF (Table XI).

The importance of organic carbon is due to its positive correlation with nutrient content of soil. The method of analyzing organic carbon of the soil in order to assess nitrogen content of the soil is most commonly adopted. Therefore, there is need to utilize Biosil + RDF as well as Vermicompost in order to get highest benefit with respect to soil fertility and crop productivity. This will be helpful to retain major portion of the soil nitrogen, phosphorus and sulphur in the soil in the organic form. As the organic matter decomposes, these nutrients are released in the soil and absorbed by the plant roots. A soil rich in organic matter is always found rich in nitrogen. However, organic carbon should not be very high that is >1.00% that make the nitrogen less available to the plants.

3.4.5 Nitrogen

Application of Biosil+RDF treatments did not brought any significant change in the content of nitrogen in soil over initial status of soil. Similarly different treatmentsof Biosil+RDF did not exhibit marked variations among the doses (TABLE IX; Fig. 4). The T6-900 treatment showed 1.08% increase in soil nitrogen, while Vermicompost showed 2.15% and T7-RDF showed 0.54%, showing Vermicompost as having best results among the treatments (TABLE XB). T6-900 is the optimum dose of Biosil and the trend of improvement is VC>Biosil+RDF>RDF (TABLE XI). Low level increase in Biosil+RDF Treatments is explained by the initial nitrogen deficiency in the soil and luxury uptake of nitrogen by the wheat crop. It is reported [20] that fly ash incorporation on soil led to uptake of nitrogen, phosphorus and potassium by rich amount and succeeding wheat also increased with increasing fly ash amendment. Better results were recorded with higher doses of fly ash [21] where a distinct increase in the concentrations of N, P, K, S, in soil plus fly ash mixtures was obtained with concomitant increase in fly ash percentage.

3.4.6 Phosphorus

The content of phosphorus markedly increased over initial status of 17.45 kg/ha due to increasing doses of Biosil+RDF (R: 0.94; R2: 0.88) that is T4-600 (17.90 kg/ha), T5-750 (17.9 kg/ha) and T7-900 (18.30 kg/ha) (TABLE IX; Fig. 3), showing 2.58% to 4.87% increase, while Vermicompost and RDF control each showed only 2.58% increase over initial level (TABLE XB). Thus, Biosil+RDF treatment is best to improve the phosphorus content of soil and facilitate the phosphorus mobilization in the edaphic environment. The optimum Biosil dose is 900 kg/ha (T6-900) and the trend of improvement is Biosil+RDF>RDF=VC (TABLE XI). These results indicate that Biosil+RDF treatment facilitate the activity of phosphate solubilizing bacteria in soil. Similar result is obtained by a worker [21] who reported good adaptability of phosphate solubilizing bacteria to fly ash amended soils and better survival exhibiting 36.4% to 86.1% phosphate solubilization, and the population of phosphate solubilizing bacteria in fly ash amended soils mixed with chemical fertilizer was higher in the presence of fly ash, a level as high as 12%. Increase in phosphorus content with increase in fly ash doses is also observed [15].

3.4.7 Potassium (K)

Good improvement in potassium content in Biosil+RDF treatment plots was observed over initial status (R: 0.64; R2: 0.41). The initial potassium content of 297 kg/ha was observed to be increased to 303 kg/ha in T6-900 treatment showing 2.02% increase, while RDF treatment showed 298 kg/ha (0.34% increase) and Vermicompost showed 380 kg/ha (1.68% increase) (TABLE IX & XB, Fig. 4). Thus, Biosil 900 kg/ha is optimum for mobilization of potassium, followed by Vermicompost, the trend being Biosil+RDF>VC>RDF (TABLE XI). Biosil+RDF was 1.34% more effective than T7-RDF and superior than T2-300 treatment. Biosil dose upto T2-300 were less effective than T8-VC but T3-450 to T6-900 treatments were more effective than T8-VC. Similar observation is recorded wherein a distinct increase in the concentrations of N, P, K, S were observed in soil plus fly ash mixtures with concomitant increase in fly ash percentage [21].

3.4.8 Sulphur

The initial sulphur content (9.2 kg/ha) is close to the critical level (10 ppm) and significant improvement was observed due to application of each dose of Biosil+RDF (R: 0.88; R2: 0.77) which proved superior over Vermicompost @ 8t/ha. The Biosil+RDF treatments showed increase in level of sulphur up to 9.5 kg/ha in T6-900 (3.26% increase over initial level), while Vermicompost and RDF controls showed 9.3 kg/ha sulphur (1.09% increase over initial level) (TABLE IX, XC and XI). Thus, the minimum optimum concentration of Biosil+RDF treatment is 600kg/ha, and the trend of improvement is Biosil+RDF>VC=RDF (TABLE XI). Biosil treatment (T6-900) was 3.26% more effective than T7-RDF and 2.15% more effective than T8-VC. This indicates that the Biosil+RDF has capacity to mobilize S from the soil and make it available to the growing crop. Similar observations have been recorded by other authors that the fly ash improves the nutrient status of soil [22].

3.4.9 Zinc

Zinc content also showed the similar improvement over initial status (1.2 kg/ha) of soil in different treatments. The Biosil+RDF treatments showed linear increase (R: 0.84; R2: 0.71) in Zn content as 1.33 kg/ha (T1-150), 1.35 kg/ha (T2-300), 1.45 kg/ha (T3-450) showing percentage increase as 10.83%, 12.50% and 20.83% respectively) (TABLE IX, XC; Fig.3). While Vermicompost and RDF controls, each one with 1.46 kg/ha zinc, showed 21.67% increase over initial level in both, showing trend as VC=RDF>Biosil+RDF (TABLE XI). Thus, all the three treatments are more or less equivalent in improving the zinc content of soil. T3-450 is the optimum Biosil treatment. This is in conformity with [21] who observed that on fly ash addition to agricultural field, micronutrients (Fe, Cu, Zn, Mn and Mo) and heavy metals (Cr, Co) were observed to occur within permissible limits in soil,

