WET SOIL ANALYSIS FOR NUTRIENT PRESCRIPTION IN PADDY SOILS

By

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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DECLARATION

I, hereby declare that this thesis entitled **"Wet soil analysis for nutrient prescription in paddy soils"** is a bona-fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or society.

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CERTIFICATE

Certified that this thesis, entitled **"Wet soil analysis for nutrient prescription in paddy soils"** is a record of research work done independently by **Ms. Irene Elizabeth John** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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We, the undersigned members of the Advisory Committee of **Ms. Irene Elizabeth Johna** candidate for the degree of **Master of Science in Agriculture** with major field in **Soil Science and Agricultural Chemistry,** agree that the thesis entitled **"Wet soil analysis for nutrient prescription in paddy soils"** may be submitted by Ms. Irene Elizabeth John in partial fulfillment of the requirements for the degree.

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Acknowledgement

I am what I am by the grace of God and his grace toward me has not been in vain.

(1 Corinthians 15:10)

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Introduction

1. INTRODUCTION

Rice is grown under varying degrees of submergence. The traditional rice growing tracts in Kerala are: Kuttanad, Palakkad central and eastern plains, Kole, Pokkali, Onattukara and wetland laterites. These soils are with widely varying fertility status. Kuttanad and Kole are potentially acid sulphate soils with high acidity and high organic matter content. Pokkali soils are acid saline in nature influenced by sea water inundation. The soils from Palakkad central plains are with acidic to near neutral pH. Soils from Palakkad eastern plains are neutral black cotton soils with high productivity. The midland lateritic soils are the most dominant soil type in the state with high acidity, low organic matter content and hence with low productivity. The sandy plains of Onattukara are very poor in fertility due to low organic matter content and sandy texture. These soils under flooded anaerobic environment behave differently with respect to dynamics and transformation of nutrient elements.

Soil test based fertilizer recommendation for rice at present is based on analysis of soil samples after drying and processing. However, the chemistry and dynamics of nutrient transformations under anaerobic soil environment is quite different from that of aerobic soils as detailed by Ponnamperuma (Ponnamperuma, 1972). Thus, analysis after drying definitely changes the levels of plant available forms due to oxidation and subsequent transformations. Hence, the analytical results may not reflect the actual status of plant available pools of nutrient in flooded environment. Thus, to get a real picture of nutrient availability in flooded anaerobic environment samples are to be taken as such without disturbing the reduced anaerobic environment and to be analyzed.

In general, the acid sulphate and acid saline soils of Kerala (Kuttanad, Pokkali and Kole) are rich in organic matter. This naturally resulted in high organic carbon status in these soils. In soil test based recommendation, nitrogen is applied based on the organic carbon status assuming that the C:N ratio tend to stabilize at 10:1. As per recommendations, for such soils with high organic matter under submergence nitrogen rates are to be reduced since the organic carbon content is very high. But if the nitrogen doses are reduced crop is found to be suffering from N deficiency. This is because under anaerobic flooded conditions the rate of decomposition of organic matter is a bit slower than under oxidized aerobic environment and the stabilization of C:N ratio definitely will take more time and the ratios naturally may attain stability at wider levels much above than 10:1, particularly when analysis is carried out maintaining the reduced atmosphere which is depicting the real rhizosphere environment of the standing rice crop. Further, attainment of stability of C:N ratio to a constant value (eg. 10-12:1 in tropical aerobic soils) may take different periods of time depending on the initial organic matter status of the soil, C:N ratio of added organic matter as well as the rate of decomposition. The enhanced rate of carbon sequestration as reported from flooded rice soils is due to lower rate of decomposition under anaerobic environment (Lal, 2004). Hence, it becomes mandatory to study the chemistry and pattern of decomposition of organic matter as well as carbon nitrogen relations in these soils under anaerobic flooded conditions to know the equilibrium C:N ratio and the time taken for equilibration. This in turn will definitely help to have a meaningful organic carbon based nitrogen recommendations.

The above background information necessitated the present study with the following objectives:

- Developing a methodology for sampling and analysis of flooded soils in comparison with routine analysis of dried samples
- To study the C:N ratio equilibrium under anaerobic soil environment so as to develop ratings for nitrogen fertility based on organic carbon content under submerged soil.

Review of Literature

2. REVIEW OF LITERATURE

Lowland rice or paddy systems in Asia make a major contribution to the global rice supply. The lowland rice system is often cited as an example of a sustainable system. Growing of rice in submerged soils is an integral component of the traditional, age-old technology in monsoon Asia (Kyuma 2004). This method of rice cultivation involves land preparation by cultivating the land in the flooded or saturated state (termed puddling), followed by transplanting rice seedlings into the puddled paddies, and growing of rice in submerged soils until two to three weeks prior to the harvest of the crop. Over 70% of Asia's rice is produced in irrigated lowland fields with high irrigation requirements to maintain a layer of standing water on the soil surface during most of the growing season (Bouman and Tuong, 2001).

Indeed, aerobic rice is seen as an emerging option to produce rice with less water than the submerged rice system (Xue *et al.*, 2008). The aerobic rice uses cultivars that maintain high productivity under aerobic, non-submerged or non-saturated soils (Kato *et al.*, 2009). There is an overlap in the definitions of traditional upland rice and aerobic rice (Bouman *et al.*, 2007). Generally, rice grown on fertile uplands using high yielding cultivars with adequate water supply can be regarded as aerobic rice (Bouman and Tuong 2001) and non-irrigated or rain-fed rice with lower productivity expectations is regarded as upland rice (Kato *et al.*, 2009).

Rice is a sub-aquatic plant, well adapted to flooded soils, and thus is able to derive the benefits following flooding of the soil. However, upland rice is also grown in well-drained soils. Lowland rice is perhaps the only food crop, which thrives in submerged soils in monsoon Asia and other regions prone to seasonal or prolonged flooding (Kamoshita, 2007). The adaptation of the lowland rice to flooded conditions is due to the presence of aerenchyma or pore space in the rice plant that conduit air from leaves to roots (Reddy and De Laune, 2008).

Submerged soils are soils that are saturated with water for a sufficiently long time annually to give the soil the distinctive gley horizons resulting from oxidation-reduction processes: (a) a partially oxidized A horizon high in organic matter, (b) a mottled zone in which oxidation and reduction alternate, and (c) a permanently reduced zone which is bluish green. Because the soil is intermittently saturated with water, oxidation of organic matter is slow and it accumulates in the A horizon. In the second horizon, iron and manganese are deposited as rusty mottles or streaks if the diffusion of oxygen into the soil aggregates is slow; if diffusion is fast, they are deposited as concretions. Some rusty mottles consist of goethite and lepidocrocite deposits· Because iron and manganese form co-precipitates, the concretions are mixtures or complex oxides. They also contain small amounts of zinc, copper, nickel and cobalt. The zone of permanent water logging is bluish green because ferrous compounds are present. In this zone, secondary minerals such as hydrated magnetite, pyrite, marcasite, siderite, vivianite and ferrous silicates may be present (Ponnamperuma, 1972).

The pH, Eh or pE, specific conductance, ionic strength, ion exchange, sorption and desorption, chemical kinetics and mineral equilibria profoundly influence the fertility of submerged soils by controlling the availability of plant nutrients and regulating their uptake by rice roots. A pH of about 6.6, an Eh from 0.01 to 0.12 V or a pE from 0.2 to 2.0 at pH 7.0, a specific conductance of about 2 mmho/cm at 25°C, and a temperature from 30 to 35°C (all in soil solution) appear to favour nutrient uptake by rice. Under these conditions, the availability of nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese and silicon is high, the supply of copper, zinc and molybdenum is adequate and injurious concentrations of aluminium, manganese, iron, carbon dioxide and organic acids are absent. In normal tropical soils, these conditions can be achieved by incorporating organic matter and keeping the soil submerged for 2 to 4 weeks before planting (Ponnamperuma, 1977).

2.1. Changes due to submergence under flooded systems

Submerged soils benefit the rice crop by providing a more conducive environment for nutrient availability and uptake as a result of the adjustment of soil pH in the neutral range (Ponnamperuma 1972, 1984). The presence of free water on the soil eliminates water stress and minimizes weed competition to the rice crop growth (De Datta, 1981; Rao *et al.*, 2007). Also, the forms and availability of nutrients are related to moisture supply and flooded condition improves both availability (favorable soil pH) and the accessibility (nutrient delivery to rice plant roots improved both by mass flow and diffusion mechanisms) (Ponnamperuma 1975, 1984). Moreover, soil physical properties related to structure, which are important under arable or drained conditions, are not as important, as long as the soil is submerged under water (Ponnamperuma, 1984). In general, soil chemical properties are improved following submergence of the soil (Narteh and Sahrawat 1999). Paddy soils also provide a congenial environment for biological nitrogen fixation by a range of aerobic, facultative anaerobes and anaerobic bacteria (Sahrawat, 2004 b).The most important effect of submerging a soil under water is to cut the supply of oxygen. As a result, the entrapped oxygen is quickly exhausted and the soil becomes devoid of free oxygen. The lack of free oxygen or anaerobiosis causes soil reduction and sets in motion a series of physical, chemical, and biological processes that profoundly influence the quality of a soil as medium for growing rice or any other wetland crop (Ponnamperuma ,1972, 1984; Kyuma 2004). However, the redox potential of the surface water and first few mm of top soil in contact with the surface water remains relatively oxidized in the redox potential range of + 300 to + 500 mV (Patrick and Reddy 1978; Fiedler *et al.*, 2007). The redox potential controls the stability of various oxidized components [oxygen, nitrate, manganese Mn(IV), ferric Fe(III) iron, sulfate (SO_4^{2-}), and carbon dioxide (CO_2)] in submerged soils and sediments (Patrick and Reddy 1978; Fiedler *et al.*, 2007). Soil reduction is influenced by the quality of the decomposable organic matter (OM) and the capacity of reduction is controlled by the quantity of easily reducible iron or active iron (Sahrawat 2004 a).

2.2.Electrochemical changes in flooded soils

Omission of oxygen from the large part of soil profile causes physical, biological, and chemical changes to occur in the submerged or flooded rice soils. These changes varied with the type of soil, presence of microbial biomass, quality and quantity of organic matter, cultivar planted, and level of soil fertility. In addition, these changes affect availability of essential plant nutrients and consequently plant growth and yield. Submerging a soil brings about a variety of electrochemical changes. These include (a) decrease in redox potential, (b) an increase in pH of acid soils and a decrease in pH of alkaline soils, (c) changes in specific conductance and ionic strength, (d) drastic shifts in mineral equilibria, (e) cation and anion exchange reactions, and (f) sorption and desorption of ions. These changes occur as a result of oxygen depletion due to submergence of soil under flooding (Ponnamperuma, 1972).

