4. RESULTS

The results obtained from series of laboratory and field experiments on collection, characterization of commercially available biodynamic and organic manures, production and characterization of cow horn manure (BD 500) and cow horn silica (BD 501) manure, dose optimization of BD 500 and BD 501, influence of biodynamic manures on the productivity and quality of rice cultivated under 2 different agro-climatic zones are presented in this chapter.

4.1. Collection, physico-chemical and microbial properties of organic & biodynamic manures

Four biodynamic manures such as Cow horn manure (BD 500), Cow horn manure (BD 501), Cow Pat Pit (CPP), Biodynamic compost (BD compost) and six biodynamic herbal preparations (BD 502, BD 503, BD 504, BD 505, BD 506 and BD 507) were obtained from Kurinji Organic Foods Pvt. Ltd. Dindigul, Tamil Nadu and M/s Supa Biotech Pvt. Ltd. Uttarakhand. Four organic manures such as Vermicompost, Farmyard manure (FYM), Panchakavya and Amirthakaraisal were obtained from a local farmer in Ariyanoor village, Kancheepuram district, Tamil Nadu. The physico-chemical and microbial properties of these 14 different manures are presented in Table 4.1 & 4.2.

Analyses of the 14 different organic and biodynamic manures have revealed that the pH of organic and biodynamic manures were acidic to slightly alkaline range (5.0 to 7.8). The pH of BD compost Panchakavya, Amirthakaraisal, Vermicompost and BD 501 was acidic whereas, pH of BD 500, six BD herbal preparations and CPP were neutral. The CPP manure recorded low EC values of 1.14 dS m⁻¹ whereas other manures recorded EC values ranged from 2.13 to 5.12 dS m⁻¹ in both the places. The
percentage of organic carbon in different manures has shown that BD compost recorded for a high organic carbon (46.23 %) content followed by CPP I (40.46 %) and vermicompost (34.69 %). The lowest content of organic carbon (0.23 and 0.12 %) was recorded in BD 501 collected from the both places (Table 4.1).

Interestingly, the macronutrients contents of the organic and biodynamic manures have shown that the CPP I (2.85 %) and BD compost (2.08 %) recorded highest nitrogen content followed by vermicompost (1.95 %), whereas in BD 501 contained high content of phosphorous recorded in both the places (1.96 and 1.22 %). The potassium content was also high in BD 501 (3.23 and 2.12 %) and BD 506 I (1.42 %) (Table 4.1).

Micronutrient analyses of different organic and biodynamic manures have also revealed that each manure was rich in some of the micronutrients. Calcium content was high (2.94 %) in BD 503 I, magnesium (1.32 %) in BD 504 II, manganese (767.00 ppm) in BD compost, zinc (114.00 ppm) in BD 502 and iron (3892.0 ppm) & copper (78.00 ppm) in BD compost (Table 4.1).

The bacteria (30.38 CFU x10^6 g⁻¹ of manure), fungi (11.20 CFU x10^4 g⁻¹ of manure), actinomycetes (16.52 CFU x10^3 g⁻¹ of manure) and humic acid content (493.00 mg 100 g⁻¹) were also high in BD compost (Table 4.2).

Based on physico-chemical properties of biodynamic manure nutritional index of biodynamic manures was derived and presented in Table 4.3 & 4.4.
4.2. Physico-chemical and microbial characterization of Cow horn Manure (BD 500) and soil collected from pit

4.2.1. Characterization of Cow Horn Manure (BD 500)

BD 500 manure was produced by stuffing cow horn with fresh cow dung and buried beneath the soil and maintained up to 120 days. The BD 500 manure was harvested periodically at 30 day interval and analysed for its physico-chemical and microbial properties (Table 4.5). The pH of the BD 500 manure was acidic (4.5) recorded during early stage of manure maturation and gradually attained neutral pH (7.6) on 120\textsuperscript{th} day. Organic carbon (42.18 %) and humic acid (242.31 mg 100 g\textsuperscript{-1}) contents of BD 500 manure were recorded high on 90\textsuperscript{th} and 120\textsuperscript{th} day respectively. In case of primary and secondary nutrients, calcium content (2.86 %) was high on 120\textsuperscript{th} day whereas high content of nitrogen (2.76 %), phosphorus (0.68 %), potassium (0.26 %) and magnesium (0.34 %) recorded on 90\textsuperscript{th} day in BD 500 manure. Similarly, micronutrients such as iron (3716.14 ppm), manganese (114.95 ppm), zinc (73.58 ppm) and copper (17.26 ppm) were recorded high on 90\textsuperscript{th} day. Highest bacterial (22.73 x10\textsuperscript{6} CFU g\textsuperscript{-1}) and fungal (8.3 x10\textsuperscript{4} CFU g\textsuperscript{-1}) loads were recorded high on 90\textsuperscript{th} day and actinomycetes load (10.0 x10\textsuperscript{2} CFU g\textsuperscript{-1}) was high on 120\textsuperscript{th} day in BD 500. The physico-chemical and microbial analysis of BD 500 revealed that manure contained high contents of the nutrients and microbial loads. Hence, the BD 500 manure was harvested on 90\textsuperscript{th} day of incubation and utilized for field experiments.

4.2.2. Characterization of soil collected pit containing from Cow horn manure (BD 500)

Soil samples collected from with and without BD 500 manure were analysed for its physico-chemical and microbial parameters and presented in Table 4.6. A
slightly alkaline pH (7.6) was recorded in soil with BD 500 manure when compared to soil without BD 500. The EC (> 1.00 dS m⁻¹) was recorded in both the soils. An increase in organic carbon content (1.42 %) was recorded in soil with BD 500 manure. The nutrient properties of the soil have shown that the available macronutrients were high in soil with BD 500 manure than the soil without BD 500. The available nitrogen (127.3 kg ac⁻¹) and potassium (65.6 kg ac⁻¹) contents were also recorded high in soil with BD 500. However, phosphorus (6.0 kg ac⁻¹) and micronutrients content such as Fe (13.7 mg kg⁻¹), Mn (5.2 mg kg⁻¹), and Cu (0.8 mg kg⁻¹) recorded high in soil without BD 500. High load of bacterial (23.0 x10⁶ CFU g⁻¹), fungal (20.0 x10⁴ CFU g⁻¹) and actinomycetes (8.0 x10² CFU g⁻¹) were also recorded in soil with BD 500 than the soil without BD 500.

4.3. Physico chemical and microbial characterization of Cow horn silica manure (BD 501) and soil collected from pit

4.3.1. Collection and identification of quartz

Quartz like stones were collected from Sevapur village, Karur district, Tamil Nadu, India and identified by petrography and geochemical analyses. Megasopic petrography analysis indicated that the colour of the quartz was milky white with hard durable mineral and exhibiting resistance to weathering. Lusture was vitreous with absence of cleavage and the streak was white in colour. In addition, some of the other properties of quartz were conchoidal fracture, brittle tenacity and opaque transparency. The specific gravity of the quartz was 2.6-2.7 and contained SiO₂ and crystallized in hexagonal system. Based on above properties the quartz was classified as vein quartz.
Microscopic petrography analysis of the quartz indicated that the quartz was crystalline and fine to medium grained. The mineral grained have undulatory extinction and deformation lamellae in them were also common. Thin section petrography of quartz stone revealed that the samples were largely composed of quartz (> 95 %) with minor to significant amounts of feldspar and sericite (Plate 7).

SiO2 (35.69 %) was predominant mineral in the quartz stone with rare distribution of other major elements such as Al2O3 (13.16 %), FeO3 (5.57 %) TiO2 (0.37 %) and CaO, K2O and MgO (>1.5 %) (Table 4.7). The quartz was utilized for the production of BD 501.

4.3.2.2. Characterization of Cow Horn Silica (BD 501)

Cow horn manure (BD 501) was harvested periodically, maintained up to 120 days and determined its physic-chemical and microbial properties (Table 4.8). It was observed that SiO2 (30.3 %) was a predominant element in BD 501 manure followed by other elements such as Fe2O3 (11.9 %), MgO (3.6 %), Na2O (4.0 %), K2O (6.5 %) P2O5 (2.0 %) and TiO2 (4.3 %) whereas high content of MnO (1.5 %), CaO (1.7 %) and Al2O3 (14.4 %) were also recorded on 90th day. Microbial analysis of BD 501 revealed that a high bacterial load (1.50 x10^6 CFU g^-1) recorded on 90th day whereas fungi (4.00 x 10^4 CFU g^-1) and actinomycetes (20.0 x 10^2 CFU g^-1) were high on 120th day in BD 501 manure.

4.3.2. Characterization of soil collected from pit containing with and without Cow Horn Silica (BD 501)

Soil samples collected from pit containing with and without BD 501 manure were analysed for its physico-chemical and microbial parameters (Table 4.9). pH of the soil with and without BD 501 was neutral. The EC (>1.00 dS m^-1) was recorded in
both the soil. An increase in organic carbon content (1.38 %) was recorded in soil with BD 501 manure.

The nutrient properties of the soils have revealed that the available macro and micronutrients contents were high in the soil with BD 501 than soil without BD 501 manure. The available nitrogen (120.9 kg ac⁻¹), phosphorus (9.2 kg ac⁻¹) and potassium (52.9 kg ac⁻¹) were high in soil with BD 501. Micronutrients such as Fe (21.5 mg kg⁻¹), Mn (7.74 mg kg⁻¹), Zn (0.22 mg kg⁻¹) and Cu (1.02 mg kg⁻¹) were also high in soil with BD 501 manure.

Bacteria (24.0 x10⁶ CFU g⁻¹), fungi (18.0 x 10⁴ CFU g⁻¹) and actinomycetes (11.0 x10² CFU g⁻¹) loads were high in soil with BD 501 than the soil without BD 501 manure.

4.4. Anti microbial and Silica solublization activities of Bacteria isolated from Cow Horn Silica Manure (BD 501)

4.4.1. Isolation of potential bacteria from Cow Horn Silica Manure (BD 501)

The predominant bacteria were isolated, identified and presented in Plate.8a. The bacterial isolates were purified and stored at -20 °C and utilized for further studies.

4.4.2. Morphological and Biochemical characterization of isolated bacteria

The bacterial isolates from BD 501 manure were characterized by both microscopical examination and biochemical tests. All the 3 isolates were recorded as gram positive with rod shape cells and presented in Table 4.10. The microscopical examination and the results of biochemical tests indicated that these bacterial isolates belong to genus Bacillus.
4.4.3. Molecular identification of bacterial isolates of Cow Horn silica manure (BD 501)

The 3 bacterial isolates such as BD (A) S1, BD (A) S2 and BD (A) S3 were identified as *B. amyloliquefaciens*, *B. amyloliquefaciens* and *B. toyonenis* respectively.