It is thus concluded that the Biosil+RDF, Vermicompost and recommended dose of fertilizers are effective in improving the soil fertility by mobilizing the macro- and micro-nutrients in the soil. Biosil+RDF range of T4-600 to T6-900 treatments with Biosil dose of 600 to 900 kg/ha was, in general, observed to be optimum for improving the physicochemical status of black soil of Jabalpur, especially nutrient content and fertility. This shows that magnetized fly ash Biosil at very low doses, has remarkable property of improving the flow of available nutrients to the plant roots, thereby improving the growth of plant. Biosil+RDF and Vermicompost were more or less equally highly effective followed by RDF. Biosil+RDF treatment was more effective for improving electrical conductivity, phosphorus, potassium,, sulphur; Vermicompost was more effective for improving organic carbon, bulk density, nitrogen and zinc; while RDF was suitable for phosphorus, sulphur and zinc. These conclusions are in conformity with other workers [19] who observed that fly ash (5, 10, 20 t/ha) with nitrogen (25, 50, 100 kg/ha) treated plots of wheat and sorghum showed decrease in pH, whereas electrical conductivity increased in accordance with the amounts of fly ash added in the soil. Organic carbon and sodium increased with fly ash addition.

3.5 Effect on Growth and Yield of Wheat

The effects of soil conditioner Biosil+RDF were assessed on wheat crop and compared with Vermicompost and RDF controls (TABLE XII, XIIIA-B, XIV; Fig. 5, 6).

3.5.1 Plant Population

Results revealed that the plant population did not vary much under different treatments; however no reduction was observed in any treatment. This shows that all the treatments are favourable for seed germination, seedling growth and vegetative growth which determine population (TABLE XII; Fig.5). TABLE XIVA indicates more positive effect of Vermicompost over Biosil+RDF treatment in respect of plant population.

3.5.2 Plant Height

Plant height is linearly increasing with the increasing dose of Biosil+RDF. The average plant height increases from 86.2 cm in T1-150 through 87.4 cm in T2-300, 88.0 cm in T3-450, 89.2 cm in T4-600, 89.5 in T5-750 and 89.8 cm inT6-900 and is well correlated with Biosil doses (R: 0.97; R2: 0.94). The plant height in T8-VC (88.2 cm) is next highest to Biosil+RDF treatment, followed by T7-RDF with 85.4 cm plant height (TABLE XII; Fig. 6). The plant height stimulation by Biosil+RDF treatments over RDF treatment range from 0.94% to 5.15%. Vermicompost treatment was superior to Biosil doses upto T3-450, however higher Biosil doses from 600 kg/ha (T4-600) to 900 kg/ha (T6-900) showed 1.13% to 1.81% higher stimulation for plant height (TABLE XIIIA). Optimum Biosil dose for plant height is 900kg/ha and the trend of plant height stimulation is Biosil+RDF>VC>RDF (TABLE XIV).

Similar improvements in the growth parameter of trees were obtained by others [11, 21], but with high doses of normal fly ash. Fly ash at 18% [21] resulted in a 15% increase in the growth of Acacia auriculiformis; and co-addition of chemical fertilizers resulted in significant rise in the collar diameter to 2.6 cm corresponding to almost a 19% increase. In *Eucalyptus tereticornis* at 12, 18, and 24% fly ash with the co-addition of chemical fertilizer, there was increase up to 26% in the collar diameter and the plant growth was significantly increased with increasing fly ash percentage and the difference was maintained over the years. Fly ash had no negative effect on the mean annual increment (MAI) of both the tree species and it was rather higher in the presence of fly ash. Similarly, the length of root and shoot of Indian mustard Brassica juncea were observed maximum in the amendment in 60% Fly ash (or 2:3, fly ash and soil) as recorded on 30, 60 and 90 days of experiment. The length of root increased gradually from 10% (28.50%) to 60% (28.55%) and then decreased from 80% fly ash (33.34%) to 100% fly ash (44.5%) as compared to control [11]. The height of wheat plant was observed to be significantly higher (89.10 cm) in treatment NPK + farm yard manure (FYM), however, it was at par with RDF+fly ash (FA) 100 t/ha (84.04 cm), RDF 75%+FA 70 t/h +Vermicompost 2 t/ha (86.12 cm), RDF + FA 40 t/ha + VC 1 t/ha (87.15 cm), RDF + FA 20 t/ha + VC 1 t/ha (85.89 cm) and RDF + VC 1 t/ha (85.28 cm), indicating that the application of FYM, VC and FA in combination with recommended dose of NPK for wheat was beneficial[23].

3.5.3 Number of Leaves/Plant

Biosil+RDF treatment was observed to be highly stimulating for number of leaves/plant which gradually increases with the increase in the dose of Biosil+RDF and both are well correlated (R: 1.0; R2: 1.0). The number of leaves/plant was 22.80 in T1-150 which increase through 22.85 in T2-300, 25.60 in T3-450, 28.55 in T4-600, 30.88 in T5-750, and 32.65 in T6-900 (TABLE XII; Fig. 6). Biosil+RDF treatment was 22.51% more effective than Vermicompost and 61.16% more effective than RDF. Vermicompost was 31.54% more effective than RDF treatment (Table XIIIA). The optimum dose of Biosil+RDF was 900 kg/ha and the trend of impact is Biosil+RDF>VC>RDF (TABLE XIV). Vermicompost treatment was superior to T3-450 treatment (TABLE XII, XIIIA). This is in conformity with the observation [23] that significantly higher leaf area (20.10 cm2) was recorded in the treatment RDF + FYM 10 t/ha over absolute control, RDF 50 % + FA 100 t/ha and RDF 75 % + FA 70 t/ha. The reduction in dose of NPK reduced flag leaf area significantly.

Similar observations have been recorded in case of other soil conditioners [24]. It is reported, in Turkey in 2004, that the number of leaves, leaf area, most developed root length, fresh and dry root weight and increasing fresh weight of strawberry plants were increased at an important level ($p<0.01$) in 30% and 45 % pumice amendments in 4-8 mm grade compared to control. The highest number of leaves, leaf area, most developed root length, fresh and dry root weight and increasing fresh weight were also obtained from 45% pumice amendments in 4-8 mm grade. It is observed in case of *Brassica juncea* that the number of leaves and flowers per plant increased from control to 60% fly ash. However, the number of pods showed a 100% increase from control to 40% fly ash (2:3 fly ash and soil). A maximum of twelve pods was observed in 40% fly ash (2:3 fly ash and soil) [11].