2.2.1. Changes in oxidation- reduction / redox potential

The single electrochemical property that serves to distinguish a submerged soil from a well-drained soil is its redox potential. The low potentials (0.2 to -0.4 V) of submerged soils and sediments reflect this reduced state, the high potentials (0.8 to 0.3 V) of aerobic media, their oxidized condition. Represented by pE or Eh and is measured in mV.

When an aerobic soil is submerged, it's Eh decreases during the first few days and reaches a minimum; then it increases, attains a maximum, and decreases asymptotically to a value characteristic of the soil, after 8-12 weeks of submergence (Ponnamperuma, 1972).Within a few hours of submergence, a soil's dissolved and gaseous oxygen is consumed by aerobic microorganisms. Then the facultative anaerobes, followed by the obligate anaerobes, use soil components and dissimilation products of organic matter as electron acceptors in their respiration, reducing the sequence predicted by thermodynamics and lowering its Eh or pE. Thus, NO_3 is reduced to N_2, manganese (IV) to manganese (II), iron (III) to iron (II),

SO_4^{2-} to H_2S, CO_2 to CH_4, N_2 to NH_3, and H^+ to H_2. Since, manganese (II) and iron (II) compounds are more soluble than their oxidized counterparts, a submerged soil is charged with water-soluble Mn^{2+} and Fe^{2+}.These ions and HCO_3^-, formed during the decomposition of organic matter, increase the specific conductance of the soil and have marked influence on ionic equilibria in submerged soils. Redox potential affects the nitrogen status of the soil, the availability of phosphorus and silicon, the concentrations of Fe^{2+}, Mn^{2+} and SO_4^{2-} directly and those of $Ca^{2+,}$ $Mg^{2+,}$ $Cu^{2+,}$ Zn^{2+} and MoO_4^{2-} indirectly and the generation of organic acids and hydrogen sulphide (Ponnamperuma, 1977).

2.2.1.1. The sequential reduction in flooded soil systems

As the O_2 depletes from the waterlogged soils, reduction processes occur in sequence. Nitrate and manganese compounds are reduced first, then ferric compounds are reduced to the ferrous form, and at last sulfate is reduced to sulfide. The sequential reduction proceeds in the order as follows.

- $O_2 + 4H^+ + 4e^- \longleftrightarrow 2H_2O$ .... 0.814 V
- $2NO_3^- + 12H^+ + 2e^- \longleftrightarrow N_2 + 8H_2O$............ 0.741V
- $MnO_2 + 4H^+ + 2e^- \longleftrightarrow Mn^{2+} + 2H_2O$ 0.401V
- $CH_3COCOOH + 2H^+ + 2e^- \longleftrightarrow CH_3CHOHCOOH$...-0.158V
- $Fe(OH)_3 + 3H^+ + e^- \longleftrightarrow Fe^{2+} + 3H_2O$......... -0.185V
- $SO_4^{2-} + 10H^+ + 8e^- \longleftrightarrow H_2S + 4H_2O$..........-0.214V
- $CO_2 + 8H^+ + 8e- \longleftrightarrow CH_4 + 2H_2O$..........-0.244V
- $N_2 + 8H^+ + 6e^- \longleftrightarrow 2NH_4^+$.............. -0.278V

- $NADP^+ + 2H^+ + 2e^- \longleftrightarrow$ NADPH...............-0.317V
- $NAD^+ + 2H^+ + 2e^- \longleftrightarrow$ NADH.................-0.329V
- $2H^+ + 2e^- \longleftrightarrow H_2$ ....-0.413V

2.2.2. Convergence of pH in flooded systems

The pH of acidic soils increases and alkaline soils decreases as a result of flooding. Overall, pH of most soils tends to change towards neutral after flooding. An equilibrium pH in the range of 6.5 to 7.5 is usually attained (Patrick and Reddy 1978). A majority of oxidation–reduction reactions in flooded soils involve either consumption or production of H^+ /OH^- ions (Ponnamperuma, 1972). The increase in pH of acidic soils is mainly determined by reduction of Fe and Mn oxides, which consume H^+ ions. The reaction occurs as follows:

$$Fe_2O_3 + 1/2\ CH_2O + 4\ H^+ \longleftrightarrow 2\ Fe^{2+} + 5/2\ H_2O + 1/2\ CO_2$$

Ferric ion (from amorphous ferric oxides) serves as electron acceptor and accept electron supplied by the organic matter acts as (electron donor) and this results in consumption of acidity and increase in the soil pH (Ponnamperuma, 1984).

In Alkaline soils, accumulation of CO_2 in the layer of water forms mild acid and neutralises alkalinity by the following reaction:

$$CO_2 + H_2O \longleftrightarrow H_2CO_3$$

$$H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

The optimum temperature requirement for the above said reaction is between 25 to 35 °C (Narteh and Sahrawat, 1999).

2.2.2.1. pH range of aerobic rice soils

The aerobic rice soils face a wide range of soil pH. The soil pH never converges to neutral range. Hence application of lime in case of acid soils and of that of gypsum in case of alkaline soils is necessary to neutralize the pH (Sahrawat, 2012).

2.2.3. Specific conductance

When a soil is submerged, the specific conductance increases in the early phase of submergence, reaches a maximum, and then decreases to a fairly stable value, which varies with the soil. The increase in conductance during the first few weeks after flooding is due to (i) release of Fe^{2+} and Mn^{2+}, following the reduction of insoluble iron (III) and manganese (IV) hydrous oxides, (ii) accumulation of NH^{4+}, HCO_3^- and $RCOO^-$ and (iii) displacement of cations from soil colloids by Fe^{2+} and Mn^{2+}(Ponnamperuma, 1977).

2.3.Chemical transformations in submerged and aerobic soils

The chemical properties of a soil undergo a drastic transformation on submergence. The oxidized constituents, Fe^{3+}, Mn^{4+}, NO^{3-}, and $SO4^{2-}$ that characterize a well drained soil, virtually disappear and are replaced by their reduced counterparts, Fe^{2+} ,Mn^{2+} , NH_4^+ and S^{2-} and the course of organic matter decomposition is diverted from CO_2 production to the formation of an array of unstable organic substances, followed by the evolution of CO_2 and CH_4. These changes have important implications for geochemistry, limnology, rice culture, and pollution control.

2.3.1. Decomposition of organic matter

The decomposition of organic matter in a submerged soil differs from that in a well drained soil in two respects: it is slower; and the end products are different. In a well drained soil, decomposition of plant residues is accomplished by a large group of microorganisms assisted by the soil fauna. Owing to the high energy release associated with the aerobic respiration of these organisms, decomposition of substrate and synthesis of cell substance proceed rapidly. The bulk of freshly added organic matter disappears as CO_2, leaving a residue of resistant material, chiefly altered lignin. Also, there is a heavy demand on nutritional elements, especially nitrogen. In submerged soils, the decomposition of organic matter is almost entirely the work of facultative and obligate anaerobes. Since anaerobic bacteria operate at a much lower energy level than aerobic organisms, both decomposition and assimilation are much slower in submerged soils than in aerobic soils. The accumulation of plant residues in marshes and in underwater sediments illustrates this point (Ponnamperuma, 1972).

The most striking difference between anaerobic and aerobic decomposition lies in the nature of the end products. In a normal well drained soil the main end products are: CO_2, nitrate, sulfate, and resistant residues (humus). In submerged soils they are CO_2, hydrogen, methane, ammonia, amines, mercaptans, hydrogen sulfide, and partially humified residues.

Lowland rice under continuous flooding improves or maintains the organic matter status. A review of recent global literature showed that the organic matter status of soils under continuous submergence is either maintained or even increased compared with soils under upland system of rice cultivation (Witt *et al.*, 2000). This is due to lack of supply of free oxygen which is the major electron acceptor in organic matter decomposition and hence, the decomposition of organic matter under flooding is slow, inefficient, and incomplete and this leads to net accumulation of organic matter under flooding. Moreover, flooded rice systems sequester C over relatively low period of time. The organic matter content of soils under aerobic rice decreases due to enhanced rate of decomposition (Cheng *et al.*, 2009).

2.3.2. Nitrogen dynamics in flooded and aerobic systems of rice cultivation

The mineralization or ammonification (ammonium production) of organic nitrogen (N) is a key process that regulates the bioavailability of N, wetland productivity and environmental quality (Reddy and De Laune 2008). Thus, N mineralization in lowland ecosystems assumes much importance for both agricultural productivity and ecological health.

Nitrogen mineralization in soils is the biological transformation of organic forms of N to ammonium and this process can occur in either aerobic or anaerobic conditions. In aerobic soils, the end product of mineralization of organic nitrogen is NO_3^-. The loss of NO_3^- is more under aerobic soil environment due to leaching compared to that of flooded soils. However, the N mineralization process in submerged soil stops at ammonium production because of lack of oxygen. Ammonium in flooded soil and sediments is produced by reductive deamination (the conversion of amino acid-N to ammonia via saturated acids) of amino acids and degradation of purines, with the release of ammonia, carbon dioxide and volatile fatty acids as the end products (Ponnamperuma 1972). Ammonium is stable under reduced conditions of lowland soils and thus accumulates in flooded soils.

The mineralization of organic N in lowland soils and sediments is influenced by soil, environmental and agronomic factors. The most important among these are temperature, soil water regime, microbial activity and microbial biomass, pH, redox potential, C:N ratio, the loadings of alternate acceptors, amount and nature of soil clay, cation exchange capacity of soil, nature and amounts of salts, inputs and quality of organic materials, amount and quality of soil organic matter and the supply of nutrients such as phosphorus among others involved in the decomposition of organic matter and release of ammonium (Sahrawat, 2005).

Moreover, the redox status of a lowland soil system impacts organic N mineralization (Savant and Ellis, 1964) and the redox potential in flooded system is controlled by the quantity and quality of organic matter and the loading of electron acceptors. A range of redox potentials are encountered in lowland soils and sediments viz., +700 to +500 mV in aerated, +400 to +200 mV in moderately reduced, +100 to -100 mV in reduced and -100 to -300 mV in highly reduced condition. The availability and amount of inorganic electron acceptors including oxygen, nitrate, manganic manganese, ferric-iron, sulfate and carbon dioxide regulates redox potential. The reduction process in a submerged soil system follows the sequence- oxygen, nitrate, manganese, iron, sulphate and carbon dioxide.