4.4.4. Antimicrobial activity of the Bacteria isolated from Cow Horn Silica Manure (BD 501) against Plant Pathogens

The *B. amyloliquefaciens* (BD (A) S1) and *B. toyonenis* isolates were evaluated for its antimicrobial activity against rice pathogens such as *Rhizoctonia solani*, *Pyricularia oryzae* and *Xanthomonas oryzae*. Among the 3 bacteria, *B. amyloliquefaciens* (BD (A) S1) effectively controlled the growth of *R. solani* recorded on 7th day ([Plate.8b](#)) whereas in the case of *P. oryzae*, the mycelial growth was slowed down initially and inhibited on 12th day. All the 3 bacterial isolates did not exhibit anti-bacterial activity against *X. oryzae*. It was concluded that the activity against BD 501 was poor in controlling rice bacterial pathogens.

4.4.5. Silica solublization of bacteria isolated from Cow horn silica manure (BD 501)

Another predominant bacterium *Bacillus* sp. (BD (A) S4) isolated from BD 501 has the ability to solubilize silica. Among the 4 bacteria, *Bacillus* sp. (BD (A) S4) solubilized silica which was observed by a larger clear zone around the colonies ([Plate 9](#)).
4.5. Antimicrobial activity and pesticidal activities of Cow Horn Silica Manure (BD 501)

4.5.1. Antimicrobial activity of Cow Horn Silica Manure (BD 501)

BD 501 manure was evaluated for its antimicrobial property against *Xanthomonas oryzae* (Bacterial leaf blight disease of rice), *Pyricularia oryzae* (leaf blast disease of rice) and *Rhizoctonia solani* (Sheath blight disease of rice) determined by amending BD 501 manure in Nutrient Agar and Potato Dextrose Agar media. The growth of *Xanthomonas oryzae* in the silica amended Nutrient Agar medium was more prolific compared to control (without silica manure) recorded within 24 h. Even at higher concentration of BD 501, it was not effective in inhibiting bacterial blight pathogen (*Xanthomonas oryzae*) (Plate 10).

The initial growth of *Pyricularia oryzae* was observed in PDA medium amended with and without BD 501 manure. However, at higher concentration (20 g L⁻¹) of BD 501 amended PDA medium inhibited the growth of *Pyricularia oryzae* recorded on day 7. Changes in colony morphology of *Pyricularia oryzae* were observed and the mycelial growth was in vertical direction compared to the usual lateral growth in PDA without BD 501 (Plate 10). Thus, BD 501 at 20 g L⁻¹ conc. was effective in controlling *Pyricularia oryzae* the blast disease of rice.

At higher concentration (30 g L⁻¹) of BD 501 amended in PDA medium, the growth of *Rhizoctonia solani* was significantly inhibited and a distinct change in morphology and sclerotia formation of *Rhizoctonia solani* were observed in BD 501 amended medium as compared to the medium without BD 501 amended medium (Plate 10). Hence it was concluded that BD 501 manure control the *Rhizoctonia solani* sheath blight of rice.
4.5.2 Pesticidal activity of Cow Horn Silica Manure (BD 501)

The artificial diet containing BD 501 manure was evaluated for its pesticidal activity against *Helicoperva armigera* and *Spodoptera litura* and presented in Table 4.11. No mortality was observed in both pests until 72 h in all concentration of BD 501 manure amended in artificial diet. After 92 h, about 30 % mortality of *Spodoptera litura* was recorded in artificial diet containing 0.25 mg mL\(^{-1}\) conc. of BD 501. The artificial diet containing various concentrations of 0.15, 0.20 and 0.25 mg mL\(^{-1}\) of BD 501 recorded for a mortality of 25 %, 30 % and 50 % of *Spodoptera litura* larvae respectively. The pesticidal study suggested that 0.25 mg mL\(^{-1}\) conc. of BD 501 manure caused 50 % mortality of *Spodoptera litura* larvae. Moreover, the BD 501 manure prevented *Spodoptera litura* from development of pupal to adult stage.

In case of *Helicoverpa armigera*, a delayed mortality was recorded upto 4 days in artificial diet containing BD 501. About 25 % larval mortality was recorded in artificial diet containing 0.25 mg mL\(^{-1}\) conc. of BD 501 recorded on day 5. About 22, 25 and 25 % mortality of *H. armigera* larvae were recorded in artificial diet medium containing 0.15, 0.20 and 0.25 mg mL\(^{-1}\) conc. of BD 501 respectively on day 6.

It was concluded that artificial diet containing 0.25 mg mL\(^{-1}\) conc. of BD 501 manure inhibited the growth of *Spodoptera litura* and *Helicoverpa armigera*.

4.6. Microbial diversity of Cow horn manure (BD 500) and Cow horn silica manure (BD 501) through metagenomic techniques.

4.6.1. Extraction of DNA, generation of reads and production of high quality reads in BD 500 and BD 501 manures

Total DNA was extracted from BD 500 and BD 501 manures and approximately 600 bp of bacterial 16S rRNA gene were amplified. PCR products with
the correct DNA fragments were cloned and then selected for sequencing. 16s rRNA sequencing analysis targeting V3–V4 region was performed using illumine bar coding sequencing. About 2150379 of parried end reads were obtained from BD 500 and 1231024 of parried end reads were obtained from the metagenomic DNA extracted from BD 501. Raw reads contained 2115798 in BD 500 and 3695014 in BD 501, contaminated sequences were trimmed and taken for subsequent analysis. In order to eliminate low quality reads, the non-overlapping reads were taken into account (Table 4.12).

4.6.2. Diversity index of BD 500 and BD 501 manures.

The rarefaction curve annotated the species richness in the manures and was represented in the plot (Fig. 4.1). This curve is a plot of the total number of distinct species annotations as a function of the number of sequences sampled. On the left, a steep slope indicated that a large fraction of the species diversity remains to be discovered. The curve becomes flatter to the right; a reasonable number of individuals are sampled: more intensive sampling is likely to yield only few additional species. Both the Shannon Weiner Index and Simpson Index recorded that BD 500 manure had the highest number of diversity than BD 501 manure. The observed species of 9447.0 and 8514.0 were recorded in BD 500 and BD 501 manures (Table 4.13) respectively.

Beta diversity and principal coordinate analysis plot of the samples were found to be dissimilar between the BD 500 and BD 501 (Fig. 4.2). The distance matrix of these 2 manures was visualized in principal coordinate analysis plot.
4.6.3. Taxonomic assignment of manures at phylum level

The relative distribution of each phylum varied among the two manure samples. The predominant phyla commonly observed in two manure samples were Proteobacteria, Firmicutes, Cyanobacteria, Actinobacteria and Planctomycetes. The result supports the fact that the representative members from these phyla were diverse and are not specific to that specific habitat or place. The relative abundance of each phylum varied among the BD 500 and BD 501 and remains distinct to each other. In BD 500 manure the Proteobacteria (50.46 %), Actinobacteria (20.28 %) and Planctomycetes (11.68 %) were predominant (Fig. 4.3). In case of BD 501, Firmicutes (26.94 %) was predominant followed by Cyanobacteria (26.94 %) and Proteobacteria (8.46 %) (Fig. 4.4). This result was also complemented by the heat map analysis in which these manure samples did not cluster together (Fig 4.5). The relative abundance of Firmicutes (Bacillus, Brevibacillus, Alicyclobacillus) was high in BD 501 and rather it was lower in BD 500 manure. However relative abundance of Proteobacteria was high in BD 500 manure.

4.6.4. Distribution of bacterial communities at class, order and family level in BD 500 and BD 501 manures

The distribution of bacterial classes such as Bacilli (51.9 %) and Chloroplast (26.1 %) and were abundant in BD 501 manure. These 3 major classes relatively distributed higher and rest of the classes such as Gammaproteobacteria, Betaproteobacteria and Actinobacteria and Planctomycetia were reported lesser occurrence (Fig.4.7). Whereas, in BD 500 manure Alphaproteobacteria (27.0 %) Gammaproteobacteria (19.2 %) Planctomycetia (10.4 %) and Acidimicrobiia (4.6 %) were abundant (Fig. 4.6). The taxonomical order of bacterial communities such as
Bacillales (51.0 %), Streptophyta (26.0 %) and Clostridiales (5.4 %) were predominately distributed in BD 501 (Fig. 4.7) and order Xanthomonadales (16.4 %), Rhizobiales (13.3 %), Actinomycetales (15.2%) Rhodospirillales (10.2 %) were rich in BD 500 manure (Fig.4.6). With respect to family, 26.0 % of unclassified family categorized under order Streptophyta and classified families such as Bacillacea (23.3 %) and Paenibacillaceae (15.0 %) were also abundant in BD 501 (Fig.4.7). Whereas, Xanthomonadaeae (15.4 %), Streptomycetaceae (10.0 %), Pirellulaceae (7.5 %), Rhodospirillaceae (7.1 %), and Hyphomicrobiaceae (6.3 %) reported to be widely distributed in BD 500 manure (Fig.4.6). The relative abundance of class, order and family classification in both the manures were varied between them.

**4.6.7. Diversity of abundant bacterial communities of manures at higher taxonomical classification in BD 500 and BD 501 manures**

In BD 500 and BD 501 manures, about 95-98 % of higher taxonomical classification (genes and species) were recurrently in unclassified category (Fig. 4.6 & 4.7). However, abundant genes and species such as Bacillus (18.2 %), Brevibacillus (8.6 %), Alicyclobacillus (4.1 %), Bacillus selenatarsenatis (2.3 %), Brevibacillus reuszeri (2.1 %), Ammoniphilus (1.9 %), Desulfotomaculum (1.7 %) and Lysinibacillus boronitolerans (1.6 %) were reported and rest of genes, accounts for about ≤1 to 0.01 like Sphingomonas, Kaistobacter, Streptomycyes, Planctomyces, Paenibacillus, Gemmata, Brevibacillus invocatus, Mycococcus Pontibacillus and Clostridium also occurred in BD 501 manure. The Streptomycyes (6.5 %), Rhodoplanes (3.7 %) and other genes such as Sphingomonas, Kaistobacter, Bacillus, Nitrospira, Planctomyces, Devosia, Gemmata, Pirellula, Amycolatopsis, Paenibacillus, Afifella, Erythrobacter nanhaisediminis, Candidatus
xiphinematobacter, Corynebacterium, Mycobacterium, Aeromicrobium, Pseudonocardia, Streptomyces mirabilis, Cohnella, Hyphomicrobium, Mesorhizobium, Agrobacterium and Sinorhizobium were also distributed in BD 500 manure.