3.5.4 Number of Effective Tillers/m2

Biosil+RDF treatments were again very effective in increasing the number of effective tillers/m2 showing linear increase in number with increasing doses of Biosil. The initial number of effective tillers 221.5 in T1-150 increases through 243.8 in T2-300, 245.0 in T3-450, 249.7 in T4-600, 256.8 in T5-750 and 299.4 in T6-900, showing good correlation (R: 0.9; R2: 0.81) (Table XII; Fig. 5) . The next highest number of tillers/m2 was 244.4 in T8-VC followed by 198.9 in T7-RDF. Vermicompost treatment was superior to T2-300 treatment. The Biosil+RDF treatment was 50.53% more effective than RDF and 22.50% more effective than VC. VC treatment was 22.88% more effective than RDF treatment. The optimum Biosil dose was 900 kg/ha (T6-900) and the trend of effective treatment was Biosil+RDF>VC>RDF (TABLE XIV). Similar observation have been noted [23] wherein numerically higher number of tillers (4.61) were obtained by the application of NPK + FA 100 t/ ha over the application of NPK only (3.89)

3.5.5 Length of Earhead

Biosil+RDF treatment was highly stimulative for the length of earhead showing linear increase in the length with increase in the doses of Biosil+RDF. The length of earhead (cm) was 9.4 in T1-150 that increased through 9.5 in T2-300, 9.6 in T3-450, 9.7 in T4-600 and T5-600 each and 9.8 in T6-900 treatment, showing good correlation (R: 0.98; R2:0.96). The next highest length was 9.5 cm in T8-VC followed by 9.1 cm in T7-RDF treatment (TABLE XII; Fig .6). Biosil+RDF treatments were 3.30% to 7.69% more effective than T7-RDF treatment. The T3-450 to T6-900 treatments were effective by 1.05% to 3.16% than T8-VC treatment. T8-VC treatment was 17.8% more effective than T7-RDF treatment and T1-150 treatment (TABLE XIIIB). Biosl 900 kg/ha dose was optimum while the trend was Biosil+RDF>VC>RDF (TABLE XIV).

Similarly the length of spike was higher in RDF + FYM 10 t/ha (9.28 cm) over absolute control, RDF, RDF 50 % + FA100 t/ha and RDF 75 % + FA 70 t/ha indicating that the application of FYM, VC and FA had beneficial effect [23]. It is interesting to note that the application of fly ash along with the recommended dose of NPK and

Vermicompost has beneficial effect on wheat. Further, it was also noticed that the application of fly ash along with NPK had beneficial effect over application NPK only.

3.5.6 Number of Grains/Earhead

There is full correlation between doses of Biosil+RDF and number of grains/earhead (R: 1.0; R2: 1.0). The number of grains/earhead was 53.9 in T1-150 and further increased through 55.7in T2-300, 57.9 in T3-450, 59.8 in T4-600, 61.1 in T5-750, and 63.4 in T6-900 (TABLE XII; Fig. 7), showing percentage increase of 7.8% to 26.8% over T7-RDF. The treatments T4-600 to T6-900 showed 1.53% to 7.64% increase over T8-VC treatment (TABLE XIIIB). Vermicompost treatment was 17.8% effective than RDF treatment and superior to T3-450 treatment.

3.5.7 Test Weight

Test weight is well correlated with the doses of Biosil+RDF (R: 0.9; R2: 0.81). Test weights (g) were recorded to be 42.1, 42.4, 42.6, 43.9, 44.4, 46.5 in T1-150, T2-300, T3-450, T4-600, T5-750 and T6-900 respectively. Next superior treatment was of T8-VC with 44.3 g test weight followed by T7-RDF treatment with 41.8 g test weight (Table XII; Fig.7) with trend Biosil+RDF>VC>RDF. Biosil 900 kg/ha (T6-900) was optimum treatment (TABLE XIV). The Biosil treatments were 0.72% to 11.24% more effective than T7-RDF treatment and the treatments T5-750 to T6-900 were better by 0.23% to 4.97% than VC treatment. VC treatment was 5.98% more effective than T7-RDF treatment and more effective than T4-600 treatment (TABLE XIIIB). Similarly, it has been observed that the application of NPK + Fly ash was found significantly superior over NPK in respect of 1000 grain weight of wheat [23].

3.5.8 Grain Yield

The grain yield and doses of Biosil+RDF were highly correlated (R: 0.97; R2: 0.94). The grain yield (q/ha) was recorded as 47.7, 50.5, 53.8, 57.8, 58.6, 59.4 in T1-150, T2-300, T3-450, T4-600, T5-750 and T6-900 respectively. Next superior treatment was of T8-VC with 56.5 q/ha followed by T7-RDF with 45.5 q/ha grain yield (TABLE XII; Fig.7), with trend as Biosil+RDF>VC>RDF and optimum dose of Biosil as 900 kg/ha (T6-900) (TABLE XIV). Biosil treatments were 4.84% to 30.55% more effective than T7-RDF treatment and the treatments T4-600 to T6-900 were 2.3% to 5.3% more effective than T8-VC. Vermicompost treatment was 24.18% more effective than T7-RDF treatment and was superior over T3-450 treatment (TABLE XIIIB).
The research trials conducted under fly ash mission projects at Farakka [25], revealed that on an average 40 per cent increase in yield of wheat was obtained with the application of fly ash @ 200 t/ha. The results obtained on research conducted at Punjab Agricultural University[26] indicated that, application of fly ash @ 10 t/ha increased the yield of wheat from 21.5 q ha-1 to 24.1 q/ha. It is reported [27] that the soil application of fly ash increased wheat grain yield by 20 percent.