2.3.3. Phosphorus dynamics in flooded and aerobic systems of rice cultivation

2.3.3.1. Phosphorus availability under flooded rice systems

The availability of original and added phosphorus to rice increases on soil submergence (Patrick and Mahapatra, 1968). In acid soils, the increase in phosphorus availability is associated with a decrease in Eh and an increase in iron (II) suggesting a role for iron (III) bonded phosphates. The increase in phosphorus availability may be due to reduction of iron (III) phosphates or to increase in pH accompanying soil reduction.

When alkaline soils are submerged, tri calcium phosphate which is the predominant form of phosphorus will be solubilized due to decrease in pH. This leads to increased availability of phosphorus (Ponnamperuma, 1972).

2.3.3.2. Phosphorus availability in aerobic rice soils

The available P is low in aerobic rice soils due to precipitation of P in the forms of Fe^{3+} - P and Al-P in acidic soils and Ca-P in alkaline soils. Maximum availability of P is under neutral soil reaction.

2.3.4. Dynamics of potassium, calcium and magnesium under flooded and aerobic system

2.3.4.1. Dynamics of potassium, calcium and magnesium under flooded system

Under acidic condition, the exchangeable K, Ca and Mg present in the solid phase are released to the soil solution. This leads to the increase in the concentration of bio-available K, Ca and Mg under flooding. The dominant cations in the acidic soil environment are Fe and Mn. The competition of K, Ca and Mg with Fe^{2+} and Mn^{2+} results in low plant uptake of K, Ca and Mg (Fagaria *et al.*, 2008).

Under alkaline condition, the exchangeable K, Ca and Mg present in the solid phase are released to the soil solution. This leads to the increase in the concentration of bio-available K, Ca and Mg under flooding. Also there are chances of exchanging K^+ with NH_4^+ since the dominant clay minerals are expanding 2: 1 type under alkaline soil environment. This results in increased Ca, Mg and K concentration under flooding which ultimately results in increased plant uptake (Fagaria and Baligar, 2008).

2.3.4.2. Dynamics of Potassium, calcium and magnesium under aerobic system

Under aerobic system, potassium, calcium and magnesium present in the soil solution are available to plants due to less competition for uptake under acidic situation and due to less leaching under alkaline condition (Fagaria *et al.*, 2002).

2.3.5. Dynamics of sulphur under flooded and aerobic system

2.3.5.1. Dynamics of sulphur under flooded system

Plants uptake sulphur in the form of SO_4^{2-} from the soil. Under flooded systems, the main changes are the reduction of SO_4^{2-} to form sulphide and the dissimilation of the amino acids, cysteine, cystine and methionine to H_2S, thiols, ammonia and fatty acids (Ponnamperuma, 1972).

Under acidic soil environment, this H_2S react with Fe^{2+} which is the dominant cation as follows:

$$H_2S + Fe^{2+} \longleftrightarrow FeS + 2H^+$$

The FeS gets precipitated and this protects microorganisms and higher plants from the toxic effects of H_2S. The deficiency of S is not observed in acidic soil environment. H_2S reacts with Zn, Cu and other metals and causes precipitation of these nutrients. Thus, it reduces the availability of these metal cations.

The free H_2S present in alkaline soils show toxicity due to sulphide. This may damage the plant as well as soil microbes due to sulphide toxicity (Fageria *et al.*, 2002).

2.3.5.2. Dynamics of sulphur under aerobic system

Sulphur is present in aerobic soils as SO_4^{2-}, which is the available form for plant uptake. Under aerobic soil environment, there is no reduction to sulphide form. The native SO_4^{2-} is available for plant uptake. Deficiency of sulphur is so far not reported in aerobic rice soils (Sahrawat, 2012).

2.3.6. Dynamics of Fe under flooded and aerobic systems of rice

2.3.6.1. Dynamics of Fe under flooded systems

Iron is a major constituent of most soils. Iron minerals commonly found in soils include geothite (FeOOH), hematite (Fe_2O_3), pyrite (FeS), siderite ($FeCO_3$) and magnetite (Fe_3O_4). Redox potential has significant influence on chemistry of iron and other nutrients in the submerged soils. Oxidation-reduction affects the valency of iron and thereby its uptake by plants. The Fe^{3+} ion is reduced to Fe^{2+} due to oxidation-reduction processes and increases its uptake. On the other hand, when Fe^{2+} is oxidized to Fe^{3+}, its concentration is reduced and uptake by plants is also reduced. The reduction of Fe^{3+} to Fe^{2+} is expressed by following equation:

$$Fe(OH)_3 + 3H_+ + e^- \Leftrightarrow Fe^{2+} + 3H_2O$$

The solubility and availability of Fe increases due to submergence due to reduction of insoluble Fe^{3+} to soluble Fe^{2+}. The reduction of iron has important consequences: (a) the concentration of water-soluble iron increases, (b) pH increases, (c) cations are displaced from exchange sites, (d) the solubility of phosphorus and silica increases and (e) new minerals are formed (Ponnamperuma, 1972, 1977).

2.3.6.2. Fe toxicity under flooded system of rice

Iron toxicity occurs in soils that are rich in reducible Fe *viz.*, Ultisols, Oxisols and acid sulfate soils. The important criteria for the occurrence of Fe toxicity in submerged soils is due to pH of the soil (less than 6.5), high reserve soil acidity, high reactivity and content of Fe(III) oxide. The soluble Fe concentration under aerobic system rarely exceeds 0.1 mg L^{-1}. The concentration of Fe increases to about 500 mg

kg^{-1} under flooding and causes Fe toxicity. This will further leads to root injury and bronzing in rice plants. Ultimately, the rice yield will get reduced by 12–100 per cent (Sahrawat, 2004).

2.3.6.3. Interaction of soluble Fe with other nutrients

Toxicity of Fe in soil due to submergence affects the uptake of other nutrients such as potassium, calcium, magnesium and zinc

2.3.6.4. Fe dynamics under aerobic system of rice

Most of the Fe present in the soil is in the insoluble form under aerobic rice soils. The bio available form of Fe is very low under this system of rice cultivation. Deficiency of iron is common in alkaline soils which are low in soil Fe. But, deficiency is not reported in acidic soils (Sahrawat, 2012).

2.3.7. Dynamics of manganese under flooded and aerobic system

2.3.7.1. Dynamics of manganese under flooded system of rice

The oxidized form of Mn which is commonly found in soil is reduced from Mn^{4+} to Mn^{2+}. This leads to increased solubility of Mn. Thus, the concentration of soluble manganese increases up to 90 ppm within two weeks of submergence and declines to 10 ppm due to precipitation of $MnCO_3$. Ultimately, flooding improves the availability of Mn (Ponnamperuma, 1972)

2.3.7.2. Dynamics of manganese under aerobic rice system

Available Mn content is low in alkaline soils due to the insolubility of manganese compounds in soil. Mn deficiency does not prevail under acidic soils (Sahrawat, 2012).

2.3.8. Dynamics of zinc under flooded and aerobic system

2.3.8.1. Dynamics of zinc in flooded system

Hazra *et al.*, (1987) reported that submergence caused an increase in concentration of amorphous sesquioxides bound form of Zn and a decrease in each of other three forms such as water soluble, exchangeable and crystalline sesquioxide bound forms respectively. Zinc deficiency is widespread in wetland rice affecting upto 50% of the area. Zinc relations in rice have therefore been studied extensively. The deficiency is most often associated with poor drainage and perennial soil wetness. The soils typically have weak profile development, reflecting the poor drainage, and much of the Zn is in primary minerals or in other highly insoluble forms. It is also often associated with high soil organic matter content, high pH and high Mg: Ca ratios in the soil.

2.3.8.2. Zinc dynamics under aerobic rice system

The availability of zinc under aerobic system of rice cultivation increases, since the content of soluble phosphates and sulphides is low under this situation. Further, the high rate of decomposition of organic matter due to ambient temperature and optimum moisture condition under aerobic rice cultivation systems also leads to increase in zinc bioavailability (Gao *et al.*, 2002).

2.3.9. Dynamics of copper under flooded and aerobic system of rice cultivation

2.3.9.1. Dynamics of Copper under flooded system of rice

Under acidic soil condition

The solubility of Cu increases immediately due to the desorption of sesquioxide occluded copper during submergence. But this solubilised copper immediately get precipitated as CuS (in acid sulphate soils) and as $Cu(OH)_2$ (with increase in pH).

Under alkaline soil condition

Formation of carbonates and bicarbonates of copper decreases the solubility of copper. Ultimately this will lead to decrease in availability of copper under both acidic as well as alkaline conditions (Das, 1996).

2.3.10. Carbon nitrogen ratio

In profile samples of kari soils, organic matter content decreases with depth. Undecomposed plant residues are seen in profiles at different depth. The C:N ratios of the soils of different horizons are wider than normal soils indicating the presence of undecomposed plant residues of higher carbohydrates like lignin of wood fossils. The C:N ratio of karappadam soil is also above 10:1 indicating the presence of undecomposed organic matter. Compared to karappadam and kari soils, the C:N ratio is low in kayal soils (Manorama, 1997). Nitrogen mineralization and nitrification in acid sulphate soils are supposed to be affected by high soil acidity (pH around 4.0) although the level of soil organic matter is very high (Sahrawat, 1980). Under aerobic and anaerobic conditions of incubation N gets mineralized and accumulated as NH_4-N since the nitrifying organism fail to function at very low pH. In acid sulphate soils rich in organic matter, the NH_4-N plays an important role in plant nutrition. Nitrogen losses in potential acid sulphate soils by leaching and denitrification are prevented because of lack of nitrate formation (Mandal, 1961). The accumulation of NH_4^+ is relatively low in Kari soils even with higher content of organic matter, possibly because of the fibrous nature of the organic matter (Kuruvila and Patnaik, 1994).

The soils having high ratios of carbon to nitrogen (13 to 17:1) gave greatest response to nitrogen fertilization. Ninety eight percent of nitrogen was associated with the organic compounds in soil. Soil nitrogen was immobilized if the C:N ratio of the added organic materials was in excess of about 33:1(Usha and Jose, 1983).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Wet soil analysis for nutrient prescription in paddy soils" was carried out at Radiotracer laboratory, College of Horticulture, Kerala Agricultural University during 2012-2014. In order to achieve the objectives of the present investigation, major rice growing tracts in state coming under 7 agro-ecological units(AEU's) were selected namely, *Onattukkara* sandy soil (AEU 3), *Kuttanad* (AEU 4), *Pokkali* (AEU 5), *Kole* (AEU 6), midland wetland laterite (AEU 10), rice soils of Palakkad (AEU 22) and black soil from Chittor Taluk of Palakkad (AEU 23). The details of locations and soil samples collected are furnished in table 1.