4.6.8. Diversity of rare species of in BD 500 and BD 501 manures

The frequency distribution of ≤0.01 % was classified as rare species. Diversity of rare species such as Rhodoplanes, Bradyrhizobium, Candidatus solibacter, Nitrospira, Candidatus koribacter, Dokdonella, Phenyllobacterium, Pirellula, Mycobacterium, Amycolatopsis, Candidatus Nitrososphaera, Haladaptatus, Methanobrevibacter, Methanocella, Methanoculleus, Afifella, Bdellovibrio, Lysobacter, Candidatus xiphinematobacter, Edaphobacter, Corynebacterium, Mycobacterium, Aeromicrobium, Pseudonocardia, Streptomyces, Flavobacterium, Segetibacter distributed in BD 500 and BD 501 manures.

4.6.9. Beneficial bacterial species identified in BD 500 and BD 501

The beneficial soil bacteria like Bacillus, Brevibacillus, Brevibacillus reuszeri, Ammoniphilus, Desulfotomaculum Sphingomonas, Streptomyces, Paenibacillus, Brevibacillus invocatus, also occurred in BD 501 manure. In BD 500 manure, Streptomyces, Azosprillium, Rhodoplanes Sphingomonas, Bacillus, Nitrospira, Paenibacillus, Streptomyces mirabilis, Mesorhizobium, and Sinorhizobium were distributed.

4.7. Optimization of different concentration of Cow Horn Manure (BD 500) for Rice crop

The experiment comprised of 12 treatments (T1 to T12), of which 10 treatment with different concentration of BD 500 (25, 37.5, 50, 62.5, 75, 87.5, 100,
112.5, 125, 137.5 g ha$^{-1}$) given as basal application and each of the recommended fertilizer dose for paddy crop and control respectively.

4.7.1. Physico-chemical and microbial characterization of soil collected from field before crop cultivation

Soil sample from the experimental field was collected before rice cultivation from Ariyanoor village, Kancheepuram district and analysed for its physico-chemical and microbial properties. The pH of the soil was neutral (7.5) and EC was normal (0.18 dS m$^{-1}$). The field soil had an organic carbon content of 0.32 %, low levels of available nitrogen (120.00 kg ha$^{-1}$), phosphorus (18.90 kg ha$^{-1}$) and medium level of potassium (160.00 kg ha$^{-1}$). The amount of secondary nutrients such as calcium (460.00 mg kg$^{-1}$), magnesium (150.00 mg kg$^{-1}$) and sulfate (5.70 mg kg$^{-1}$) recorded in the soil. The available micronutrient status of the soil revealed that, the iron content was high (12.40 mg kg$^{-1}$) compared to manganese (7.72 mg kg$^{-1}$), zinc (0.68 mg kg$^{-1}$) and copper (1.56 mg kg$^{-1}$). The microbial properties of the soil revealed that 13.90 x10$^6$ CFU g$^{-1}$ of bacteria, 4.10 x10$^4$ CFU g$^{-1}$ of fungal and 11.20 x10$^2$ CFU g$^{-1}$ of actinomycetes loads were also recorded in soil collected from the experimental plot (Table 4.14).

4.7.2. Different concentration of BD 500 on growth attribute of rice crop

4.7.2.1. Different concentration of BD 500 on plant height of rice crop

The plant height with reference to the different treatments were recorded at various phenological stages of crop illustrated in Fig. 4.8a.

Among 12 treatments, the rice crop cultivated under T7 (BD 500 @ 100 g ha$^{-1}$) recorded for maximum plant height (78.99±8.35 cm) which was on par with T6, T9
and T8 treatments. In general, a steep increase recorded in plant height was recorded at panicle initiation (S2) stage. Later, there was a steady increase in plant height of the crop until maturity stage. The maximum plant height with a mean value of 89.49 ± 1.65 cm was recorded at maturity stage (S4). Interaction effect between treatments and stages have recorded for a maximum plant height of 97.63 ± 9.06 cm in T7 at S4 stage compared to other treatments.

4.7.2.2. Different concentration of BD 500 on number of leaves of rice crop

The maximum number of leaves (43.58 ± 7.89) was recorded in rice crop cultivated under T6 (BD 500 @ 87.5 g ha⁻¹), followed by T5 (41.00 ± 6.71), T9 (37.92 ± 5.60) and T7 (36.50 ± 5.63) (Fig. 4.8b). These results revealed that there was no significant difference recorded on the number of leaves among 12 treatments. In case of different growth stages there was a significant difference was observed, however the maximum number of leaves (20.88 ± 2.42) was recorded in S3 and minimum number of leaves (10.86 ± 1.11) was recorded in S1 stages. The interaction effect between the treatments and stages of plant revealed that the maximum number of leaves (22.16 ± 3.17) was recorded in T6 at S4 stage (Fig. 4.8b).

4.7.2.4. Different concentration of BD 500 on number of tillers of rice crop

Production of tillers in rice crop was influenced by various treatments and a significant difference in number of tillers of crop was recorded (Fig. 4.8c). Significantly, an increased number of tillers (10.58 ± 1.32) was recorded in rice crop cultivated under T10 (BD 500 @ 137.5 g ha⁻¹) which was on par with T7, T9, T8 and T6. When comparing the 4 different stages of crop growth, the maximum number of tillers was recorded at S4 stage (11.69 ± 1.45) and the minimum number of tillers at S1 stage (5.92 ± 0.33). The interaction effect between different treatments and stages of
growth revealed that a maximum number of tillers (14.67±0.33) were recorded in T10 at S4 stage and minimum number of tillers (3.33±0.33) in T12 at S1 stage.

4.7.2.3 Different concentration of BD 500 on total dry matter production of rice crop

Total Dry Matter Production (TDMP) showed an increasing trend from tillering to maturity stage was recorded (Fig. 4.8d). A significant difference in the total dry matter production (TDMP) of crop was recorded at all the 4 stages whereas there was no significant difference recorded among 12 treatments in TDMP (22.31±0.77 g hill⁻¹) of crop. A steep increase in TDMP was recorded in panicle initiation (S2) stage. The TDMP was gradually increased and maximum TDMP (30.16±1.05 g hill⁻¹) was recorded at maturity stage (S4). Among the treatments, the maximum TDMP (26.15±2.34 g hill⁻¹) was recorded at T9 treatment. Similar content of TDMP was recorded in T8, T10 and T7. The interaction effect has revealed that the maximum TDMP (31.62±4.52g hill⁻¹) recorded in T10 at S4 minimum (17.65±2.51g hill⁻¹) in T12 at S1.

4.7.2.4. Different concentration of BD 500 on root length of rice crop

A significant difference in root length of rice crop was recorded among 10 different concentrations of BD 500 and at 4 different stages of crop growth (Fig. 4.8e). Among 12 treatments, maximum root length was recorded in rice cultivated under T6 (BD 500 @ 87.5g ha⁻¹) (16.74±1.36 cm) followed by T7 (16.62±1.47 cm). The root length of crop in other treatments such as T10, T9, T8, T5, T4 and T3 were almost equal to T6 and T7. The minimum root length (11.40±0.70 cm) was observed in control (T12). At various phenological stages of crop growth, the flowering stage (S3) recorded for maximum root length (20.88±0.78 cm) followed by maturity (S4)
(15.94 ±0.38 cm), panicle initiation (S2) (13.91±0.27 cm) and tillering (S1) (10.86±0.33 cm) stages. The interaction effect among treatments with different crop growth stages revealed that the maximum root length (22.37±3.20 cm) was recorded in T7 at S3 stage and minimum (7.67±0.33 cm) in T12 at S1 stage.

4.7.3. Different concentration of BD 500 on physico-chemical properties of Soil

4.7.3.1 Different concentration of BD 500 on pH and EC

The pH of the soil revealed that no significant difference observed between the 12 treatments and result was presented in Fig 4.9a. The pH of the soil ranged from 7.2 to 7.6 and EC value registered >1.00 dS m⁻¹ in all the treatments (Fig 4.9b). There was not much difference in EC values recorded at different stages of crop growth.

4.7.3.2. Different concentration of BD 500 on available nitrogen

Fertility rate of the soil based on available nitrogen was recorded in all the treatments falls under low status and no significant trend was observed in available nitrogen between treatments. The available N content of the soil was high (124.12±13.69 kg ha⁻¹) in rice crop cultivated under T3 (BD500 @ 50 g ha⁻¹), followed by T10 (123.31±13.30 kg ha⁻¹). When comparing the available nitrogen in the soil of other treatments, the amount of available nitrogen observed in the range of 112.99±13.73 kg ha⁻¹ to 117.60±12.71 kg ha⁻¹. However, a significant difference was recorded in available nitrogen in soil between different stages. The maximum content of available nitrogen (128.20±8.86 kg ha⁻¹) in soil recorded at S2 stage (Panicle initiation) and minimum (107.86±7.72 kg ha⁻¹) at S4 stage (maturity). Effect of interaction between treatments with stages were also recorded to be significant and the maximum content of available nitrogen (135.00±38.81 kg ha⁻¹) was recorded in
T10 at S2 stage and the minimum content (85.02 ± 24.44 kg ha\(^{-1}\)) was recorded in T1 at S4 stage (Fig.4.9c).

**4.7.3.3. Different concentration of BD 500 on available phosphorus**

The status of available P content of soil was found to be in medium range and no significant difference was observed among all 12 treatments. However, high content of available phosphorus (13.55±1.72 kg ha\(^{-1}\)) was recorded in the rice crop cultivated under control (T12) and same amount of available phosphorus was recorded in treatment T3, T4 and T6. In case of different stages of crop growth, the available P was high (15.79±1.12 kg ha\(^{-1}\)) at panicle initiation stage (S2) and then reduced and reached the value of 10.23±0.75 kg ha\(^{-1}\) at maturity (S4) stage. The interaction effect of treatments with various stages recorded that the high content of available P (18.57±5.34 kg ha\(^{-1}\)) recorded in T6 at S2 stage and low content (8.23±2.37 kg ha\(^{-1}\)) in T12 at S4 stage (Fig. 4.9d).