3.5.9 Straw Yield

There was good correlation between straw yield and doses of Biosil+RDF (R: 0.97; R2: 0.94). The recorded straw yields (q/ha) were 70.4, 73.8, 78.5, 86.8, 88.5, 89.6 in treatments T1-150, T2-300, T3-450, T4-600, T5-750 and T6-900 respectively. Next superior treatment was T8-VC with 85.5 q/ha followed by T7-RDF with 74.4 q/ha straw yield (TABLE XII; Fig. 7), with trend as Biosil+RDF>VC>RDF and optimum dose as 900 kg Biosil/ha (T6-900) (TABLE XIV). The Biosil treatments T3-450 to T6-900 were 5.51% to 20.43% more effective than T7-RDF and T4-600 to T6-900 treatments by 1.52% to 4.8% more effective than T8-VC. For the first time, T7-RDF was more superior treatment than T2-300 treatment. T8-VC treatment was superior to T3-450 treatment (TABLE XIIIB).
It is reported that [27] the soil application of fly ash increased wheat grain yield by 2%, and the application of fly ash to soil increased both grain and straw yield in pearl millet (direct) and subsequent wheat (residual) crop significantly at all levels of fly ash [28]. A two year experiment [29] indicated that clay loam soil being higher in CEC, organic matter content, water holding capacity and available nutrients brought an improvement in growth, yield attributes, grain and straw yields and uptake of plant nutrients by wheat when compared with sandy loam soil.

IV. CONCLUSION

These treatments were effective in mobilizing macro and micro nutrients in soil and in improving the soil fertility. Biosil is based on fly ash that generally contains small amounts of C and N, it is medium in available K and high in available P and micronutrients [20], which also form source of nutrients to the soil. Though all the three soil conditioners have some role in mobilizing all the nutrients in soil, it is interesting to see their dominant role in some of them and that Biosil+RDF has better results than RDF as well as vermicompst. This indicates that the potency of RDF (and may be of Vermicompost) may be increased in presence of Biosil.

Similar observation shows [29] that incorporation of fly ash manure and fly ash at 10t/ha, in general, improved cation exchange capacity of soil, organic content, available nutrient status and decrease the soil pH.

Biosil+RDF was highly effective in improving the growth and yield parameters of wheat crop. Next superior treatment was of Vermicompost, which was followed by RDF. This indicates the important contribution of Biosil, Vermicompost and RDF in improving the wheat growth and yield. Biosil (+RDF) in the range of 600 to 900 kg/ha is optimum for stimulating the crop growth and yield in Jabalpur black soils. Overall, it is concluded that the Biosil is very effective at a very low dose of 600 to 900 kg/ha in improving the soil quality and fertility and wheat growth and yield. The promoting effect of Biosil is enhanced by the RDF. Similar observations have been made by other workers [19, 23, 28, 29, and 30]. It is noted [19] that application of fly ash in combination with nitrogen had some advantageous effect on grain and biomass yield of wheat crop irrespective of the variety though the positive effect was non-significant. It is also observed [23] that the application of fly ash @ 100 t/ha along with recommended dose of NPK was found superior over recommended dose of NPK to wheat crop and for soil properties also. A mixture of fly ash and sludge for 4 years [30], each at 26 t/ha, increased the yield of French bean and soybean by 53% and 30%, respectively, over the control treatment that received NPK fertilizers at recommended rates. Unlike sewage sludge or the fly ash-sludge mixture, the application of only fly ash at 52 t ha-1 did not sustain crop yields [28]. Thus it is evident that the fly ash potency can be increased by its combined treatment with RDF and any other organic source.

Thus Biosil may be termed as 'Nuclear Soil conditioner', as it is useful in very low doses to soil. High fly ash doses have been reported to decrease seed germination in Indian mustard as compared to control in very high doses of fly ash from 10% to 100% fly ash [11] and heavy metal and Boron toxicity. This was most likely due to increased impedance offered by the soil / ash matrix to germinating seeds [2].

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VI. REFERENCES

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Table I: Details of Treatments

Code	Treatments
T1-150	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 150 kg/ha)
T2-300	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 300 kg/ha)
T3-450	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 450 kg/ha)
T4-600	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 600 kg/ha)
T5-750	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 750 kg/ha)
T6-900	RDF (120:60:40 kg NPK/ha) + SOIL conditioner (Biosil@ 900 kg/ha)
T7-RDF	RDF (120:60:40 kg NPK/ha) alone
T8-VC	SOIL Conditioner Vermicompost @ 8t/ha)

Table II: Meteorological Status and Climate of Jabalpur

Year	**T**	**TM**	**Tm**	**PP**	**V**	**RA**	**TS**	**FG**	**GR**
2010	26.2	32.5	20.6	1470.40	3.0	62	24	5	0
2011	25.1	31.6	19.6	--	2.9	86	33	0	0
2012	25.2	31.5	19.6	1375.40	3.0	75	17	2	1

Note: T: Annual average temperature (^{0}C); TM: Annual average maximum temp (^{0}C); Tm: Annual average minimum temp. (^{0}C); PP: Total annual precipitation of rain (mm); V: Annual average wind speed (km/h); RA: Total days with rain during the year; TS: Total days with thunderstorm during the year; FG: total days with fog during the year; GR: Total days with hail during the year

Table III: Physicochemical Quality of Soil before Sowing

Texture	**Soil pH**	**E.C. (dS/m)**	**Organic Carbon (%)**	**Bulk Density(g/cc)**	**Available Plant Nutrients (kg/ha)**				
					N	**P**	**K**	**S**	**Zn**
Clayey	7.1	0.31	0.64	1.46	372	17.45	297	9.2	1.20

Table IV: Rating Chart for Soil pH

Soil pH	Rating
Less than 6	Acidic
7.0 - 8.5	Normal (all essential nutrients available)
8.6 – 9.0	Tendency to become alkaline
Above 9.0	Alkali

Table V: Soluble Salt Levels Measured by EC for Crops

S. N.	**E.C. (dS/m)**	**Suitability to Crops**
1.	0 – 0.25	Very low – indicates probable deficiency
2.	0.25 – 0.75	Suitable for seedlings and salt sensitive plants
3.	0.75 – 1.25	Desirable level for most plants
4.	1.25 – 2.25	Reduced growth, leaf margins burn

Source: Douglas Cox (2014) how to use pH and EC “Pens” to monitor Greenhouse Crop Nutrition. University of Massachusetts, Amherst (online site by Center for Agriculture)

Table VI: General Relationship of Soil Bulk Density to Root Growth Based on Soil Texture

Soil Texture	Ideal Bulk Density (g/cm3) for Plant Growth	Bulk Density (g/cm3) that Restrict Root Growth
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

Source: Arshad M.A., Lowery B., and Grossman B. 1996. Physical Tests for Monitoring Soil Quality. In: Doran J.W.,Jones A.J., editors. Methods for Assessing Soil Quality. Madison, WI., 123-41.