Table 1. Locations of soil sampling, soil taxonomy and agro-ecological units

Soil sample No.	Soil type	Location	Soil taxonomy	Agro-ecological unit
1	Kuttanad (1)	Poovathikkari,Vechoor, Vaikom N 09°41.026' E 076°26.666'	Entisol	Kuttanad (AEU 4)
2	Kuttanad (2)	C.K.N Block, Thottakam, Vaikom N 09°43.691' E 076°25.582'	Entisol	Kuttanad (AEU 4)
3	Kuttanad (3)	Kaayippadam, Karumadi N 09°22.795' E 076°23.231'	Entisol	Kuttanad (AEU 4)
4	Onattukkara (1)	ORARS campus, Kayamkulam N 09°10.717'	Entisol	Onattukara sandy plains

		E 076°31.17'		(AEU 3)
5	Onattukkara (2)	Eerezhuthekku, Chettikulangara N 09°13.297' E 076°31.504'	Entisol	Onattukara sandy plains (AEU 3)
6	Onattukkara (3)	Muttathumuri padasekharam, Chettikulangara N 09°13.499' E 076°31.849'	Entisol	Onattukara sandy plains (AEU 3)
7	Rice soils of Palakkad (1)	Elavampadam, Kizhakkenchery N 10°33.775' E 076°31.100'	Inceptisol	Palakkad central plain (AEU 22)
8	Rice soils of Palakkad (2)	Thekkinkkalla padasekharam Vadakkenchery N 10°32.333' E 076°29.444'	Inceptisol	Palakkad central plain (AEU 22)
9	Rice soils of Palakkad (3)	Ambittantarishu padasekharam Vadakkenchery N 10°31.680' E 076°29.623'	Inceptisol	Palakkad central plain (AEU 22)
10	Midland laterite (wetland) (1)	RARS campus, Pattambi N 10°48.726' E 076°11.811'	Ultisol	North central laterite (AEU 10)
11	Midland laterite (wetland) (2)	Bankalamppadam, Ongalloor N 10°47.602' E 076°12.988'	Ultisol	North central laterite (AEU 10)
12	Midland laterite (wetland) (3)	Pampadyppadam, Ongalloor N 10°47.628' E 076°12.861'	Ultisol	North central laterite (AEU 10)

13	Black cotton (1)	Nalleppilly N 10°42.901' E 076°47.398'	Vertisol	Palakkad eastern plains (AEU 23)
14	Black cotton (2)	Kozhinjampara N 10°45.082' E 076°49.718'	Vertisol	Palakkad eastern plains (AEU 23)
15	Black cotton (3)	Kozhinjampara N 10°45.157' E 076°49.565'	Vertisol	Palakkad eastern plains (AEU 23)
16	Pokkali (1)	RRS campus, Vytilla N 09°58.568' E 076°19.34'	Entisol	Pokkali lands (AEU 5)
17	Pokkali (2)	Kottuvalli N 10°06.746' E 076°14.085'	Entisol	Pokkali lands (AEU 5)
18	Pokkali (3)	Kottuvalli N 10°06.751' E 076°14.341'	Entisol	Pokkali lands (AEU 5)
19	Kole (1)	Vadakkekonchira, Vengidangu N 10°30.773' E 076°06.292'	Entisol	Kole lands (AEU 6)
20	Kole (2)	Manalurthazhum padavu N 10°29.211' E 076°07.633'	Entisol	Kole lands (AEU 6)
21	Kole (3)	Ponnamotha N 10°30.975' E 076°07.129'	Entisol	Kole lands (AEU 6)

3.1.1. Collection of soil samples

Soil samples were collected at 3 stages viz. the first before starting rice cultivation and the second and third at active tillering and visual panicle initiation stages of rice crop. Plant samples were also collected during the above stages of the crop.

3.1.1.1. Method of collection and preparation of soil samples

The first sample before the rice crop was collected and air dried, sieved through 2 mm sieve and the processed samples were used for characterization. The surface soil samples (0-20 cm) collected before cropping season were used for characterization with respect to pH, EC, organic carbon, total C and N, available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. Both wet and air dried samples collected during cropping season were also characterized for pH, EC, organic carbon, Total C and N, Available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. The soil samples were collected and used for analyses as detailed below.

3.1.1.2. Procedure for sampling and analysis of soil from lowlands

Soil sampling was done using core sampler from 0-20 cm depth without disturbing the reduced condition as far as possible. Part of the sample was sealed as such and used for wet analysis, while the remaining part was dried, processed, sieved through 2 mm sieve and analyzed by routine methods. The initial soil samples as well as both wet and dried samples collected during 2^{nd} and 3^{rd} stages were analyzed for pH, EC, organic carbon, total carbon and nitrogen, available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. The data on both wet and dry analysis of soil samples was correlated with nutrient content in plant at the corresponding stages.

3.1.1.3. Expression of results of wet analysis

To express the results of wet analysis, the moisture content of the sample were estimated gravimetrically. In order to find out the moisture percentage, an initially weighed soil (W1) sample was kept in the hot air oven at 105°. After drying, the sample was again weighed (W2). Percentage of moisture= [(W1-W2)/W1] x 100.

Suppose a soil contains 80 % moisture, the actual percentage weight of the soil on wet basis is 20 %. Hence, if 5 g soil was taken for analysis, actual dry weight = 5 x 20/100= 1 g.

Plate 1. Soil sampling in wetlands

Plate 2. Soil samples collected using core sampler at a depth of 0 to 15cm

Plate 3. Transferring soil samples to polythene cover

Plate 4. Sealed and labeled soil sample for analysis

3.2. Collection and analysis of plant samples of rice

Soil and plant samples of rice were collected from the same locations during the crop seasons at two stages viz., at active tillering and visual panicle initiation stages. The plant samples were oven dried at 70 ± 5°C, powdered and estimated the contents of total C, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B in different plant parts namely, root, shoot and panicle .The details of procedure followed for analysis of soil and plant samples are given below.

Table 2. Methods of soil analysis

Sl.No.	Particulars	Method
1	pH	Potentiometric method using a pH meter in 1: 2.5 soil water suspension (Jackson, 1958)
2	EC	Estimated using a conductivity meter in the supernatant liquid used for pH determination (Jackson, 1958)
3	Organic carbon	Wet digestion method (Walkley and Black, 1934)
4	Total C and N	Estimated by CHNS analyzer (Model: Elementar's vario EL cube)
5	Available nitrogen	Alkaline permanganate method (Subbiah and Asija, 1956)
6	Available phosphorus	Extracted (Bray and Kurtz, 1945) and estimated colorimetrically by reduced molybdate ascorbic acid blue colour method (Watanabe and Olsen, 1965)
7	Available potassium	Flame photometry (Jackson, 1958)

8	Available Ca and Mg	Atomic absorption spectrophotometry (Model: Analyst 400)
9	Available sulphur	Extraction: Tabatabai, 1982 Estimation: Massoumi and Cornfield , 1963
9	Available Fe, Mn, Cu and Zn	Atomic absorption spectrophotometry (Model: Analyst 400) (Sims and Johnson, 1991)
10	Available B	Hot water extraction method (Berger and Truog, 1939, Gupta, 1972) and estimated colorimetrically by Azomethine H using spectrophotometer

Table 3. Methods of plant analysis

Sl.No.	Element	Method
1	Total carbon and nitrogen	Estimated by CHNS analyzer (Model: Elementar's vario EL cube)
2	Phosphorus	Diacid digestion of plant sample (2:1 HNO_3:$HClO_4$) followed by filtration. Vanadomolybdate phosphoric yellow colour in nitric acid system (Piper,1966)
3	Potassium	Diacid digestion of plant sample (2:1 HNO_3 : $HClO_4$) followed by filtration. Flame

		photometry determination (Jackson, 1973)
4	Calcium and magnesium	Diacid digestion of plant sample (2:1 HNO_3:$HClO_4$) followed by filtration. The filtrate was collected, analyzed for Ca and Mg using Perkin-Elmer AAS (Piper, 1966)
6	Sulphur	Diacid digestion of plant sample (2:1 HNO_3:$HClO_4$) followed by filtration. Extraction: Tabatabai, 1982 Estimation: Massoumi and Cornfield , 1963
5	Iron, manganese,zinc and copper	Diacid digestion of plant sample (2:1 HNO_3:$HClO_4$) followed by filtration. The filtrate was collected, analyzed for Fe, Mn, Zn and Cu using Perkin-Elmer AAS (Piper, 1966)
6	Boron	Diacid digestion of plant sample (2:1 HNO_3:$HClO_4$)followed by filtration. The filtrate was collected and estimated colorimetrically by Azomethine –H using UV-VIS spectrophotometer (Gupta, 1975)

3.3. Incubation experiment

Four soil types namely, (i) *Onattukara* sandy soils (Entisol AEU 3), (ii) *Kari* soils from *Kuttanad* soil (Entisol AEU 4), (iii) Wet land lateritic soil (Ultisol AEU 10) and (iv) Black soil from Chittoor Taluk of Palakkad (Vertisol AEU 23) were used for an incubation study on the pattern of decomposition of added organic matter and to identify the corresponding variations and stabilization of C: N ratio at equilibrium.

For this, the above four soils were incubated under submerged conditions with and without incorporation of paddy straw as the source of organic matter. Water level was maintained at 5 cm above the surface of soil in all pots. The experimental details are given below:

Treatments:

(a) Soil types: 4

(5 kg soil per pot)

(1) Onattukara sandy soils (S_1)

(2) *Kari* soil from Kuttanad soil (S_2)

(3) Wetland lateritic soil (Pattambi) (S_3)

(4) Black soil from Chittor Taluk of Palakkad (S_4)

(b) Levels of organic matter: 2

(Source of organic matter: Paddy straw)

(1) 0 t ha^{-1} (O_1)

(2) 5 t ha^{-1} (O_2)

Treatment combinations: 4 x 2 = 8

Replications: 3

Design: CRD

The pH and redox potential in the incubated soils were recorded at daily interval for the first two weeks and later at 15 days interval using a portable pH meter (Cyberscan pH 11) and redox meter (TOA Type SH-1) respectively. The organic carbon, total C and N were estimated at fortnightly interval till the C: N ratio was stabilized.

Plate 5. Treatment combinations of incubation study

3.4. Statistical analysis

The data on soil analysis were correlated with soil properties as well as the concentrations of different elements in the plant. Spearman's ranked correlation was done after cross tabulation based on weightage given to highly variable parameters in soils based on their ranges. Analysis of variance in CRD for incubation experiment was made in SPSS package.