**4.7.3.4. Different concentration of BD 500 on available potassium**

The status of the available K content of the soil was found to be in the medium range. The K content was greatly influenced by 12 different treatments. Among 12 treatments, the high content of K (160.55±22.53 kg ha\(^{-1}\)) was recorded in recommended fertilizer dose (T11), followed by T6 and T10. Among 4 stages of crop growth, the available K content of soil was high (157.60±12.40 kg ha\(^{-1}\)) in flowering stage (S3 stage), which then reduced and reached (142.10±11.50 kg ha\(^{-1}\)) at maturity stage (S4). The interaction between treatments and stages revealed that a high content (210.40±60.48 kg ha\(^{-1}\)) of available K was recorded in T11 (recommended fertilizer dose) at S3 stage and the low available K content (72.03±20.71 kg ha\(^{-1}\)) was recorded in T1 (control) at S4 (maturity) stages (Fig. 4.9e).
4.7.3.5. Different concentration of BD 500 on calcium

The calcium (Ca) content of the soil (Fig. 4.9 f) was significantly influenced by 12 different treatments. Field application of BD 500 @ 100 g ha\(^{-1}\) (T7) for rice crop recorded significantly high (433.26 ± 48.19 mg kg\(^{-1}\)) when compared to other treatments. This was followed by T9, T6 and recommended fertilizer dose (T11). Soil Ca content at different stages of crop growth, recorded for the high (409.02 ± 30.46 mg kg\(^{-1}\)) in S2 stage. Later, the calcium in the soil reduced and reached the value of 321.54± 24.91 mg kg\(^{-1}\) at the maturity stage. However, high Ca content (530.97 ± 152.63 mg kg\(^{-1}\)) was recorded in T6 at S2 stage.

4.7.3.6. Different concentration of BD 500 on magnesium

The magnesium (Mg) content of the soil in all the treatments were recorded to be non significant in rice crop cultivation. Among 12 treatments, Mg content was high (167.83±18.94 mg kg\(^{-1}\)) in T8 (BD 500 @ 112.5 g ha\(^{-1}\)) followed by T9, T10 and T7 which were on par with each other. When comparing the different stages of crop growth, the high magnesium content (187.24±12.95 mg kg\(^{-1}\)) was recorded in S2 (panicle initiation). Later, the Mg content of the soil was gradually reduced and the low Mg (130.83±9.90 mg kg\(^{-1}\)) was recorded at the maturity stage (S4). The interaction effect of treatments with various stages were recorded to be significant and the high Mg content of 198.43±57.02 mg kg\(^{-1}\) was recorded in T8 at S2 stage and the low content of 81.13±47.27 mg kg\(^{-1}\) was recorded in T3 at S4 stage (Fig. 4.9 g).

4.7.3.7. Different concentration of BD 500 on sulphate

The high amount of sulphate was recorded in rice crop cultivated under recommended fertilizer dose T11 (19.53±2.37 mg kg\(^{-1}\)) which was on par was T7 (19.30±2.25 mg kg\(^{-1}\)). Among 4 different stages of crop growth, high amount of
sulphate (19.87±1.49 mg kg⁻¹) was recorded in S2 (panicle initiation stage) and low
(15.09±1.07 mg kg⁻¹) in S4 (maturity stage). Interaction effect of treatments with
stages revealed that high content of sulphate (24.33±6.99 mg kg⁻¹) was recorded in
T11 at S2 and low content of sulphate (11.27±3.25 mg kg⁻¹) was recorded in T1 at S3
in soil (Fig. 4.10f).

4.7.3.8. Different concentration of BD 500 on iron

The soil iron (Fe) content of 12 different treatments and at 4 different stages of
crop growth is presented in Fig. 4.10a. Although a no significant difference was
recorded among 12 treatments, the high content of Fe (8.86±0.97mg kg⁻¹) was
recorded in rice crop cultivated under T10 (BD 500 @ 137.5 g ha⁻¹). The treatments
such as T5, T3, T1 and T11 were equal to T10. The low content of Fe (7.47±0.85
mg kg⁻¹) was recorded in T2. When comparing the Fe content recorded at various
stages of crop growth, maximum Fe content (9.23±0.64 mg kg⁻¹) was recorded at S2
stage and minimum content (6.96±0.50 mg kg⁻¹) at S4 (maturity) stage.

4.7.3.9. Different concentration of BD 500 on manganese

No significant difference on manganese was recorded among 12 treatments
(Fig. 4.10b). However, the high content of Mn (7.79±0.85 mg kg⁻¹) was recorded in
rice crop cultivated under T10 (BD 500 @137.5 g ha⁻¹). The Mn content of the soil in
other treatments was in the range of 7.54±0.86 mg kg⁻¹ to 7.70±0.91 mg kg⁻¹. The
high Mn content (8.45±0.59 mg kg⁻¹) was recorded in flowering stage (S2) and
thereafter it reduced and reached a value of 6.5±0.46 mg kg⁻¹ at maturity stage (S4).
The interaction between treatments and stages recorded that a significant effect, the
high content of Mn (9.39±2.70 mg kg⁻¹) was recorded in T3 at S2 stage whereas the
low (5.33±1.54 mg kg⁻¹) Mn in T2 at S4.
4.7.3.10. Different concentration of BD 500 on zinc

The zinc (Zn) content of the soil in 12 different treatments is presented in Fig. 4.10c. Among the treatments there is no significant difference was recorded in zinc content. However, application of BD 500 @ 100 g ha\(^{-1}\) (T7) in rice crop recorded for a high content (0.78±0.08 mg kg\(^{-1}\)) of Zn in soil. The Zn values in treatments such as T10, T8, T3 and T4 were on par with each other. The Zn content (0.72±0.05 mg kg\(^{-1}\)) of soil increased progressively up to panicle initiation stage (S2) and thereafter it recorded for a decreasing trend and reached the low content of Zn (0.61±0.04 mg kg\(^{-1}\)) at S4 (maturity stage). The interaction effect between treatments with stages, revealed that a high Zn content (0.88±0.21 mg kg\(^{-1}\)) was recorded in T3 at S1 stage and the low Zn content (0.43±0.13 mg kg\(^{-1}\)) was recorded in T1 at S4 stage in soil.

4.7.3.11. Different concentration of BD 500 on copper

The Cu content of 12 different treatments in soil is presented in Fig. 4.10d. High content of copper (1.53±0.22 mg kg\(^{-1}\)) was recorded in rice crop cultivated under T4 (BD 500 @ 62.5 g ha\(^{-1}\)) followed by T3 (1.42±0.20 mg kg\(^{-1}\)) and an equivalent content was recorded in T11 (recommended fertilizer zone). A significant increase in Cu content (1.60±0.12 mg kg\(^{-1}\)) was recorded at panicle initiation stage (S2). After that, the content of Cu (0.55±0.07 mg kg\(^{-1}\)) was decreased at maturity stage (S4). The treatments and stages had a significant interaction effect on Cu. A high Cu content (2.10±0.60 mg kg\(^{-1}\)) was recorded in T4, T7 and T11 at S2 (panicle initiation) stage.

4.7.3.12. Different concentration of BD 500 on boron

The result of boron content in soil with 12 different treatments is presented in Fig. 4.10e. The boron content (0.39±0.05 mg kg\(^{-1}\)) was high in rice crop cultivated under T1 (BD 500 @ 25 g ha\(^{-1}\)) and T5 (BD 500 @ 75 g ha\(^{-1}\)). An equivalent content was
recorded in T3, T10 and T6. In case different growth stages of rice crop the boron content in the soil increased (0.40±0.03 mg kg\textsuperscript{-1}) up to panicle initiation (S2) stage and decreasing trend (0.29±0.02 mg kg\textsuperscript{-1}) was recorded at maturity (S4) stage. The interaction effect of treatments with stages revealed that high boron content (0.45±0.05 mg kg\textsuperscript{-1}) was recorded in T10 at S1 & S2 and the low (0.20±0.02 mg kg\textsuperscript{-1}) in T4 at S1 stage.

4.7.3.13. Different concentration of BD 500 on sodium

It is evident that the sodium (Na) was significantly influenced by the 12 treatments Fig. 4.9f. The Na content was significantly high (132.43±18.15 mg kg\textsuperscript{-1}) in BD 500 @ 100 g ha\textsuperscript{-1} (T6) than rice crop cultivated under all other treatments, followed by T5 (127.80 ± 14.68 mg kg\textsuperscript{-1}). In case of different stages of crop growth, S1 (tillering) stage recorded the high Na content (129.02±5.08 mg g\textsuperscript{-1}). The interaction effects of treatments with stages were recorded to be significant and the high content of Na (153.34± 26.04 mg kg\textsuperscript{-1}) was recorded in T12 at S1 stage and the low content (84.00±24.16 mg kg\textsuperscript{-1}) was recorded in T2 at S2 stage.

4.7.3.14. Different concentration of BD 500 on soil carbon

The soil carbon such as organic, in-organic and total carbon are presented in Table 4.15. Among 12 treatments, the maximum percentage of organic carbon (1.47±0.18 %) and total carbon (1.48±0.18 %) were recorded in rice crop cultivated under T9 (BD 500 @ 125 g ha\textsuperscript{-1}) followed by T4 and T6 whereas, the minimum percentage was in T1 (BD500@ 25 g ha\textsuperscript{-1}). A negligible amount difference of inorganic carbon was recorded in all the treatments. In case of different stages, the maximum organic carbon (1.31±0.09 %) and total carbon (1.32±0.09 %) were recorded at S2 stage. The interaction between treatments and stages, have recorded a
maximum content (1.54±0.44 %) of organic carbon and total carbon were recorded in T9 at S2 stage and minimum OC 0.93±0.27 % and TOC 0.94±0.27 % recorded in T12 at S4.

4.7.4. Different concentration of BD 500 on soil microbial properties

4.7.4.1. Different concentration of BD 500 on bacterial load

The application of 10 different concentration of BD 500 significantly influenced the soil bacterial load at all the stages of crop growth and presented in Fig. 4.11a. Field spray of BD 500 @ 137.5 g ha⁻¹ (T10), BD 500 @ 125 g ha⁻¹ (T9), BD 500 @112.5 g ha⁻¹ (T8) and BD 500@100 g ha⁻¹ (T7) resulted for an increases in bacterial load of 31.59± 3.62 x10⁶ CFU g⁻¹, 29.18± 3.30 x10⁶ CFU g⁻¹, 28.24±3.15 x10⁶ CFU g⁻¹ and 27.15±2.99 x10⁶ CFU g⁻¹ respectively recorded in rice crop cultivated soil. At various stages of plant growth, high bacterial load (30.12±1.64 x10⁶ CFU g⁻¹) was recorded at S4 (maturity) stage. The interaction effect of treatments and various stages were recorded as non-significant. However, high bacterial load (42.80±6.12 x10⁶ CFU g⁻¹) was recorded in T10 at S4 stage.