Table VII: Soil Fertility Classification Followed in Maharashtra and 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 HLS (2005)

Table VIII: Qualitative Ratings of Soil Nutrients

Organic Carbon	Total N	Avail P	Available K
Medium	Medium Low	Low	Medium

Table IX: Effect of Different Treatments on Soil Properties

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 before sowing	7.1	0.31	0.64	1.46	372	17.45	297	9.2	1.20
After harvest of crop									
T1-150	7.1	0.32	0.65	1.44	374	17.50	298	9.4	1.33
T2-300	7.2	0.33	0.66	1.43	375	17.70	297	9.4	1.35
T3-450	7.2	0.32	0.67	1.43	374	17.80	304	9.4	1.45
T4-600	7.1	0.31	0.69	1.43	375	17.90	306	9.5	1.43
T5-750	7.1	0.31	0.69	1.42	375	17.90	302	9.5	1.44
T6-900	7.2	0.32	0.69	1.41	376	18.30	303	9.5	1.45
T7-RDF	7.1	0.33	0.64	1.50	374	17.90	298	9.3	1.46
T8-VC	7.1	0.32	0.73	1.37	380	17.90	302	9.3	1.46
SEm ±	0.04	0.005	0.005	0.01	32.9	0.31	2.99	0.13	0.09
CD (at 5%)	NS	0.01	0.01	0.03	98.7	0.93	8.97	0.39	0.27
Coefficient of Determination (R^2)	0.01	0.25	0.88	0.86	0.02	0.88	0.41	0.77	0.71
Correlation Coefficient (R)	0.1	0.5	0.94	- 0.93	0.15	0.94	0.64	0.88	0.84

(NS: not significant; SEm: Standard Error around mean; CD: Critical Difference)

Table X A - B - C: Percentage Increase / Decrease in the Growth and Yield of Wheat in Biosil+RDF Treatments over RDF and VC Control A

Treat-ment	Percentage Increase / Decrease in EC			Percentage Increase / Decrease in Organic Carbon			Percentage Increase / Decrease in Bulk Density		
	Over initial Value	Over T7-RDF	Over T8-VC	Over initial Value	Over T7-RDF	Over T8-VC	Over initial Value	Over T7-RDF	Over T8-VC
T7-RDF	6.45	--	3.13	0.0	--	-12.33	2.74	--	9.49
T8-VC	3.23	-3.03	--	14.06	14.06	--	-6.16	8.67	--
T1-150	3.23	-3.03	0.0	1.56	1.56	-10.9	-1.37	-4.0	5.11
T2-300	6.45	0.0	3.13	3.13	3.13	-9.59	-2.06	-4.67	4.38
T3-450	3.23	-3.03	0.0	4.69	4.69	-8.22	-2.06	-4.67	4.38
T4-600	0.0	-6.06	-3.13	7.81	7.81	-5.48	-2.06	-4.67	4.38
T5-750	0.0	-6.06	-3.13	7.81	7.81	-5.48	-2.74	-5.33	3.65
T6-900	3.23	-3.03	0.0	7.81	7.81	-5.48	-3.43	-6.0	2.92

B

Treat-ment	Percentage Increase / Decrease in Nitrogen			Percentage Increase / Decrease in Phosphorus			Percentage Increase / Decrease in Potassium		
	Over initial Value	Over T7-RDF	Over T8-VC	Over initial Value	Over T7-RDF	Over T8-VC	Over initial Value	Over T7-RDF	Over T8-VC
T7-RDF	0.54	--	-1.58	2.58	--	0.0	0.34	--	-1.33
T8-VC	2.15	1.60	--	2.58	0.0	--	1.68	1.34	--
T1-150	0.54	0.0	-1.58	0.29	-2.24	-2.24	0.34	0.0	-1.33
T2-300	0.81	0.27	-1.32	1.01	-1.12	-1.12	0.0	-0.34	-1.66
T3-450	0.54	0.0	-1.58	1.02	-0.56	-0.58	2.36	2.01	0.66
T4-600	0.81	0.27	-1.32	2.58	0.0	0.0	3.03	2.69	1.33
T5-750	0.81	0.27	-1.32	2.58	0.0	0.0	1.68	1.34	0.0
T6-900	1.08	0.54	-1.05	4.87	1.02	1.02	2.02	1.68	0.33

C

Treatment	Percentage Increase / Decrease in Sulphur			Percentage Increase / Decrease in Zinc		
	Over initial Value	Over T7-RDF	Over T8-VC	Over Initial Value	Over T7-RDF	Over T8-VC
T7-RDF	1.09	--	0.0	21.67	--	0.0
T8-VC	1.09	0.0	--	21.67	0.0	--
T1-150	2.17	1.08	1.08	10.83	-8.90	-8.90
T2-300	2.17	1.08	1.08	12.5	-7.53	-7.63
T3-450	2.17	1.08	1.08	20.83	-0.69	-0.69
T4-600	3.26	2.15	2.15	19.17	-2.06	-2.06
T5-750	3.26	2.15	2.15	20.00	-1.37	-1.37
T6-900	3.26	2.15	2.15	20.83	-0.69	-0.69

Table XI: Optimum Dose of Biosil + RDF and Comparison of the Results of Treatments of Biosil+RDF, Vermicompost (VC) and Recommended Dose of Fertilizer (RDF) on Soil Fertility

Parameter of Plant Growth / Yield	Optimum Dose of Borosil with RDF (kg/ha)	Trend of Positive Impact	Remark
EC	T2-300	(Biosil+RDF)>RDF>VC	Improvement in all three treatments
Organic Carbon	T4-600	VC>(Biosil+RDF)>RDF	VC is most effective, followed by (Biosil+RDF) and RDF
Bulk Density	T6-900	VC>(Biosil+RDF)	VC and (Biosil+RDF) only effective
Nitrogen	T6-900	VC>(Biosil+RDF)>RDF	VC treatment superior to all
Phosphorus	T6-900	(Biosil+RDF)>RDF=VC	(Biosil+RDF) highly effective
Potassium	T4-600	(Biosil+RDF)>VC>RDF	VC superior to T2-300
Sulphur	T4-600	(Biosil+RDF)>VC=RDF	All are more or less equally effective
Zinc	T4-600	VC=RDF>(Biosil+RDF)	All are more or less equally effective.