Results

4. RESULTS

The data generated for the characterization of major rice growing tracts in state coming under 7 agro-ecological units and analytical data from the pot culture experiments are presented here under.

4.1. Electrochemical properties and carbon nitrogen status

The data on pH, EC, organic carbon, total carbon, total nitrogen, available nitrogen and carbon nitrogen ratios computed based on total carbon : total nitrogen ratio (C:N)1, total carbon:available nitrogen ratio (C:N)2,organic carbon:total nitrogen ratio (C:N)3, organic carbon : available nitrogen ratio (C:N)4 are given in table 4 – 14 respectively.

4.1.1. Initial Characterization

The data on electrochemical properties and carbon nitrogen status are given in table No. 4 and 5. Initial characterization was done after drying and sieving the sample through 2 mm sieve.

Table No. 4. Electrochemical properties before cropping season

Location	pH	EC	OC	Tot C	Tot N	Av N
		dS m^{-1}	%			
1	3.47	2.06	8.39	9.03	0.49	0.0156
2	2.86	2.46	7.67	8.36	0.32	0.0784
3	3.28	1.20	8.03	8.70	0.40	0.0470
4	3.74	0.10	0.28	0.35	0.03	0.0058
5	3.93	0.27	0.38	0.49	0.04	0.0078
6	3.09	1.43	0.56	0.66	0.05	0.0150
7	3.87	0.10	0.97	1.01	0.10	0.0190
8	4.93	0.14	0.58	0.61	0.06	0.0110
9	4.86	0.11	0.76	0.87	0.09	0.0160
10	4.67	0.20	1.10	1.31	0.14	0.0100
11	4.74	0.36	1.20	1.34	0.14	0.0160
12	4.32	0.27	1.40	2.34	0.25	0.0084
13	5.68	1.09	1.45	2.16	0.2	0.0053
14	6.35	0.12	1.74	1.96	0.19	0.0180
15	7.14	1.28	1.10	1.31	0.14	0.0098
16	6.06	1.46	1.68	2.81	0.31	0.0336
17	6.68	2.11	0.32	0.40	0.05	0.0260
18	6.13	3.18	0.68	0.92	0.08	0.0117
19	5.70	0.90	1.12	1.56	0.12	0.0114
20	5.88	0.16	1.68	2.31	0.22	0.0250
21	5.56	0.11	1.68	2.35	0.16	0.0260

4.1.1.1. Soil pH

The pH of the soils ranged from 2.86 to 7.14. The lowest pH was recorded in the soils of Kuttanad, CKN Block, Vechoor (AEU 4, sample No. 2) and highest in the Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara (AEU 23, sample No. 15).

4.1.1.2. Electrical conductivity

The lowest EC of 0.10 dS m^{-1} was recorded in the soils of Onattukkara (AEU 3, sample No. 4) and the highest of 3.18 dS m^{-1} was recorded in Pokkali soils from Kottuvalli (AEU 5, sample No. 18).

4.1.1.3. Organic carbon

The organic carbon status of the soils varied from 0.28 to 8.39 percent. Soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from Poovathikkari, Vechoor (AEU 4, sample No. 1) recorded the highest value.

4.1.1.4. Total carbon

The total carbon status of the soils varied from 0.35 to 9.03 percent. Soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from Poovathikkari, Vechoor (AEU 4, sample No. 1) recorded the highest value.

4.1.1.5. Total nitrogen

The lowest total nitrogen of 0.04 percent was recorded in the soils of Onattukkara, Chettikulangara (AEU 3, sample No. 5) and Karumadi (AEU 4, sample No. 3) and the highest of 0.49 percent in Poovathikkari, Vechoor (AEU 4, sample No. 1).

4.1.1.6. Available nitrogen

The available nitrogen status of the soils varied from 0.0053 to 0.0784 percent. Black cotton soils of Chittor taluk of Palakkad, Nalleppilly (AEU 23, sample No. 13) recorded the lowest and soils from Kuttanad, CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value.

4.1.1.7. Total carbon:total nitrogen ratio (C:N)1

The carbon nitrogen ratio of the soils varied from 8 to 26.12. The Pokkali soils from Kottuvalli (AEU 5, sample No. 17) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value.

4.1.1.8. Total carbon:available nitrogen ratio (C:N)2

The carbon nitrogen ratio of the soils varied from 15.03 to 575.89. Soils from Pokkali region, Kottuvalli (AEU 5, sample No. 17) recorded the lowest and soils from Kuttanad, Poovathikkari, Vechoor (AEU 4, sample No. 1) recorded the highest value.

4.1.1.9. Organic carbon:total nitrogen ratio (C:N)3

The carbon nitrogen ratio of the soils varied from 5.41 to 23.96. The Pokkali soils from RRS, Vytilla (AEU 5,sample No. 16) recorded the lowest and soils from Kuttanad, CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value.

4.1.1.10. Organic carbon:available nitrogen ratio (C:N)4

The carbon nitrogen ratio of the soils varied from 12.03 to 535. Soils from Kottuvalli (AEU 5,sample No. 17) recorded the lowest and soils from Poovathikkari (AEU 4, sample No. 1) recorded the highest value.

4.1.2. Active tillering stage

In active tillering, the samples collected under wet anaerobic conditions were analyzed both under the wet condition as well as after drying. In both cases the results are expressed on dry weight basis. The data on electrochemical properties and carbon nitrogen status during active tillering stage are given in table No. 6 and 7.

Table No. 5. Carbon nitrogen status (C: N) before cropping season

Location	(C:N)1	(C:N)2	(C:N)3	(C:N)4
1	18.42	575.89	17.12	535.00
2	26.12	106.63	23.96	97.83
3	21.75	185.10	20.75	170.85
4	11.66	59.52	9.33	47.61
5	12.25	62.50	9.50	48.46
6	13.20	42.85	11.20	36.36
7	10.10	50.65	9.70	48.64
8	10.16	54.46	9.66	51.78
9	9.66	51.78	8.44	45.23
10	9.35	129.96	7.85	109.12
11	9.57	79.76	8.57	71.42
12	9.36	278.57	5.60	166.66
13	10.80	407.54	7.25	273.58
14	10.31	107.69	9.15	95.60
15	9.35	133.67	7.85	112.24
16	9.06	83.63	5.41	50.00
17	8.00	15.03	6.40	12.03
18	11.50	78.23	8.50	57.82
19	13.00	135.88	9.33	97.56
20	10.50	91.66	7.63	66.66
21	13.82	88.01	9.88	62.92

4.1.2.1. Soil pH

The pH of the soils ranged from 4.23 to 7.5 when it was analyzed on wet condition while the soils showed a pH range from 4.05 to 6.03 on analysis after drying. The lowest pH was recorded in the soils of Onattukkara, Chettikulangara (AEU 3, sample No. 5) and highest in the Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara (AEU 23, sample No. 14) in case of wet analysis. In case of dry analysis, pH observed in soils of Chettikulangara (AEU 3, sample No. 5) was 5.91 and in soils from Kozhinjampara(AEU 23, sample No. 14) it was 5.45. Kuttanad soils from Poovathikkari, Vechoor (AEU 4,sample No. 1) recorded the lowest and soils from Vadakkenchery(AEU 22, sample No. 7) recorded the highest value in case of dry analysis. It is also clear from the table that pH in most of the soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.1.2.2. Electrical conductivity

The lowest EC of 0.03 dS m^{-1} was recorded in the soils of Onattukkara, Chettikulangara (AEU 3, sample No. 5) and the highest of 1.39 dS m^{-1} was recorded in Pokkali soils from Kottuvalli (AEU 5, sample No. 18) on wet analysis. In case of dry analysis, EC observed in soils of Chettikulangara (AEU 3, sample No. 5) was 0.031 dS m^{-1} and in soils from Kottuvalli (AEU 5, sample No. 18) it was 1.65mS cm^{-1}. Soils of Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from Kuttanad, CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value in case of dry analysis. EC in most of the soil samples was found to be increased when analyzed after drying in comparison with the values obtained during wet analysis.

4.1.2.3. Organic carbon

The organic carbon status of the soils varied from 0.58 to 8.42 percent when it was analyzed on wet condition while the same soils showed a range of 0.19 to 5.31 percent on analysis after drying. Soils from RRS,Vytilla (AEU 5, sample No. 16) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on wet analysis. In case of dry analysis, organic carbon observed in soils of RRS,Vytilla (AEU 5, sample No. 16) was

0.76 percent and in soils from CKN Block, Vechoor (AEU 4, sample No. 2) it was 5.1 percent. Soils from Vadakkenchery (AEU 22, sample No. 9) recorded the lowest and soils from Poovathikkari, Vechoor (AEU 4, sample No. 1) recorded the highest value in case of dry analysis. Organic carbon in most of the soil samples was found to be decreased when analyzed after drying in comparison with the values obtained during wet analysis.

Table No. 6. Electrochemical properties of soil during active tillering stage

Location	pH		EC (ds m^{-1})		OC (%)		Av N (%)		Tot C (%)		Tot N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	4.85	4.05	1.970	1.830	5.31	5.31	0.018	0.0150	6.66	7.96	0.32	0.32
2	4.58	5.05	0.110	2.780	8.42	5.10	0.026	0.0220	9.42	16.11	0.47	0.56
3	5.98	4.78	0.260	0.520	6.86	5.20	0.0220	0.0185	8.04	12.03	0.40	0.44
4	4.6	5.47	0.120	0.051	1.20	0.38	0.0030	0.0050	1.35	0.38	0.14	0.03
5	4.23	5.91	0.030	0.031	0.68	0.68	0.0020	0.0053	0.92	0.78	0.09	0.06
6	4.73	5.86	0.040	0.049	1.10	0.38	0.0030	0.0060	1.32	0.82	0.12	0.07
7	5.25	6.03	0.040	0.072	1.18	0.38	0.0030	0.0130	1.22	0.97	0.12	0.09
8	4.67	4.81	0.130	0.059	1.10	0.38	0.0030	0.0090	1.19	0.45	0.10	0.04
9	5.41	5.82	0.058	0.055	0.98	0.19	0.0029	0.0080	1.05	0.21	0.08	0.02
10	6.82	5.16	0.053	0.046	1.23	0.53	0.0048	0.0090	1.74	1.23	0.10	0.12
11	6.85	5.17	0.060	0.100	1.56	0.79	0.0052	0.0110	1.89	1.61	0.12	0.14
12	6.3	5.23	0.040	0.089	1.58	0.61	0.0053	0.0150	1.90	1.61	0.13	0.14
13	6.03	5.73	0.090	0.160	1.00	0.79	0.0028	0.0090	1.03	1.36	0.10	0.10
14	7.55	5.45	0.470	0.290	0.92	0.25	0.0028	0.0090	1.01	1.54	0.09	0.12