4.7.4.2. Different concentration of BD 500 on fungal load

The fungal load in soil is presented in Fig. 4.11b. Significantly high fungal load was recorded in T10 (9.96±0.87 x10⁴ CFU g⁻¹), T9 (9.79±0.87 x10⁴ CFU g⁻¹), T8 (9.53±0.86 x10⁴ CFU g⁻¹) and T7 (9.23±0.89 x10⁴ CFU g⁻¹) in rice crop cultivated soil. In case of different stages, the high fungal load (10.94±0.47x10⁴ CFU g⁻¹) was recorded at S4 (maturity) stage and the low fungal load (5.91± 0.28 x10⁴ CFU g⁻¹) was recorded at S1 stage. The interaction between treatments and stages revealed that maximum fungal load (10.68±1.53 x10⁴ CFU g⁻¹) was recorded in T10 at S3 stage and minimum (3.56±0.51 x10⁴ CFU g⁻¹) in T11 at S1 stage.
4.7.4.3 Different concentration of BD 500 on actinomycetes load

The different of concentration of BD 500 significantly influenced the actinomycetes load in soil (Fig. 4.11c). The actinomycetes load was maximum in soil maintained under T10 (97.85±7.45 x10² CFU g⁻¹). The minimum actinomycetes load (30.81±2.86 x10² CFU g⁻¹) was recorded in control (T12), which was significantly less than other treatments. At various stages of crop growth, high and low actinomycetes load recorded at S4 (85.02±28.67 x10² CFU g⁻¹) and S1 stages (52.23±22.17 x10² CFU g⁻¹) respectively.

4.7.5. Different concentration of BD 500 on yield attributes and yields of rice crop

4.7.5.1. Different concentration of BD 500 on yield attributes of rice crop

The yield attributes of rice crop under 10 different concentration of BD 500 is presented in Fig. 4.12a, b, c & d. The mean data on yield parameters inferred that the rice crop cultivated under the treatment T7 (BD 500 @ 100 g ha⁻¹) registered for a maximum number of panicle hill⁻¹ (16.33±2.33), length of primary panicle (27.93±1.34 cm), weight of panicle (1.87±0.20), numbers of grain spiklets⁻¹ (17.67±1.86) and numbers of grains panicle⁻¹ (115.67±16.75) than the recommended fertilizer dose of fertilizer applied rice crop.

4.7.5.2. Different concentration of BD 500 on crop Yield

The 1000 grain weight (19.03±0.03 gm) of rice crop was maximum in T8 (BD 500 @ 112.5 g ha⁻¹), whereas straw yield 7.90 t ha⁻¹), grain yield (3.86 t ha⁻¹), harvest index (0.33 %), unit area efficiency (3.00 % ) and dry matter efficiency (0.35 %)
were high in the treatments T7 when compared to other treatments (Fig. 4.12e, f, g & h.)

4.8. Optimization of concentration of cow horn silica (BD 501) for rice crop

The experiment comprised of 13 treatments (T1 to T13) and treatment containing different doses of BD 501 (2.5, 7.5, 10, 15, 20, 25, 30, 35, 40, 45, 50 g ha\(^{-1}\)) applied as foliar spray.

4.8.1. Physico-chemical and microbial characterization of soil collected from field before crop cultivation

Soil sample from the experimental field before and after crop cultivation was collected from Ariyanoor village, Kancheepuram district and analysed for its physico-chemical and microbial properties. Initially soil pH was neutral (pH 7.6) and EC content was normal (0.13 dS m\(^{-1}\)). The organic carbon content (0.50 %) of soil was in the range of medium. The available nitrogen (130.00 kg ha\(^{-1}\)) and available phosphorus (22.00 kg ha\(^{-1}\)) were in medium status. The available potassium (190.00 kg ha\(^{-1}\)) was in low range. The content of calcium (430.12 mg kg\(^{-1}\)), magnesium (160.21 mg kg\(^{-1}\)) and sodium (130.34 mg kg\(^{-1}\)) were also recorded in the soil. The micronutrients of the soil recorded with high iron content (15.20 mg kg\(^{-1}\)) than other micronutrients such as manganese (7.75 mg kg\(^{-1}\)), zinc (0.72 mg kg\(^{-1}\)) and copper (1.62 mg kg\(^{-1}\)). The microbial load of the soil were also enumerated for bacteria (16.32 \(\times\)10\(^6\) CFU g\(^{-1}\)), fungi (3.12 \(\times\)10\(^4\) CFU g\(^{-1}\)) and actinomycetes (13.10 \(\times\)10\(^2\) CFU g\(^{-1}\)) (Table 4.14).
4.8.2. Different concentration of BD 501 on growth attribute of rice crop.

4.8.2.1. Different concentration of BD 501 on plant height of rice crop

The plant height with reference to the 13 different treatments and at 4 phenological stages indicated the existences of a significant difference in plant height at all the stages of growth and result is presented in Fig. 4.13a.

Among 13 treatments, rice crop cultivated under T7 (BD 501 @ 30 g ha⁻¹) recorded for a maximum plant height (82.38±5.56 cm) followed by T2. A steep increase in plant height (70.66±1.19 cm) was recorded at panicle initiation (S2) stage. A marked increase in plant height (94.32±1.19 cm) was attained at flowering stage (90.18±0.97 cm) followed by maturity stage. Interaction effect between treatments and stages revealed that the maximum plant height (105.00±2.89 cm) was recorded in T2 at S4 (maturity) stage and minimum (31.70±9.11 cm) in control (T12) recorded at tillering stage.

4.8.2.2. Different concentration of BD 501 on number of leaves of rice crop

A significant difference in numbers of leaves was recorded between the 12 treatments and illustrated in Fig. 4.13b. Maximum number of leaves (48.17±4.97) was recorded in rice crop cultivated under T7 (BD 501 @ 30 g ha⁻¹) compared to other treatments. With respect to 4 growth stages of rice crop, the maximum of number of leaves (54.55±2.00) was recorded at S4 stage and minimum (17.41±1.26) at tillering stage. The interaction effect between the treatments and stages revealed that the maximum number of leaves (64.00±1.00) was recorded in T7 at S4 and minimum (10.00±1.53) was recorded in T3 at S1.
4.8.2.3. Different concentration of BD 501 on number of tillers of rice crop

The difference in number of tillers of rice crop was recorded in 13 different treatments and presented in Fig. 4.13c. The maximum numbers of tillers (12.86±1.18) was recorded in rice crop cultivated under T7 treatment (BD 501 application 30 kg ha⁻¹) and which was on par with T8. Among 4 different stages of crop growth, the maximum number of tillers (12.80±0.40) were recorded at S4 (maturity) stage. The interaction effect of treatments with stages revealed that the maximum number of tillers (15.67±2.19) was recorded in T7 at S4 stage and the minimum number of tillers (4.33±0.33) in T13 at S2 stage.

4.8.2.4. Different concentration of BD 501 on total dry matter production of rice crop

Plant dry matter production showed that an increasing trend from tillering to maturity stage. A significant difference in the total dry matter production (TDMP) of crop was recorded at all the 4 stages (Fig. 4.13d). A steep increase in TDMP (25.35±0.99 g hill⁻¹) was recorded at panicle initiation (S2) stage of rice crop. The maximum TDMP (39.24±1.54 g hill⁻¹) was recorded in S4 stage (maturity) with an equivalent TDMP at S3 stage followed by S2 and S1 stages.

Among 13 treatments, rice crop cultivated under T8 (BD 501@ 35g ha⁻¹) recorded for a maximum TDMP (32.20±4.18 g hill⁻¹). An equal content of TDMP was also recorded in T11, T10, T9 and T7. The interaction effect of treatments with stages on TDMP have revealed that the maximum TDMP (44.73±6.39 g hill⁻¹) recorded in T8 at S4 (maturity) stage and minimum TDMP (10.27±1.45 g hill⁻¹) in T13 at S1 (tillering) stage.
4.8.2.5. Different Concentration of BD 501 on Root length

The root length of crop plants significantly differed among 12 different treatments and at different stages of crop growth (Fig. 4.13e). Maximum root length (19.65±0.70 cm) was recorded at flowering stage (S3). The interaction effect among treatments at different stages of crop growth revealed that the maximum root length (22.47±3.20 cm) was recorded in T7 at S3 stage and minimum (7.67±0.33 cm) was recorded in control (T13) at S1 stage. Among the treatments, rice crop cultivated under T7 (BD501 @ 30 g ha⁻¹) recorded for a maximum root length (18.33±1.36 cm) followed by T5, T11 and T6 and which were on par with each other.

4.8.3. Different concentration of BD 501 on physico-chemical properties of rice crop Soil

4.8.3.1. Different concentration of BD 501 on soil pH and EC

The pH of the soil was neutral to alkaline (Fig. 4.14a). Among 13 treatments, an alkaline pH (8.1±0.4) was recorded in control (T12), followed by T4 and T11. The EC of >1.00 dS m⁻¹ was recorded in the soil treatments. There was not much difference in EC values recorded at different stages of crop growth.

4.8.3.2. Different concentration of BD 501 on soil available nitrogen

High content of available nitrogen (129.80 ±3.04 kg ha⁻¹) was recorded in rice crop cultivated under T7 (BD 501 @ 30 g ha⁻¹) followed by T4 and T1. The treatments T3, T8, T9, T10, T2, T11, and T12 and the values were on par with each other. However treatment T7 revealed for a significant difference in values than other treatments. The high nitrogen content (130.00±3.47 kg ha⁻¹) of soil was recorded at S2 stage and low (99.35±3.80 kg ha⁻¹) at S4 stage. Interaction effect between treatments
and stages were also significant and high in nitrogen (136.40±5.51 kg ha\(^{-1}\)) recorded in T7 at S1 stage, whereas the low in T13 (71.63±2.90 kg ha\(^{-1}\)) at S3 stage (Fig. 4.14c).

**4.8.3.4. Different concentration of BD 501 on soil available phosphorus**

Among 13 different treatments (Fig. 4.14d) high content of available P (13.71 ± 0.67 kg ha\(^{-1}\)) was recorded in rice crop cultivated under T4 (BD 501 @ 15g ha\(^{-1}\)). The values updated under treatments such as T2, T7 and T6 were on par. The other treatments T1, T2, T3, T4, T5, T8, T9, T10, T11 and T12 were found to be non significant. In case of different stages of crop growth, the soil available P (14.86±0.41 kg ha\(^{-1}\)) was high at tillering (S1) stage, which reduced and attained the low (9.81±0.35 kg ha\(^{-1}\)) at maturity stage (S4). The interaction effect of treatments and various stages recorded the high available P content (19.83±0.80 kg ha\(^{-1}\)) was recorded in T7 at S1 stage when compared to other treatments.