*“ =” more or less as effective as

Table XII: Effect of Different Treatments on Plant Growth and Yield Parameters of Wheat

Treat-ments	**Plant Growth Parameters**					**Crop Yield Parameters**			**Straw Yield (q/ha)**
	Plant Popul-ation (m-2)	**Plant Height (cm)**	**Number of Leaves per Plant**	**Number of Effective Tillers per m-2**	**Length of earhead (cm)**	**Number of Grains/ Earhead**	**Test Wei-ght (g)**	**Grain Yield (q/ha)**	
T1-150	200.25	86.2	22.80	221.5	9.4	53.9	42.1	47.7	70.4
T2-300	200.38	87.4	22.85	243.8	9.5	55.7	42.4	50.5	73.8
T3-450	200.36	88.0	25.60	245.0	9.6	57.9	42.6	53.8	78.5
T4-600	200.34	89.2	28.55	249.7	9.7	59.8	42.9	57.8	86.8
T5-750	200.40	89.5	30.88	256.8	9.7	61.1	44.4	58.6	88.5
T6-900	200.30	89.8	32.65	299.4	9.8	63.4	46.5	59.4	89.6
T7-RDF	200.32	85.4	20.26	198.9	9.1	50.0	41.8	45.5	74.4
T8-VC	200.35	88.2	26.65	244.4	9.5	58.9	44.3	56.5	85.5
SEm ±	0.33	1.15	2.08	15.41	0.11	0.66	0.61	1.89	3.91
CD at 5%	NS	3.45	6.24	46.23	0.33	1.98	1.83	5.67	9.30
CD (R^2)	--	0.94	1.0	0.81	0.96	1.0	0.81	0.94	0.94
CC (R)	--	0.97	1.0	0.9	0.98	1.0	0.9	0.97	0.97

(NS: not significant; SEm: Standard Error around mean; CD: Critical Difference); CD: Coefficient of Determination; CC: Correlation Coefficient

Table XIII(A) - (B): Percentage Increase / Decrease in the Growth and Yield of Wheat in Biosil+RDF Treatments over Recommended Dose of Fertilizers (RDF) and Vermicompost (VC) Controls

(A)

Treatment	Percentage Increase / Decrease in Plant Population m-2		Percentage Increase / Decrease in Plant Height (cm)		Percentage Increase / Decrease in No. of leaves/ plant		Percentage Increase / Decrease in No. of Effective Tillers/ m-2	
	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC
T1-150	-0.035	-0.05	0.94	-2.27	12.54	-14.45	11.36	-9.37
T2-300	0.030	0.015	2.34	-0.91	12.78	-14.26	22.57	-0.25
T3-450	0.020	0.005	3.05	-0.23	26.36	-3.94	23.18	0.25
T4-600	0.01	-0.005	4.45	1.13	40.92	7.13	25.54	2.17
T5-750	0.0004	0.025	4.80	1.47	52.42	15.87	29.11	5.07
T6-900	-0.01	-0.025	5.15	1.81	61.16	22.51	50.53	22.50
T7-RDF	--	-0.015	--	-3.18	--	-23.98	--	-18.62
T8-VC	0.015	--	3.28	--	31.54	--	22.88	--

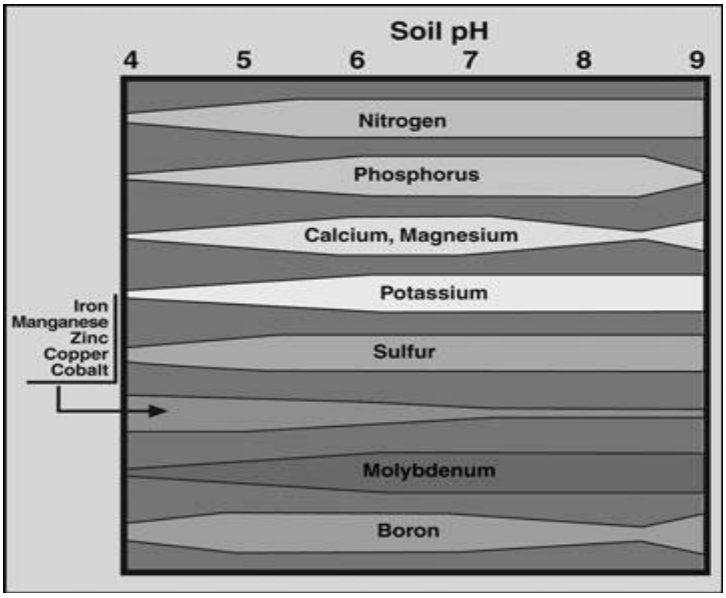
(B)

Treatment	Percentage Increase / Decrease in Length of Earhead (cm)		Percentage Increase / Decrease in No. of Grains/ Earhead		Percentage Increase / Decrease in Test Weight (gm)		Percentage Increase / Decrease in Grain Yield (q/ha)		Percentage Increase / Decrease in Straw Yield (q/ha)	
	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC	Over T7-RDF	Over T8-VC
T1-150	3.30	-1.05	7.8	-8.49	0.72	-4.97	4.84	-15.58	-5.38	-17.66
T2-300	4.40	0.0	11.4	-5.43	1.44	-4.29	10.99	-10.62	-0.81	-13.68
T3-450	5.50	1.05	15.8	-1.70	1.91	-3.84	18.24	-4.78	5.51	-8.19
T4-600	6.59	2.11	19.6	1.53	2.63	-3.16	27.03	2.3	16.67	1.52
T5-750	6.59	2.11	22.2	3.74	6.22	0.23	28.79	3.72	18.95	3.51
T6-900	7.69	3.16	26.8	7.64	11.24	4.97	30.55	5.13	20.43	4.80
T7-RDF	--	-4.21	--	-15.11	--	-5.64	--	19.47	--	-12.98
T8-VC	4.40	--	17.8	--	5.98	--	24.18	--	14.92	--

Table XIV: Optimum Dose of Biosil + RDF and Comparison of the Results of Treatments of Biosil+RDF, Vermicompost (VC) and Recommended Dose of Fertilizers (RDF)