Table No. 6. Electrochemical properties of soil during actie tillering

Location	pH		EC (ds m^{-1})		OC (%)		Av N (%)		Tot C (%)		Tot N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
15	7.68	5.28	0.450	0.530	1.12	0.31	0.0035	0.0090	1.27	1.55	0.09	0.13
16	4.24	5.06	0.180	2.15	0.58	0.76	0.0023	0.1100	0.85	2.00	0.05	0.15
17	6.56	4.36	0.170	1.56	1.28	0.98	0.0039	0.0180	1.41	7.59	0.12	0.41
18	6.68	3.45	1.390	1.65	1.45	0.70	0.0051	0.0050	1.83	1.03	0.08	0.09
19	5.88	5.74	0.270	0.46	0.68	1.28	0.0022	0.0160	0.81	0.85	0.05	0.07
20	4.54	5.17	0.090	0.24	1.23	1.80	0.0052	0.0150	1.89	3.83	0.13	0.18
21	6.14	5.27	0.100	0.23	1.30	1.70	0.0053	0.0190	1.91	3.20	0.12	0.11

4.1.2.4. Total carbon

The total carbon status of the soils varied from 0.81 to 9.42 percent when it was analyzed on wet condition while the same soils showed a range of 0.38 to 16.11 percent on analysis after drying .Soils from Vengidangu (AEU 6, sample No. 19) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on wet analysis. In case of dry analysis, total carbon observed in soils from Vengidangu (AEU 6, sample No. 19) was 0.85 percent and in soils from CKN Block, Vechoor (AEU 4, sample No. 2) it was 16.11 percent. Soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from Kuttanad, CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on dry analysis. Total carbon in most of the soil samples was found to be decreased when analyzed after drying in comparison with the values obtained during wet analysis.

4.1.2.5. Total nitrogen

The lowest total nitrogen of 0.05 percent was recorded in the soils of RRS, Vytilla (AEU 5, sample No. 16) and Vengidangu (AEU 6, sample No. 19) and the highest of 0.47 percent in Poovathikkari (AEU 4, sample No. 1) on wet analysis. In case of dry analysis, total nitrogen observed in soils from RRS, Vytilla (AEU 5, sample No. 16) was 0.15 percent and in soils from Vengidangu (AEU 6, sample No. 19) it was 0.07 percent. The lowest total nitrogen of 0.02 percent was recorded in the soils of Kizhakkenchery (AEU 22, sample No. 9) and the highest of 0.56 percent total N in Poovathikkari (AEU 4, sample No. 1) on dry analysis. Total nitrogen in most of the soil samples was found to be increased when analysed after drying in comparison the with the values obtained during wet analysis

Table No. 7. Carbon nitrogen (C:N) status in soil during active tillering stage

Location	(C:N)1ratio		(C:N)2 ratio		(C:N)3 ratio		(C:N)4 ratio	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	20.81	24.87	370.00	507.65	16.59	16.59	284.74	338.64
2	20.04	28.76	409.50	719.19	17.91	10.85	319.22	227.67
3	20.10	27.34	365.45	668.33	17.15	11.81	311.81	281.00
4	9.64	12.66	450.00	67.85	8.57	2.71	317.46	67.85
5	10.22	13.00	368.00	146.61	7.55	7.55	263.97	127.81
6	11.00	11.71	366.60	133.11	9.16	3.16	297.61	61.68
7	10.16	10.77	358.82	73.70	9.83	3.16	345.43	28.87
8	11.90	11.25	360.60	45.91	11.00	3.80	330.00	38.77
9	13.12	10.50	362.00	25.00	12.25	2.375	333.33	22.61
10	17.40	10.25	362.50	125.51	12.30	2.65	252.46	54.08
11	15.75	11.50	363.46	143.75	13.00	6.58	294.78	70.53
12	14.61	11.50	358.49	104.54	12.15	4.69	296.99	39.61
13	10.30	13.60	367.85	138.77	10.02	7.90	347.43	80.61
14	11.22	12.83	360.71	166.66	10.22	2.77	325.31	27.05
15	14.11	11.92	362.85	158.16	12.44	3.44	314.96	31.63
16	17.00	13.33	369.56	178.57	11.60	15.2	243.69	67.85
17	11.75	18.51	361.53	417.00	10.66	8.16	324.21	53.84
18	22.87	11.44	358.82	175.17	18.12	8.75	282.98	119.00
19	16.20	12.14	368.18	50.59	13.60	14.22	299.82	76.19
20	14.53	21.27	363.46	248.70	9.46	10.00	232.42	116.88
21	15.91	29.09	360.37	168.00	10.83	9.44	243.00	89.28

4.1.2.6. Available nitrogen

The available nitrogen status of the soils varied from 0.0022 to 0.0263 percent when it was analyzed on wet condition while the soils showed a range of 0.0053 to 0.0224 percent on analysis after drying. Soils from Vengidangu (AEU 6, sample No. 19) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on wet analysis. In case of dry analysis, available nitrogen observed in soils from Vengidangu (AEU 6, sample No. 19) was 0.016 percent and in soils from CKN Block, Vechoor(AEU 4, sample No. 2) it was 0.024 percent. The lowest available nitrogen of 0.0053 percent was recorded in the soils from Onattukkara (AEU 3, sample No. 5) and the highest of 0.022 percent in CKN Block, Vechoor (AEU 4, sample No. 2) in case of dry analysis. Available nitrogen in most of the soil samples was found to be increased when analyzed after drying in comparison with the values obtained during wet analysis.

4.1.2.7. Total carbon: total nitrogen ratio (C:N)1

The carbon nitrogen ratio of the soils varied from 9.64 to 22.87 when it was analyzed on wet condition while the soils showed a range of 10.25 to 29.09 on analysis after drying. Soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from Kottuvalli (AEU 5,sample No. 18) recorded the highest value on wet analysis. In case of dry analysis, $(C:N)_1$ observed in soils from ORARS, Kayamkulam (AEU 3, sample No. 4) was 12.66 and in soils from Kottuvalli (AEU 5,sample No. 18) it was 11.44. The lowest $(C:N)_1$ of 10.5 was recorded in the soils from RARS, Pattambi and the highest of 29 in Manalurthazhum (AEU 6, sample No.21) on analysis after drying.

4.1.2.8. Total carbon: available nitrogen ratio (C:N)2

The carbon nitrogen ratio of the soils varied from 358.49 to 450 when it was analysed on wet condition while the same soils showed a range of 25 to 719.19 on analysis after drying. Soils from wetland lateritic soils of Pattambi(AEU 10,sample No. 15) recorded the lowest and soils from ORARS, Kayamkulam (AEU 3, sample

No. 4) recorded the highest value in case of wet analysis. On analysis after drying, $(C:N)_2$ observed in wetland lateritic soils of Pattambi (AEU 10,sample No. 15) was 158.16 and in soils from ORARS, Kayamkulam (AEU 3, sample No. 4) it was 67.85. Lowest $(C:N)_2$ (25) was observed in soils from Vadakkenchery(AEU 22, sample No. 9) and highest of 719.19 in soils from CKN Block, Vechoor (AEU 4, sample No. 2) on analysis after drying.

4.1.2.9. Organic carbon :total nitrogen ratio (C:N)3

The carbon nitrogen ratio of the soils varied from 5.64 to 17.91 when it was analysed on wet condition while the same soils showed a range of 2.37 to 16.59 on analysis after drying. Soils from Karumadi (AEU 4, sample No. 3) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value in case of wet analysis. On analysis after drying $(C:N)_3$ observed in soils from Karumadi (AEU 4,sample No. 3) it was 5.64 and in soils from CKN Block, Vechoor (AEU 4, sample No. 2)it was 10.85. Soils from Vadakkenchery (AEU 22, sample No. 9) recorded the lowest (2.37) and in soils from Poovathikkari (AEU 4, sample No. 1) recorded the highest value (16.59) on analysis after drying.

4.1.2.10. Organic carbon: available nitrogen ratio (C:N)4

The carbon nitrogen ratio of the soils varied from 145.43 to 345.43 when it was analyzed on wet condition while the same soils showed a range of 22.61 to 338.64 on analysis after drying. Soils from Karumadi (AEU 4, sample No. 3) recorded the lowest and soils from Kizhakkenchery (AEU 22, sample No. 7) recorded the highest value in case of wet analysis. Soils from Kizhakkenchery (AEU 22, sample No. 9) recorded the lowest and soils from Poovathikkari(AEU 4, sample No. 1) recorded the highest value on analysis after drying.

4.1.3. Visual panicle initiation stage

In visual panicle initiation stage, the samples collected under wet anaerobic conditions were analyzed both under the wet condition as well as after drying. In both cases the results are expressed on dry weight basis. The data on electrochemical properties and carbon nitrogen status during visual panicle initiation stage are given in table No.8 and 9.

4.1.3.1. Soil pH

The pH of the soils ranged from 4.07 to 7.87 when it was analyzed on wet condition while the soils showed a range of 3.54 to 6.17 on analysis after drying. The lowest pH was recorded in the soils of Onattukkara (AEU 3, sample No. 5) and highest in the Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara(AEU 23, sample No. 15) on wet analysis. In case of dry analysis, pH in soils of Onattukkara(AEU 3, sample No. 5) was 5.98 and in Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara(AEU 23, sample No. 15) it was 5.57. The lowest pH was recorded in the soils of Kottuvalli (AEU 5, sample No. 17) and highest in the Kizhakkenchery (AEU 22, sample No. 8) on analysis after drying.

4.1.3.2. Electrical conductivity

The lowest EC of 0.039 dS m^{-1} was recorded in the soils of Kizhakkenchery (AEU 22, sample No. 9) and the highest of 1.80 dS m^{-1} was recorded in Pokkali soils from Kottuvalli (AEU 5, sample No. 18) in case of wet analysis. EC recorded in the soils of Kizhakkenchery (AEU 22, sample No. 9) was 0.0675 dS m^{-1} and in Kottuvalli (AEU 5, sample No. 18) it was 1.586 on analysis after drying. The lowest EC of 0.0492 mS cm^{-1} was recorded in the soils of ORARS, Kayamkulam (AEU 3, sample No. 4) and the highest of 2.97 dS m^{-1} was recorded in CKN Block, Vechoor (AEU 4, sample No. 2) when analyzed after drying.