**4.8.3.5. Different concentration of BD 501 on soil available potassium**

Among 13 treatments, the high available K content (161.26±10.61 kg ha\(^{-1}\)) was recorded in rice crop cultivated under T7 (BD501 @ 30g ha\(^{-1}\)) followed by recommended fertilizer dose (T12) (160.55±22.53 kg ha\(^{-1}\)) which were not significantly different from each other. The available K content (152.76±6.33 kg ha\(^{-1}\)) was high on panicle initiation stage (S2) compared to tillering stage (S1), which then decreased with time and attained the low available K content (114.34±5.90 kg ha\(^{-1}\)) on maturity stage (S4). The interaction between treatments and stages revealed that a high content of available K (210.40 ± 60.48 kg ha\(^{-1}\)) was recorded in T12 at S2 stage and the low available K content (72.03±20.71 kg ha\(^{-1}\)) was recorded in T13 (control) at S4 stage (Fig. 4.14e).
4.8.3.6. Different concentration of BD 501 on soil calcium

The Ca content of the soil was presented in Fig. 4.14f. The application of BD 501 @ 45 g ha\(^{-1}\) (T10) for rice crop recorded high calcium (447.40±19.93 mg kg\(^{-1}\)) content in soil, followed by T7, T9 and T11. With regard to soil Ca content at different growth stages, the high content (459.43±16.07 mg kg\(^{-1}\)) was recorded at flowering stage (S3) and it get decreased (345.55±13.50 mg kg\(^{-1}\)) on maturity stage (S4). The interaction effect between treatments with stages recorded the maximum Ca content (541.56 ±21.88 mg kg\(^{-1}\)) in T11 at S3 stage and minimum (218.20±62.72 mg kg\(^{-1}\)) in control at S4 stage.

4.8.3.7. Different concentration of BD 501 on soil magnesium

The Mg content of the soil was presented in Fig 4.14g. The high Mg content (188.40±7.10 mg kg\(^{-1}\)) recorded in rice crop cultivated under T8 (BD 501 @ 35 g ha\(^{-1}\)). The treatments such as T10, T11, T9 and T7 were on par with each other. The low Mg content (143.60±1.10 mg kg\(^{-1}\)) was recorded in control treatment (T12), which was significantly differing from T8. The Mg content was significantly altered over time in all the 13 treatments and the high Mg content (186.35±5.07 mg kg\(^{-1}\)) was recorded at S2 stage, after which there was a gradual decrease and the low content (136.60±4.41 mg kg\(^{-1}\)) was attained at the S4 (maturity) stage. The interaction effect of treatments and various stages have revealed that the high Mg content (221.71±8.96 mg kg\(^{-1}\)) in T8 at S3 stage and low content (116.40±33.46 mg kg\(^{-1}\)) in control at S4 stage.

4.8.3.8. Different concentration of BD 501 on soil sulphate

Among 13 treatments, there was no significant difference in the sulphate content was recorded (Fig. 4.15f). The high content of sulphate (21.38±1.73 mg kg\(^{-1}\)) was recorded in rice crop cultivated under treatment T8 (BD 501 @ 35 g ha\(^{-1}\)).
Equivalent content of sulphate was recorded in T9 and T6. Among 4 different stages of crop growth, high content (21.64±0.54 mg kg^{-1}) of sulphate was recorded in S1 (tillering) stage and low content (11.59±0.63 mg kg^{-1}) in S4 (maturity) stage. With respect to interaction effect of treatments with stages revealed that the high content of sulphate (28.73±1.16 mg kg^{-1}) was recorded in T8 at S2 stage whereas the low content of sulphate (8.80±0.36 mg kg^{-1}) was recorded in T5 at S4 stage.

4.8.3.9. Different concentration of BD 501 on soil iron

The data on soil Fe at different stages of crop growth and treatments are presented in Fig. 4.15a. The Fe content of the soil was high (14.34±0.59 mg kg^{-1}) in rice crop cultivated under T11 (BD 501 @ 50 g ha^{-1}) followed by T9. The treatments T1, T2, T3, T4, T5, T6, T7, T8 and T10 were on par with each other. In case of various stages, the Fe content was recorded maximum at tillering stage (S1) (11.13±0.27 mg kg^{-1}) and minimum at (8.43±0.49 mg kg^{-1}) maturity stage (S4). Among the interactions, the treatment T11 at S2 and S3 stage recorded highest Fe value of 15.59±0.63 mg kg^{-1} compared to other treatments.

4.8.3.10. Different concentration of BD 501 on soil manganese

The total Mn content of soils from various treatment and different stages of crop growth are presented in Fig. 4.15b. High content of Mn (9.15±1.08 mg kg^{-1}) was recorded in rice crop cultivated under T7 (BD 501 @ 30 g ha^{-1}). With respect to the effect of various stages, highest Mn content (12.51±0.45 mg kg^{-1}) was recorded in all the treatments at S1 stage (tillering). The interaction effect of treatments and various stages were significant and the maximum Mn content (14.74±0.60 mg g^{-1}) was recorded in T7 at S1 stage and minimum content (4.03±0.16 mg g^{-1}) recorded in T2 at S4 stage of soil.
4.8.3.11. Different concentration of BD 501 on soil zinc

The results of soil Zn content are presented in Fig. 4.15c. Significantly high Zn content (0.92±0.04 mg g⁻¹) was recorded in rice crop cultivated under T7 (BD 501 @ 30 g ha⁻¹). In case of different stages, the high Zn content (0.83 ±0.03 mg g⁻¹) was recorded at S1 stage and the low Zn content (0.61±0.02 mg g⁻¹) was recorded at S4 stage. The interaction between treatments and stages was significant. Among the 13 treatments, T11 at S1 stage was recorded the high Zn content (1.27±0.05 mg g⁻¹) and low Zn content (0.44±0.02 g⁻¹) was recorded in T2 at S4 stage of soil.

4.8.3.12. Different concentration of BD 501 on soil copper

The Cu content of different treatments in soil is presented in Fig. 4.15d. High content (1.83±0.19 mg kg⁻¹) of Cu recorded in rice crop cultivated under T10 (BD 501 @45 g ha⁻¹) and an equivalent content of Cu was also recorded in T11, T6, T9 and T8. The significantly high content of Cu (2.34±0.07 mg kg⁻¹) was recorded at tillering stage (S1). After that, Cu started decreasing in content (1.02±0.05 mg kg⁻¹) at maturity stage (S4). The treatments and stages had a significant interaction effect on Cu. The high content (2.85±0.12 mg kg⁻¹) of Cu was recorded in T10 at S1 stage and the low Cu content (0.15±0.04 mg kg⁻¹) was recorded in T13 at S4 stage.

4.8.3.13. Different concentration of BD 501 on soil boron

The result of boron content in soil presented in Fig. 4.15e. Boron content of soil was high (0.36±0.03 mg kg⁻¹) in rice crop cultivated under T8 (BD 500 @ 35 g ha⁻¹) which was on par with all the treatments. Among the different stages of plant growth, the content of boron (0.39±0.01 mg kg⁻¹) was high at tillering stage (S1) and low (0.22±0.01 mg kg) at maturity (S4) stage. The interaction effect of treatments with
stages on the boron have revealed that the high boron content \((0.53\pm0.02 \text{ mg kg}^{-1})\) in T8 at S1, whereas the low content \((0.15\pm0.01 \text{ mg kg}^{-1})\) was recorded in T1 at S4 stage.

**4.8.3.14. Different concentration of BD 501 on soil sodium**

The Na content was high \((141.75\pm5.51 \text{ mg kg}^{-1})\) in rice crop cultivated under T4 \((\text{BD 501 @ 15 g ha}^{-1})\) followed by T7. Among 4 different stages, S1 stage (tillering) recorded the maximum content \((139.09\pm3.56 \text{ mg kg}^{-1})\), which gradually decreased \((101.51\pm3.43 \text{ mg kg}^{-1})\) at S4 (maturity) stage. The interaction effects of treatments with stages recorded the high Na content \((161.09\pm6.51 \text{ mg kg}^{-1})\) was recorded in T4 at S2 and low content \((79.95 \pm3.23 \text{ mg kg}^{-1})\) in T1 at S4 stage (Fig. 4.14f).

**4.8.3.15. Different Concentration of BD 501 on Soil carbon**

The soil carbon such as organic, in-organic and total carbon are presented in Table 4.16. The high percent \((1.97\pm0.25 \%)\) organic carbon and total carbon were recorded in rice crop cultivated under T4 \((\text{BD 500 @ 40 g ha}^{-1})\) followed by T9, T10 and T11. The percent of in-organic carbon in all treatments was negligible. In the case of different stages, the high value of \(1.33\pm0.13 \%\) of organic carbon and total carbon was observed at S2 stage and the low value of \(1.19\pm0.12 \%\) organic carbon and total carbon was recorded at S4 (maturity) stage. The interaction between treatments and stages have revealed that the maximum content of organic carbon \((2.26\pm0.64 \%)\) and total carbon \((2.25\pm0.65 \%)\) recorded in T4 at S2 stage and minimum content \((0.78\pm0.22 \%)\) of both organic and total carbon were recorded in T1 at S4.
4.8.4. Different concentration of BD 501 on soil microbial properties

4.8.4.1. Different concentration of BD 501 on bacterial load

Rice crop cultivated under T10 (24.85±2.83 $\times 10^6$ CFU g$^{-1}$), T7 (23.92 ±2.67 $\times 10^6$ CFU g$^{-1}$), T3 (23.72±2.52 $\times 10^6$ CFU g$^{-1}$) and T5 (22.43±2.52 $\times 10^6$ CFU g$^{-1}$) were recorded high which were on par with each other. With respect to the effect of various stages, maximum bacterial load (27.89 ±1.18 $\times 10^6$ CFU g$^{-1}$) was recorded in all the treatments at S4 (maturity) stage. The interaction effect of treatments and various stages, the maximum number of bacterial load (34.56±4.94 $\times 10^6$ CFU g$^{-1}$) in T7 at S4 and minimum (12.40±1.77 $\times 10^6$ CFU g$^{-1}$) in T12 at S1 stage (Fig. 4.16a).

4.8.4.2. Different concentration of BD 501 on fungal load

Fungal load are presented in Fig 4.16b. Significantly high fungal load recorded in rice crop cultivated under T8 (10.58±0.89 $\times 10^4$ CFU g$^{-1}$), T10 (10.45±1.04 $\times 10^4$ CFU g$^{-1}$), T2 (9.10±0.92 $\times 10^4$ CFU g$^{-1}$) and T7 (8.74±0.94 $\times 10^4$ CFU g$^{-1}$) were on par with each other. In case of different stages, the high fungal load (10.87±0.45 $\times 10^4$ CFU g$^{-1}$) was recorded at S4 stage. The interaction between treatments and stages of plant growth was non significant. However, high fungal (13.27±1.90 $\times 10^4$ CFU g$^{-1}$) load was recorded in T8 at S4 and low fungal load (3.56±0.51 $\times 10^4$ CFU g$^{-1}$) was recorded in T12 at S1.