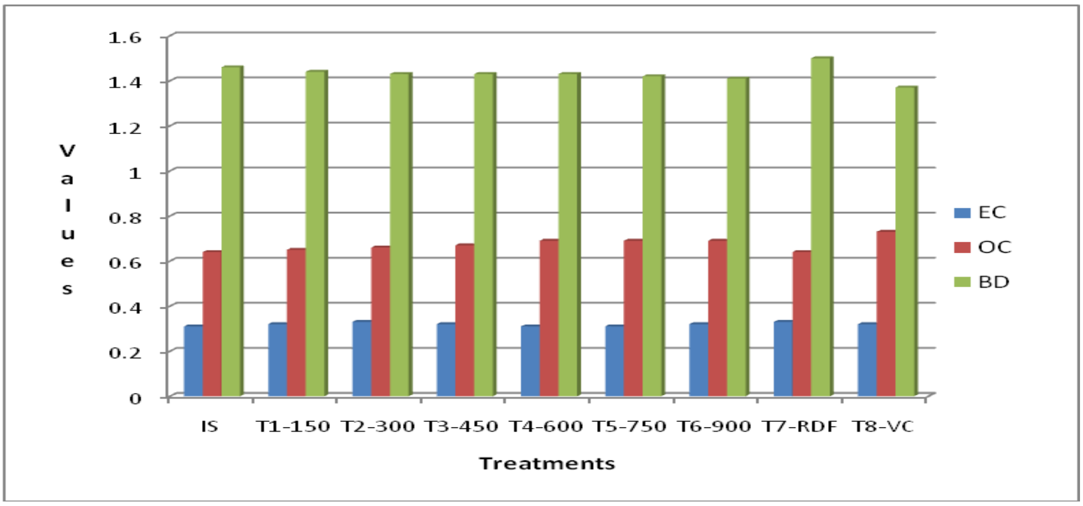
Parameters of Plant Growth and Yield	Optimum Dose of Borosil with RDF (kg/ha)	Trend of Positive Impact	Remark
Plant Population	T1-150	(Biosil+RDF)=VC=RDF	No significant impact
Plant Height	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T2-300
Number of Leaves/plant	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T3-450
Number of Effective Tillers/m2	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T2-300
Length of Earhead	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T1-150
Number of Grains per Earhead	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T3-450
Test Weight	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T4-600
Grain Yield	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T3-450
Straw Yield	T6-900	(Biosil+RDF)>VC>RDF	VC superior than T3-450

*“ =” more or less as effective as



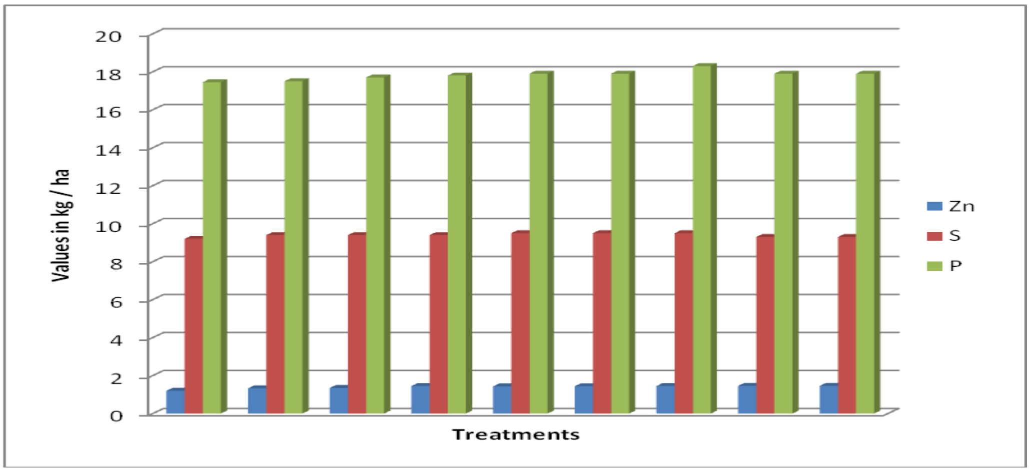
(The width of the band indicates the relative availability of each plant nutrient at various pH levels)

Figure 1: Soil pH Ranges and Nutrient Availability to Plants.



(Electrical Conductivity, EC; Organic Content, OC; Bulk Density, BD)

Figure 2: Effect of Different Treatments on Soil Characteristics



(Zinc, Zn; Suphur, S; Phosphorus, P)
Figure 3: Effect of Different Treatments on Soil Characteristics