Table No. 8. Electrochemical properties in soil during visual panicle initiation stage

Location	pH		EC (dS m^{-1})		OC (%)		Av. N (%)		Tot C (%)		Tot N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	5.07	4.82	0.22	0.480	4.38	5.31	0.0084	0.018	4.38	5.31	0.27	0.33
2	4.67	4.75	0.72	2.970	5.34	5.40	0.0100	0.0330	5.34	5.4	0.35	0.65
3	5.45	4.57	0.11	0.580	4.86	5.35	0.0092	0.0255	4.86	5.35	0.19	0.16
4	4.52	5.98	0.088	0.049	1.16	0.53	0.0058	0.0078	1.16	0.53	0.12	0.03
5	4.07	5.98	0.084	0.099	0.38	0.61	0.0056	0.0070	0.38	0.61	0.06	0.06
6	4.58	5.92	0.046	0.049	1.10	0.38	0.0056	0.0061	1.10	0.38	0.11	0.07
7	6.29	5.95	0.049	0.069	0.96	0.38	0.0072	0.0072	0.96	0.38	0.09	0.08
8	6.21	6.17	0.08	0.053	1.28	0.34	0.0056	0.0098	1.28	0.34	0.12	0.08
9	4.74	5.58	0.039	0.067	1.24	0.40	0.0081	0.0056	1.24	0.40	0.08	0.04
10	6.02	5.75	0.097	0.046	1.43	0.68	0.0098	0.0100	1.43	0.68	0.14	0.11

Table No. 8. Electrochemical properties in soil during visual panicle initiation stage

Location	pH		EC (dS m^{-1})		OC (%)		Av. N (%)		Tot C (%)		Tot N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
11	4.87	5.69	0.12	0.090	1.28	0.83	0.0070	0.0110	1.28	0.83	0.16	0.11
12	4.75	5.67	0.044	0.075	1.32	1.13	0.0095	0.0150	1.32	1.13	0.16	0.18
13	7.12	5.82	0.11	0.150	1.09	0.76	0.0056	0.0090	1.09	0.76	0.10	0.16
14	7.78	5.35	0.39	0.260	0.79	0.13	0.0061	0.0078	0.79	0.13	0.05	0.04
15	7.87	5.57	0.61	0.420	1.19	0.31	0.0056	0.0084	1.19	0.31	0.10	0.13
16	5.12	5.05	0.12	1.630	1.78	1.58	0.0050	0.0160	1.78	1.58	0.19	0.25
17	5.95	3.54	1.95	1.980	1.16	0.91	0.0042	0.0092	1.16	0.91	0.09	0.21
18	6.17	3.78	1.80	1.580	0.98	0.68	0.0058	0.0070	0.98	0.68	0.09	0.09
19	5.07	5.46	0.13	0.240	1.42	0.98	0.0064	0.0140	1.42	0.98	0.14	0.16
20	4.36	5.07	0.067	0.120	1.32	2.20	0.0061	0.0084	1.32	2.20	0.12	0.18
21	4.27	5.18	0.057	1.020	1.38	2.30	0.0064	0.0150	1.38	2.3	0.10	0.11

Table No. 9. Carbon nitrogen (C:N) status in soils during visual panicle initiation stage

Location	(C:N)1 ratio		(C:N)2 ratio		(C:N)3 ratio		(C:N)4 ratio	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	19.88	26.21	639.28	475.27	16.22	16.09	521.42	291.75
2	17.77	30.76	617.06	595.23	15.25	8.30	529.76	160.71
3	15.67	10.91	528.26	209.80	15.67	10.91	528.26	209.80
4	10.08	12.66	205.78	48.46	9.66	17.66	197.27	67.60
5	7.00	10.50	75.00	90.00	6.33	10.16	67.85	87.14
6	10.9	11.71	214.28	133.11	10.00	5.42	196.42	61.68
7	10.77	11.75	133.24	129.12	10.66	4.75	131.86	52.19
8	11.75	10.12	251.78	82.65	10.66	4.28	228.57	35.00
9	13.25	12.75	130.54	91.07	15.50	10.00	152.7	71.42
10	13.71	11.54	195.91	125.99	10.21	6.18	145.91	67.46
11	9.06	12.27	207.14	117.59	8.00	7.54	182.85	72.29
12	9.93	12.22	167.00	142.85	8.25	6.27	138.65	73.37
13	12.20	14.18	217.85	238.44	10.90	4.75	194.64	79.83
14	16.80	14.50	136.36	73.97	15.80	3.25	128.24	16.58
15	14.00	9.53	250.00	147.61	11.90	2.38	212.50	36.90
16	11.20	13.2	422.61	196.42	9.36	6.32	353.17	94.00
17	14.22	11.38	304.76	258.65	12.88	4.33	276.19	98.48
18	11.55	13.11	176.87	168.57	10.88	7.55	166.66	97.14
19	11.92	12.43	259.31	134.00	10.14	6.12	220.49	66.03
20	12.75	21.27	248.37	455.95	11.00	12.22	214.28	261.9
21	14.5	29.09	225.15	204.08	13.8	20.9	214.28	146.68

4.1.3.3. Organic carbon

The organic carbon status of the soils varied from 0.38 to 5.34 percent when it was analysed on wet condition while the soils showed a range of 0.13 to 5.4 percent on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on wet analysis. In case of dry analysis, percent organic carbon in soils from Chettikulangara(AEU 3, sample No. 5) was 0.61 and soils from CKN Block, Vechoor (AEU 4, sample No. 2) was 5.4 percent.Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara(AEU 23, sample No. 14) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on analysis after drying.

4.1.3.4. Total carbon

The total carbon status of the soils varied from 0.42 to 6.22 percent when it was analysed on wet condition while the soils showed a range of 0.38 to 20 percent on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on wet analysis. In case of dry analysis, total carbon percent in soils from Chettikulangara(AEU 3, sample No. 5) was 0.63 and in soils from CKN Block, Vechoor (AEU 4, sample No. 2) it was 20 percent. Soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on analysis after drying.

4.1.3.5. Total nitrogen

The lowest total nitrogen of 0.05 percent was recorded in the Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara(AEU 23, sample No. 14) and the highest of 0.35 percent in CKN Block, Vechoor (AEU 4, sample No. 2) on wet analysis. In case of dry analysis, percent total nitrogen in Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara (AEU 23, sample No. 14) was 0.04 and in CKN Block, Vechoor (AEU 4, sample No. 2) it was 0.65.The lowest total nitrogen of

0.03 percent was recorded in the soils of ORARS, Kayamkulam (AEU 3, sample No. 4) and the highest of 0.65 percent in CKN Block, Vechoor (AEU 4, sample No. 2) on analysis after drying.

4.1.3.6. Available nitrogen

The available nitrogen status of the soils varied from 0.0042 to 0.010 percent when it was analyzed on wet condition while the soils showed a range of 0.0056 to 0.018 percent on analysis after drying. Soils from Kottuvalli (AEU 5, sample No. 17) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value in case of wet analysis. The available nitrogen in Pokkali soils from Kottuvalli (AEU 5,sample No. 17) was 0.0092 and in CKN Block, Vechoor (AEU 4, sample No. 2) it was 0.033 on analysis after drying. Soils from Vadakkenchery (AEU 22, sample No. 9) recorded the lowest and soils from Poovathikkari (AEU 4, sample No. 1) recorded the highest value on analysis after drying.

4.1.3.7. Total carbon: total nitrogen ratio (C:N)1

The carbon nitrogen ratio of the soils varied from 7 to 19.88 when it was analysed on wet condition while the same soils showed a range of 9.53 to 30.76 on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from Poovathikkari, Vechoor (AEU 4, sample No. 1) recorded the highest value in case of wet analysis. $(C:N)_1$ in soils from Chettikulangara (AEU 3, sample No. 5) was 10.5 and in Poovathikkari, Vechoor (AEU 4, sample No. 1) it was 26.21 on analysis after drying. Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara (AEU 23, sample No. 15) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value in case of dry analysis.

4.1.3.8. Total carbon :available nitrogen ratio (C:N)2

The carbon nitrogen ratio of the soils varied from 75 to 639.28 when it was analyzed on wet condition while the same soils showed a range of 48.46 to 595.23

percent on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from Poovathikkari (AEU 4, sample No. 1)recorded the highest value in case of wet analysis. $(C:N)_2$ in soils from Chettikulangara (AEU 3, sample No. 5) was 90 and in Poovathikkari(AEU 4, sample No. 1) it was 475.27 on analysis after drying. When analysed after drying, soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value on analysis after drying.

4.1.3.9. Organic carbon: total nitrogen ratio (C:N)3

The carbon nitrogen status of the soils varied from 6.33 to 16.22 when it was analyzed on wet condition while the soils showed a range of 3.25 to 17.66 on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from Poovathikkari (AEU 4, sample No. 1) recorded the highest value in case of wet analysis. (C:N)3 in soils from Chettikulangara (AEU 3, sample No. 5) was 10.16 and in Poovathikkari (AEU 4, sample No. 1) it was 16.09 upon dry analysis. Black cotton soils of Chittor, Kozhinjampara (AEU 23, sample No. 14) recorded the lowest and soils from ORARS, Kayamkulam (AEU 3, sample No. 4) recorded the highest value on analysis after drying.

4.1.3.10. Organic carbon: available nitrogen ratio (C:N)4 ratio

The carbon nitrogen ratio of the soils varied from 67.85 to 529.76 when it was analysed on wet condition while the same soils showed a range of 16.58 to 291.75 on analysis after drying. Soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest and soils from CKN Block, Vechoor (AEU 4, sample No. 2) recorded the highest value in case of wet analysis. In case of dry analysis, $(C:N)_4$ in soils from Chettikulangara (AEU 3, sample No. 5) was 87.14 and in soils from CKN Block, Vechoor(AEU 4, sample No. 2) it was 160.71. Black cotton soils of Chittor taluk of Palakkad, Kozhinjampara (AEU 23, sample No. 14) recorded the lowest and soils from Poovathikkari(AEU 4, sample No. 1) recorded the highest value on analysis after drying.

4.1.4. Mean values of initial characterization

Agroecological unit based values of electrochemical properties and carbon nitrogen status are presented in table No. 10, 11 and 12.

4.1.4.1. Initial dry analysis

4.1.4.1.1. Soil pH

The AEU based mean values of pH of the soils ranged from 3.20 to 6.39. The lowest mean pH was recorded in the soils of Kuttanad (AEU 4) and highest in the Black cotton soils of Chittor taluk of Palakkad (AEU 23).

4.1.4.1.2. Electrical conductivity

The lowest mean EC of 0.123 dS m^{-1} was recorded in the soils of rice soils of Palakkad (Vadakkenchery) (AEU 22) and the highest of 2.75 dS m^{-1} was recorded in Pokkali (AEU 5).