4.8.4.3. Different concentration of BD 501 on actinomycetes load

The 13 different treatments containing various concentration of BD 501 influenced significantly on actinomycetes load in the soil (Fig. 4.16c.). The high actinomycetes loads in rice crop cultivated under T11 (58.20±6.59 $\times 10^2$ CFU g$^{-1}$) and T8 (58.05±3.83 $\times 10^2$ CFU g$^{-1}$) recorded the maximum actinomycetes load. The
actinomycetes load in various stages of plant growth, high (60.53±2.73 x10² CFU g⁻¹) and low (33.04±1.83 x10² CFU g⁻¹) were recorded at S4 and S1 stage respectively. The interaction between treatments and stages revealed that the maximum actinomycetes of load (73.40±10.49 x10² CFU g⁻¹) was recorded in T5 at S4 and minimum (21.35±3.05 x10² CFU g⁻¹) in T13 at S1.

**4.8.5. Different concentration of BD 501 on yield and yield attributes of rice crop**

**4.8.5.1. Different Concentration of BD 501 on Yield attributes of rice crop**

The yield attributes such as number of panicle, panicle length, panicle weight, number of grains per panicle and number of grain per spikelet’s were recorded for rice crop cultivated under 13 different treatments. The mean data on yield parameters inferred that the treatment rice crop cultivated under T7 (BD 501 @ 30 g ha⁻¹) registered for maximum number of panicle hill⁻¹ (13.67±0.67), primary panicle length (28.97± 0.71 cm) and panicle weight (2.15±0.12 g) than recommended fertilizer dose of BD 501. The maximum no of grains panicle⁻¹ (136.3±15.4) was recorded in T8 and T7 (Fig. 4.17a, b, c & d).

**4.8.5.2. Different concentration of BD 501 on yield of rice crop**

The 1000 grain weight (19.4±0.18 gm), grain yield (4.10±0.21 kg ha⁻¹) harvest index (0.28±0.04) unit area efficiency (2.93±0.15 %) and dry matter efficiency (0.29±0.06 %) indicated were high in T7 (BD 501 @ 30g ha⁻¹) than the other treatments. However, high straw yield (11.18±1.53 t ha⁻¹) recorded in T8 (BD 501 @ 35g ha⁻¹) (Fig. 4.17e, f, g & h).
4.9. Evaluation of biodynamic practices on rice crop under two agro climatic zones of Tamil Nadu

Field experiments were conducted at farmers’ fields in Ariyanoor, Kancheepuram District (North-Eastern zone) and Kadavur, Karur District (South zone) of Tamil Nadu, India. The optimized concentration of BD 500 and BD 501 was utilized in package of practices. Paddy varieties ADT43 was chosen for North-Eastern zone and White Ponni varieties rice in South zone. The experiment comprised of 4 treatments such as Biodynamic (T1), Organic (T2), Conventional (T3) and Control (T4).

4.9.1. Physico-Chemical and microbial characterization of soil collected from field before crop cultivation

Initially, the soils from the experimental fields in North-Eastern zone and South zone were characterized and the results are presented in Table 4.17. The soil pH was neutral and EC values of 0.23 dS m⁻¹ and 0.20 dS m⁻¹ respectively in North-Eastern and South zones. The total carbon content (1.38 % and 1.40 %) recorded in North-Eastern and South zones. The low range of available N, P and K recorded in both zones. With regards to the available micronutrient status of the soil, Fe was high (6.20 mg kg⁻¹ and 8.30 mg kg⁻¹) compared to Mn, Zn and Cu in both zones. The bacterial (10.00 x 10⁶ CFU g⁻¹ and 19.00 x 10⁶ CFU g⁻¹), fungal (2.00 x 10⁴ CFU g⁻¹ and 5.00 x 10⁴ CFU g⁻¹) and actinomycetes loads (5.00 x 10² CFU g⁻¹ and 7.00 x 10² CFU g⁻¹) respectively recorded in North-Eastern and South zones.
4.9.2. Growth attribute of rice crop cultivated under different method of practices

4.9.2.1. Plant height of rice crop cultivated under different method of practices

There was no significant difference in plant height recorded at all the stages of growth in rice crop cultivated under 2 zones with different treatments.

Among 4 treatments in North-Eastern zone, rice crop cultivated under T1 (biodynamic) recorded for maximum plant height (80.74±1.44 cm) followed by organic and conventional practices at maturity stage (S4) in North-Eastern zone. A steep increase in plant height was recorded in panicle initiation for all the treatments (Fig. 4.18a). Maximum plant height (83.62±1.32) was recorded in rice crop cultivated under biodynamic practices (T1) in South zone (Fig. 4.19a). However, plant height in both zones among various treatments did not significantly differ from each other.

4.9.2.2. Numbers of tillers and leaves of rice crop cultivated under different method of practices

The maximum number of tillers (63.4±1.04) and leaves per plant (63.40±1.21) were recorded in biodynamic treatment (T1) at maturity stage maintained under North-Eastern zone (Fig. 4.18b,c). Similarly, maximum number of tillers (65.00±1.23) and leaves (58.00±2.01) per plant in a biodynamic treatment at maturity stage were recorded in South zone (Fig. 4.19b,c). Number of tillers and leaves in all treatments differed significantly from control.

4.9.2.3. Root system of rice crop cultivated under different method of practices

Root length, root volume and root biomass of rice crop cultivated under various practices were presented in Fig. 4.18d, e & f and Fig. 4.19d, e & f.
Maximum root length \( (14.86 \pm 1.81 \text{ cm}) \) in biodynamic treatment (T1) at flowering stage, root volume \( (16.92 \pm 4.42 \text{ cc}) \) and biomass \( (14.07 \pm 4.79 \text{ g}) \) in biodynamic treatment at maturity stage was recorded in North-Eastern zone. In South zone, the maximum root length \( (30.52 \pm 1.23 \text{ cm}) \), root volume \( (80.7 \pm 1.44 \text{ cc}) \) and root biomass \( (42.5 \pm 1.78 \text{ g hill}^{-1}) \) were also recorded in biodynamic treatment at maturity stage.

4.9.3. Physiological parameters of rice crop cultivated under different method of practices

4.9.3.1. Leaf area, leaf area index and total dry matter production of rice crop cultivated under different method of practices

Rice crop cultivated under biodynamic treatment had an effect on the physiological parameters of ADT 43 rice variety in North-Eastern zone. The maximum leaf area \( (1472.6 \pm 124.4 \text{ cm}^2) \), leaf area index \( (3.68 \pm 0.31) \) and total dry matter production \( (7.08 \pm 0.08 \text{ t ha}^{-1}) \) were recorded at maturity stage. The recorded values of leaf area, leaf area index and total dry matter production in organic treatment were on par with biodynamic treatment \((\text{Fig. 4.20a, b & c})\).

In case of South zone, the same trend as mentioned above was observed. In biodynamic treatment, a maximum leaf area \( (1920 \pm 145.6 \text{ cm}^2) \), leaf area index \( (4.80 \pm 0.37) \) and total dry matter production \( (8.62 \pm 0.28 \text{ t ha}^{-1}) \) were recorded. The minimum leaf area \( (1680 \pm 127.4 \text{ cm}^2) \), leaf area index \( (4.2 \pm 0.32) \) and dry matter production \( (5.14 \pm 0.17 \text{ t ha}^{-1}) \) were recorded in control. \((\text{Fig. 4.21a, b & c})\). When comparing the two different zones on the effect of various treatments on the rice crop, it was concluded that biodynamic treatment had a highly remarkable effect on in white ponni variety at South zone.
4.9.3.2. Leaf area duration, crop growth rate and net assimilation rate of rice crop cultivated under different method of practices

The duration of leaf, growth rate and assimilation rate were enhanced in biodynamic treatment in both zones. The maximum leaf duration (95.12±7.13 days), crop growth rate (0.67±0.13 mg m⁻² day⁻¹) and net assimilation rate (2.32±0.45 gm⁻² day⁻¹) were recorded at S3-S4 growth stage in North-Eastern zone (Fig. 4.20d, e & f). Likewise, in South zone the maximum duration of leaf (96.82±7.34 days), growth rate (0.46±0.14 mg m⁻² day⁻¹) and assimilation rate (2.73±0.39 gm⁻² day⁻¹) were recorded at S3-S4 growth stage (Fig. 4.21d, e & f).

4.9.3.3. Photosynthetic pigments of rice crop cultivated under different method of farming

The contents of photosynthetic pigments such as chlorophyll ‘a’, chlorophyll ‘b’ total chlorophyll, ab ratio and carotenoids are presented in Fig. 4.22a, b, c, d & e). Among treatments in North-Eastern zone, the high content of chlorophyll ‘a’ (0.78±0.13 mg g⁻¹), total chlorophyll (1.12±0.19 mg g⁻¹) and carotenoids (0.37±0.06 mg g⁻¹) were recorded in biodynamic treatment whereas highest values of chlorophyll ‘b’ (0.49±0.15 mg g⁻¹) and a/b ratio (2.75±0.64 mg g⁻¹) were recorded in control. In case of South zone, the high content of chlorophyll ‘a’ (0.76±0.08 mg g⁻¹), chlorophyll ‘b’ (0.48±0.08 mg g⁻¹) and total chlorophyll (1.24±0.13 mg g⁻¹) were recorded in biodynamic treatment (T1) and lowest values of chlorophyll ‘a’ (0.50±0.06 mg g⁻¹), chlorophyll ‘b’ (0.29±0.04 mg g⁻¹) and total chlorophyll (0.76±0.09 mg g⁻¹) were recorded in control. In both zones showed a progressive increase till flowering (S3) and gradually declined in maturity stage (S4) Fig.
However, biodynamic and organic farming methods retained the green colour even after maturity stage (Plate 11).

4.9.4. Soil properties of rice crop cultivated under different method of practices

4.9.4.1. Soil pH and EC of rice crop cultivated under different method of farming

The soil pH significantly varied between different farming practices (Fig. 4.24a & 4.25a) in both zones. Both in North-Eastern and South zones, neutral pH was recorded in biodynamic (T1), conventional (T3) and control (T4) respectively. The effect of different farming method of practices on electrical conductivity was presented in Fig. 4.24b & Fig. 4.25b). The EC content of all the treatments recorded < 1.00 dSm⁻¹ in both zones.

4.9.4.2. Major nutrients of rice crop cultivated under different method of farming

The available nutrients such as Nitrogen, Phosphorus and Potassium in the soil in different treatments at both the zones are presented in Fig. 4.24 (c, d, e) and Fig. 4.25 (c, d, e). The macronutrients present in the soil was decreasing during the growth of the crop from tillering to harvesting stage

Among the treatments in North-Eastern Zone, the high content of available nitrogen (126.76±0.22 kg ha⁻¹) was recorded under organic practices at tillering-panicle initiation stage (S1-S2) and the low content available nitrogen was recorded in conventional treatment (T3) at S1-S2, The phosphorus content (16.00±1.29 kg ha⁻¹) was high in control at S2-S3 stage and potassium (175.03±14.11 kg ha⁻¹) was high in biodynamic treatment at S2-S3 stage where as phosphorus and potassium contents were low in organic treatment (T2) at all the stages of crop growth. In South zone,
nitrogen (129.83±10.47, kg ha⁻¹) and phosphorus (17.11±1.38 kg ha⁻¹) contents were recorded high in biodynamic treatment at S1-S2 whereas; potassium (157.42±12.69 kg ha⁻¹) content was recorded high in control at S1-S2. However, major nutrient content in both zones doesn’t differ significantly from each other.