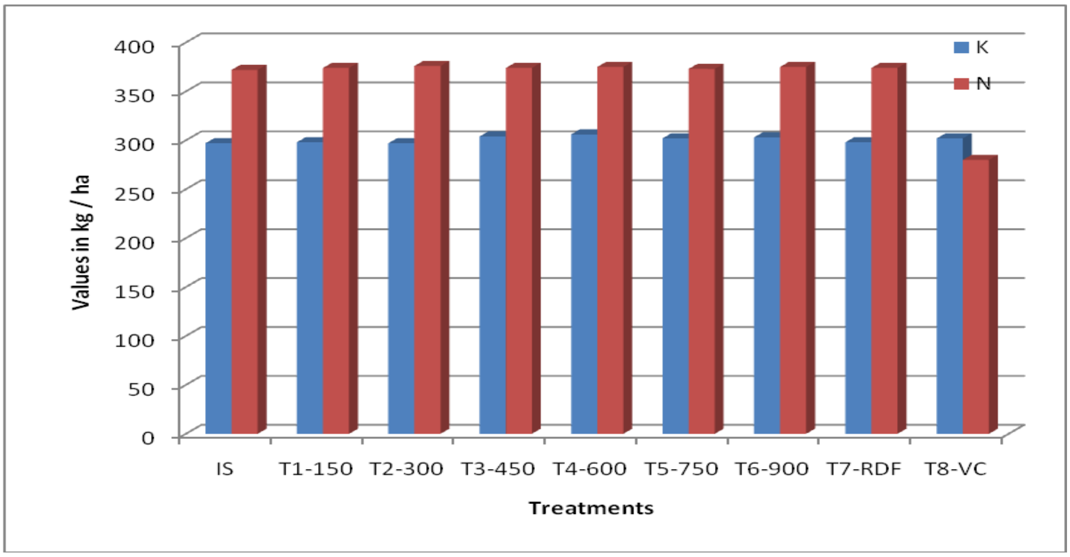
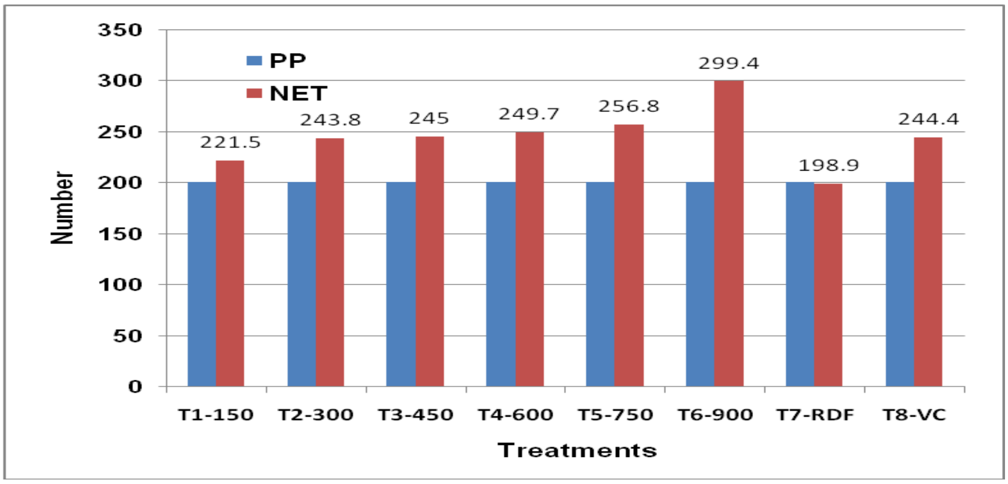
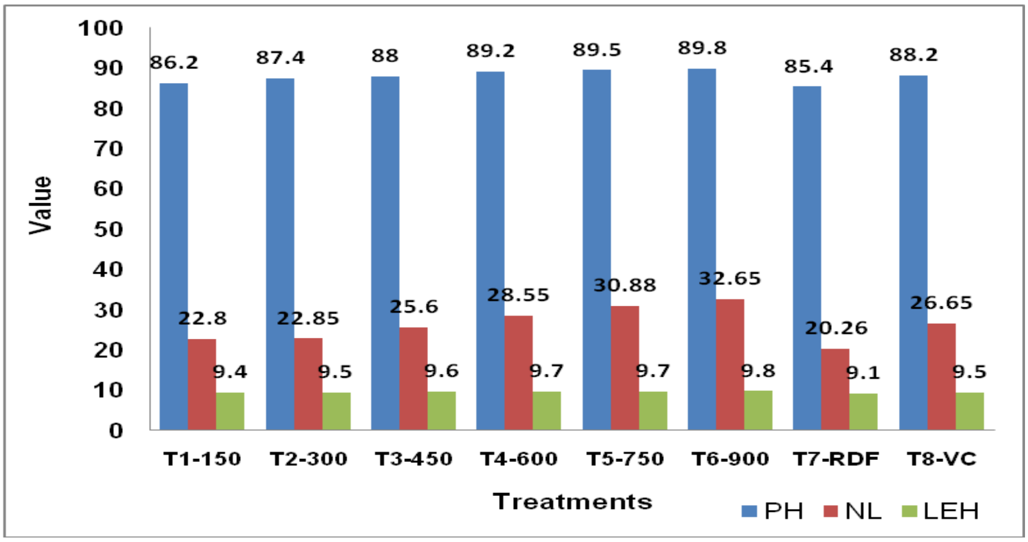


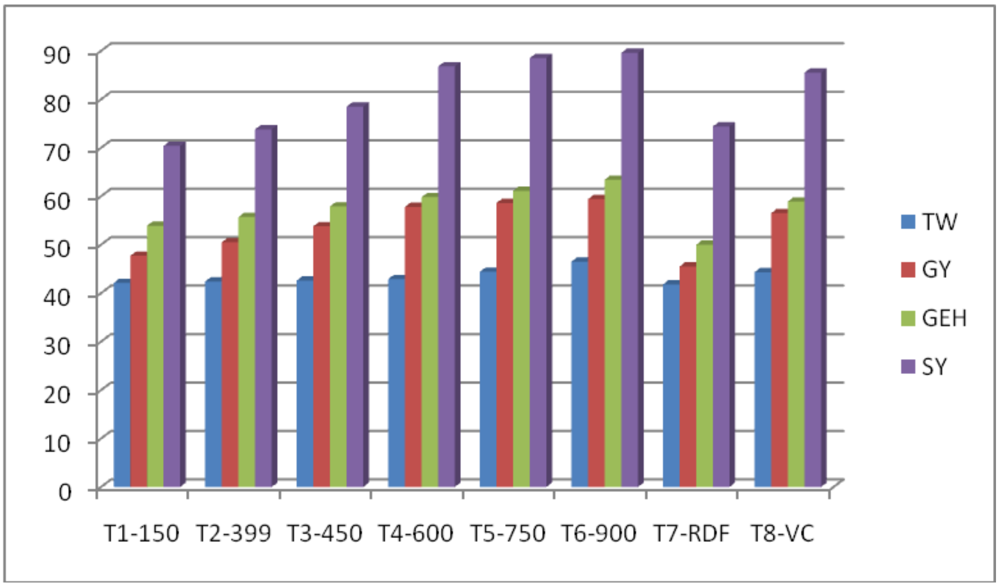
Figure 4: Effect of Different Treatments on Soil Characteristics (Potassium, K; Nitrogen, N)



(PP: plant population; NET: no of effective tillers/m2)
Figure 5: Effect of Different Treatments on Plant Growth Characteristics



(PH: plant height; NLP: no of leaves/plant; LEH: length of earhead)
Figure 6: Effect of Different Treatments on Plant Growth Characteristics



(TW: Test Weight; GY: Grain Yield; GEH: Number of Grains/Earhead; SY: Straw Yield)
Figure 7: Effect of Different Treatments on Plant Growth Characteristics