4.9.4.3. Secondary nutrients of rice crop cultivated under different method of practices

The secondary nutrients such as calcium, magnesium and sulphate content in the soil of different treatments at both the zones are presented in Fig. 4.24 (f, g, h) and Fig. 4.25 (f, g, h). In all the treatments the Ca (314.24±10.62 mg kg⁻¹ to 515.56±41.57 mg kg⁻¹), Mg (139.05±11.21 mg kg⁻¹ to 192.22±1.79 mg kg⁻¹) and SO₄ (7.49±0.60 mg kg⁻¹ to 32.04±2.58 mg kg⁻¹) contents were ranged from tillering to maturity stage. In South zone Ca (362.22±29.20 mg kg⁻¹ to 689.64±55.60 mg kg⁻¹), Mg (139.81±11.27 mg kg⁻¹ to 212.27±17.11 mg kg⁻¹) and SO₄ content (6.74±0.54 mg kg⁻¹ to 30.98± mg kg⁻¹) contents were ranged from tillering to maturity stage.

4.9.4.4. Minor nutrients of rice crop cultivated under different method of practices

The effect of different farming methods on minor nutrients such as iron, manganese, zinc, copper, boron and sodium in both the zones are given in Fig. 4.26 (a, b, c, d, e, f) and Fig. 4.27(a, b, c, d, e, f)

The Fe content showed no significant variation under different treatments both in North-Eastern and South zones. At various crop growth stages it was (9.12±0.49 mg kg⁻¹ to 15.59±1.26 mg kg⁻¹ and 8.42 ±0.68 mg kg⁻¹ to 16.17±1.30 mg kg⁻¹) ranged from tillering to maturity stage in North-Eastern and South zones respectively. The content of Mn ranged from tillering to maturity stage at North-Eastern zone
(4.07±0.33 mg kg⁻¹ to 12.72±1.03 mg kg⁻¹) and South zone (5.00±0.33 mg kg⁻¹ to 18.56±1.50 mg kg⁻¹) respectively.

The Zn content of soil ranged from 0.49±0.04 mg kg⁻¹ to 1.21±0.10 mg kg⁻¹ and 0.37±0.03 mg kg⁻¹ to 1.94±0.16 mg kg⁻¹ in North-Eastern and South zone respectively. The Cu content ranged from 1.24±0.10 mg kg⁻¹ to 2.68±0.22 mg kg⁻¹ in North-Eastern zone and 0.18±0.01 mg kg⁻¹ to 0.57±0.05 mg kg⁻¹ in South zone.

The B and Na values of soil ranged in North-Eastern Zone was 0.20±0.02 mg kg⁻¹ to 0.42±0.03 mg kg⁻¹ of B and 161.67±13.03 mg kg⁻¹ to 94.50±7.64 mg kg⁻¹ of Na. In South Zone, it were ranged from 1.24±0.10 mg kg⁻¹ to 2.33±0.19 mg kg⁻¹ of B and 98.77±7.96 mg kg⁻¹ to 168.85±13.61 mg kg⁻¹.

4.9.4.5. Soil Carbon content of rice crop cultivated under different method of farming

The effect of different farming method on carbon content such as organic, inorganic and total carbon content of soil were given in Fig. 4.28 (a,b,c) and Fig. 4.29 (a,b,c).

In North-Eastern zone, the high percentage of organic, in-organic and total carbon of soil was recorded in biodynamic treatment (T1) at various stages of crop growth. The organic carbon content recorded high in biodynamic practices at various growth stages, S1-S2 (1.40 ± 0.0 3 %), S2-S3 (1.89±0.15 %) and S3-S4 (1.17±0.09 %) stages. Inorganic carbon content (1.08 ± 0.09 %) was recorded only in the biodynamic practices at S3-S4 stage where as other stages recorded negligible in inorganic carbon content. With respect to South zone, the high percentage of organic carbon of soil was recorded in organic treatment (T2) at various stages of crop growth such as S1-S2 (2.50±0.20 %), S2-S3 (1.60±0.13 %) and S3-S4 (2.59±0.21 %). In case
of In-organic carbon, high percentage was recorded in conventional treatment (T3) at various stages. Whereas, total carbon content of soil was high in biodynamic treatment (T1) at various growth stages were S1-S2 (2.22±0.18 %), S2-S3 (3.03±0.24 %) and S3-S4 (4.47±0.36 %).

4.9.4.6. Microbial load of rice crop cultivated under different method of practices

The effects of different farming method on microbial load such as total bacteria, fungi and actinomycetes in both the zones were given in Fig. 4.28 (a,b,c) and Fig. 4.29 (a,b,c). In North-Eastern zone, an increasing trend of bacterial & fungal load was recorded at all the stages of crop growth whereas actinomycetes load of soil increased progressively up to S2- S3 stages. The maximum number of bacteria and actinomycetes were recorded in organic treatment and fungal was maximum in biodynamic practices (T1). The minimum loads of bacteria and fungi were recorded in conventional (T3). Whereas, actinomycetes load was minimum in biodynamic practices (T1).

With respect to South zone, an increasing trend of bacterial was observed at all the stages of crop growth whereas fungi and actinomycetes load increased progressively up to S2- S3 stages. The maximum bacterial and fungal loads were recorded in biodynamic practices. The maximum actinomycetes load was recorded in organic practices. The minimum number of bacteria and actinomycetes were recorded in control (T4). In case of fungi, minimum number was recorded in conventional practices (T3).
4.9.5. Yield and yield attributes of rice crop of rice crop cultivated under different method of practices

4.9.5.1. Yield attributes of rice crop cultivated under different method of practices

The maximum yield attributes such primary panicle length (22.22±0.76 cm) and no of grains panicle⁻¹(120.84±6.47) was recorded in T1 (biodynamic treatment) whereas high panicle weight (2.15±0.10) recorded in T2 (organic treatment) under North-Eastern zone. In case of South zone, the maximum primary panicle length (22.9±0.31 cm) (Plate 11), no of grains panicle⁻¹(170.8±1.47) and panicle weight (2.66±0.19) were recorded in T1 (biodynamic treatment) (Fig 4.30 and Fig 4.31).

4.9.5.2. Yield of rice crop cultivated under different method of practices

The 1000 grain weight (18.76±3.12 gm), straw yield (6.30±0.29 t ha⁻¹), grain yield (1.98±0.34 kg ha⁻¹) and harvest index (0.24±0.03) indicated that the treatment biodynamic (T1) registered high mean values as compared to other treatments in North-Eastern zone (Fig. 4.30). In case of South zone, except harvest index, 1000 grain weight (14.99±1.14 g), straw yield (6.28±0.38 t ha⁻¹) and grain yield (5.06±0.34 kg ha⁻¹) were high in treatment biodynamic (T1) as compared to other treatments. Harvest index was recorded high in conventional treatment (T3) however it was on par with organic (T2) and biodynamic treatments (T1). The lower values were recorded in control in all yield and yield attributes in both the zones (Fig. 4.30 and Fig 4.31).
4.10. Physical, milling and cooking quality characters of rice grains cultivated under different method of practices

4.10.1. Physical quality of paddy grains of cultivated under different method of practices

The physical quality such as length (6.0 mm), breath (2.2 mm) and hardness (4.8 kg cm\(^2\)) were high in paddy grain cultivated under biodynamic practices at North-Eastern zone. However, thickness paddy grain was registered high in conventional practices. Similarly, in case of South zone physical character of paddy grain such as length (5.8 mm), breath (2.3 mm) and hardness (6.2 mm) were recorded in biodynamic practices (Table 4.18).

4.10.2. Milling quality of paddy grains of cultivated under different method of practices

The raw milling performance of paddy grain, the husk yield (24.7 %) and polished rice yield (69.2 %) were recorded high in rice cultivated under biodynamic practices. However, no significant difference in husk and polished grain yields were recorded among all the treatments. Maximum head rice (92.5 %) and minimum broken rice (7.5 %) were recorded in control treatment of rice cultivated in North Eastern zone. In case of South zone maximum husk (25.7 %) and recorded in control. Significant quantities of head rice (87.5 %) and minimum broken rice (12.5 %) were registered in crop cultivated under biodynamic practices (Table 4.19).

4.10.3. Cooking quality of rice grains of cultivated under different method of practices

The cooking properties rice grains revealed that an optimal cooking time was maximum (18 min) in biodynamic practices and minimum (16 min) in control.
Volume of cooked rice was expended high in organic grain (440 ml100g⁻¹) followed by conventional practices under North-Eastern zone. In South zone minimum cooking time (14 min) and volume of cooked rice expended (450 ml 100 g⁻¹) high in biodynamic practices. No significant differences in taste and aroma were observed in rice under various treatments of both zones (Table 4.20).

4.10.4. Physico-chemical characteristics of rice grains of cultivated under different method of practices

Among 4 treatments there was no significant difference in gelatinization temperature (75.5 °C) recorded. Gel consistency (57 mm) was high in rice cultivated under conventional practices followed by organic practices in North-Eastern zone. The high gel consistency (52 mm) was recorded in rice grain under biodynamic treatment from South zone. Therefore, hard consistency in rice grains was recorded in North-Eastern zone under biodynamic treatment whereas, medium consistency was recorded rice grain in South zone under biodynamic treatments (Table 4.21).

High percentage of equilibrated moisture content was recorded on soaking of milled rice from both organic and conventional treatments. The percentage of gruel loss (12.2 %) was high in biodynamic rice cultivated under North-Eastern zone. In case of South zone, a high percentage of equilibrated moisture content and lower gruel loss were recorded in biodynamic treatment rice samples.

4.10.5. Carbohydrates and protein content of rice grains cultivated under different method of practices

The rice grain contains >70 % of carbohydrates and >5 % of protein contents were recorded in all the treatments (Table 4.22) from North-Eastern zone. The high contents of carbohydrates (78.42 %) and protein (5.32 %) were recorded in rice grains
under biodynamic practices (T1) in North-Eastern zone. In case of South zone >80 % of carbohydrates and >7 % of protein contents were recorded in all the treatments (Table 4.22). The high contents of carbohydrates (85.18 %) and protein (7.43 %) were also recorded in rice grains under biodynamic treatment (T1).