4.1.4.1.3. Organic carbon

The mean organic carbon status of the soils varied from 0.40 to 5.57 percent. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

Table No. 10. Mean electrochemical and C:N status in soil on agro ecological unit basis before cropping season

AEU	Parameter									
	pH	EC	OC	Tot C	Tot N	Av N	(C:N)1	(C:N)2	(C:N)3	(C:N)4
		dS m^{-1}	%				Ratio			
Kuttanad	3.20	1.90	8.03	8.69	0.40	0.047	22.09	289.20	20.61	267.89
Onattukkara sandy plains	3.58	0.60	0.40	0.50	0.04	0.0097	12.50	51.54	10.00	41.23
Palakkad central plains	4.55	0.12	0.77	0.83	0.08	0.0470	10.00	17.65	9.27	16.38
North central laterites	4.57	0.28	1.23	1.66	0.17	0.0621	9.43	26.73	6.98	19.80
Palakkad eastern plains	6.39	0.83	1.43	1.81	0.19	0.0110	9.52	164.54	7.52	130.00
Pokkali lands	6.29	2.75	0.89	1.37	0.14	0.0239	9.78	57.32	6.35	37.23
Kole lands	5.71	0.39	1.49	2.07	0.16	0.0211	12.93	98.10	9.31	70.61

4.1.4.1.4. Total carbon

The mean total carbon status of the soils varied from 0.50 to 8.69 percent. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.1.4.1.5. Total nitrogen

The lowest mean total nitrogen of 0.04 percent was recorded in the Onattukkara sandy soils (AEU 3) and the highest of 0.40 percent in Kuttanad (AEU 4).

4.1.4.1.6. Available nitrogen

The mean available nitrogen status of the soils varied from 0.0097 to 0.062 percent. Onattukkara sandy soils (AEU 3) recorded the lowest and wetland lateritic soils (Pattambi) (AEU 10) recorded the highest value.

4.1.4.1.7. Total carbon : total nitrogen ratio (C:N)1

The mean carbon nitrogen ratio of the soils varied from 9.43 to 22.09. Wetland lateritic soils (Pattambi)(AEU 10) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.1.4.1.8. Total carbon: available nitrogen ratio (C:N)2

The mean carbon nitrogen ratio of the soils varied from 17.65 to 289.20. Palakkad central plains (Vadakkenchery)(AEU 22) recorded the lowest and Kuttanad (AEU 4) recorded the highest value.

4.1.4.1.9. Organic carbon:total nitrogen ratio (C:N)3

The mean carbon nitrogen ratio of the soils varied from 6.35 to 20.61. Soils from Pokkali (AEU 5) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.1.4.1.10. Organic carbon :available nitrogen ratio (C:N)4

The mean carbon nitrogen ratio of the soils varied from 16.38 to 267.89. Soils from Palakkad central plains (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.1.4.2. Active tillering stage

4.1.4.2.1. Soil pH

The mean values of pH of the soils ranged from 4.52 to 7.08 when it was analysed on wet condition while the same soils showed a range of 4.29 to 5.74 on analysis after drying. The lowest mean pH was recorded in the Onattukkara sandy soils (AEU 3) and highest in the Black cotton soils of Chittor taluk of Palakkad (AEU 23) in case of wet analysis. In case of dry analysis, mean pH recorded in the Onattukkara sandy soils (AEU 3) was 5.74 and in the Black cotton soils of Chittor taluk of Palakkad (AEU 23) it was 5.48. The lowest mean pH was recorded in the Pokkali soils(AEU 5)and highest in the Onattukkara sandy soils(AEU 3) on analysis after drying.

Table No. 11. Mean electrochemical properties during active tillering stage

AEU	pH		EC ($dS\ m^{-1}$)		OC (%)		Tot C (%)		Tot N (%)		Av N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Kuttanad	5.13	4.62	0.78	1.71	6.86	5.20	8.04	12.03	0.400	0.44	0.0222	0.0180
Onattukkara sandy plains	4.52	5.74	0.063	0.043	0.99	0.48	1.19	0.66	0.110	0.053	0.0026	0.0054
Palakkad central plains	5.11	5.55	0.076	0.062	1.08	0.31	1.15	0.54	0.100	0.05	0.0029	0.0100
North central laterite	6.65	5.18	0.051	0.078	1.45	0.64	1.84	1.48	0.110	0.13	0.0051	0.0110
Palakkad eastern plains	7.08	5.48	0.33	0.32	1.01	0.45	1.10	1.48	0.093	0.11	0.0030	0.0090
Pokkali	5.82	4.29	0.58	1.78	1.10	0.81	1.36	3.54	0.083	0.21	0.0037	0.0440
Kole lands	5.52	5.39	0.15	0.31	1.07	1.59	1.53	2.62	0.100	0.12	0.0042	0.0160

4.1.4.2.2. Electrical conductivity

The lowest mean EC of 0.05 dS m^{-1} was recorded in the Wetland lateritic soils(Pattambi)(AEU 10) and the highest of 0.78 mS cm^{-1} was recorded in soils from Kuttanad (AEU 4) in case of wet analysis. In case of dry analysis, EC of 0.08 dS m^{-1} was recorded in the Wetland lateritic soils (Pattambi) (AEU 10) and 1.71 dS m^{-1} was recorded in soils from Kuttanad (AEU 4). The lowest mean EC was recorded in the Onattukkara sandy soils (AEU 3)and highest in the Pokkali (AEU 5) on analysis after drying.

4.1.4.2.3. Organic carbon

The mean organic carbon status of the soils varied from 1.01 to 6.86 percent when it was analyzed on wet condition while the soils showed a range of 0.31 to 5.20 percent on analysis after drying. Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. Upon dry analysis, percent organic carbon in Black cotton soils of Chittor taluk of Palakkad (AEU 23) was 0.45 percent and in soils from Kuttanad (AEU 4) it was 3.73. Palakkad central plains (Vadakkenchery) (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.1.4.2.4. Total carbon

The mean total carbon status of the soils varied from 1.10 to 8.04 percent when it was analysed on wet condition while the soils showed a range of 0.54 to 12.03 percent on analysis after drying. Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest values of total carbon in case of wet analysis. The total carbon in Black cotton soils of Chittor (AEU 23) was 1.48 percent and in soils from Kuttanad (AEU 4) it was 12.03 percent when analysed after drying.

4.1.4.2.5. Total nitrogen

The lowest mean total nitrogen of 0.10 percent was recorded in the Palakkad central plains (Vadakkenchery) (AEU 22)and in Kolelands(AEU 6)and the highest of 0.40 percent in Kuttanad (AEU 4) in case of wet analysis. In case of dry analysis, total nitrogen in Rice soils of Palakkad (Vadakkenchery) (AEU

22) was 0.05, in Kolelands(AEU 6)it was 0.12 percent and 0.44 percent in Kuttanad (AEU 4).The lowest mean total nitrogen of 0.11 percent was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23) and the highest of 0.44 percent in Kuttanad (AEU 4) on analysis after drying.

4.1.4.2.6. Available nitrogen

The mean available nitrogen status of the soils varied from 0.003 to 0.022 percent when it was analyzed on wet condition while the soils showed a range of 0.0054 to 0.018 percent on analysis after drying. Onattukkara sandy soils(AEU 3) and Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, percent available N in Onattukkara sandy soils (AEU 3) was 0.0054 and in Black cotton soils of Chittor taluk of Palakkad (AEU 23) it was 0.009 and in soils from Kuttanad (AEU 4) it was 0.018 percent. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on analysis after drying.

4.1.4.2.7. Total carbon :total nitrogen ratio (C:N)1

The mean carbon nitrogen ratio of the soils varied from 10.28 to 20.31 when it was analyzed on wet condition while the same soils showed a range of 10.84 to 26.99 on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. Palakkad central plains (Vadakkenchery) (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on analysis after drying.

4.1.4.2.8. Total carbon : available nitrogen ratio (C:N)2

The carbon nitrogen ratio of the soils varied from 360.47 to 394.88 when it was analyzed on wet condition while the same soils showed a range of 115.85 to 449 on analysis after drying. Palakkad central plains(Vadakkenchery)(AEU 22) recorded the lowest and Onattukkara sandy soils (AEU 3)recorded the highest value in case of wet analysis. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on analysis after drying.

4.1.4.2.9. Organic carbon: total nitrogen ratio (C:N)3

The mean carbon nitrogen ratio of the soils varied from 8.42 to 17.21 when it was analyzed on wet condition while the soils showed a range of 3.11 to 13.08 on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. Palakkad central plains (Vadakkenchery) (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on analysis after drying.

Table No. 12. Mean carbon nitrogen status (C:N) during active tillering stage

AEU	(C:N)1 ratio		(C:N)2 ratio		(C:N)3 ratio		(C:N)4 ratio	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Kuttanad	20.31	26.99	381.65	631.72	17.21	13.08	305.25	282.43
Onattukkara sandy plains	10.28	12.45	394.86	115.85	8.42	4.47	293.01	85.78
Palakkad central plains	11.72	10.84	360.47	48.20	11.02	3.11	336.25	30.08
North central laterite	15.92	11.08	361.48	124.6	12.48	4.64	281.41	54.74
Palakkad eastern plains	11.87	12.78	363.80	154.53	10.89	4.70	329.23	46.43
Pokkali	17.20	14.42	363.30	256.91	13.46	10.70	283.62	80.23
Kole lands	15.54	20.83	364.00	155.76	11.29	11.22	258.41	94.11

4.1.4.2.10. Organic carbon: available nitrogen ratio (C:N)4

The mean carbon nitrogen ratio of the soils varied from 249.79 to 336.29 when it was analysed on wet condition while the same soils showed a range of 18.24 to 282.43 on analysis after drying. Soils from north central laterite (AEU 10) recorded the lowest and Palakkad central plains (Vadakkenchery)(AEU 22) recorded the highest value in case of wet analysis. Palakkad central plains (AEU 22) recorded the lowest and Kuttanad (AEU 4) recorded the highest value on analysis after drying.

4.1.4.3. Visual panicle initiation

4.1.4.3.1. Soil pH

The mean values of pH of the soils ranged from 5.06 to 7.59 when it was analyzed on wet condition while the same soils showed a range of 4.12 to 5.96 on analysis after drying. The lowest mean pH was recorded in the Kuttanad (AEU 4) and highest in the Black cotton soils of Chittor taluk of Palakkad (AEU 23) in case of wet analysis. In case of dry analysis, pH recorded in the Kuttanad (AEU 4) was 4.71 and in the Black cotton soils of Chittor taluk of Palakkad (AEU 23) it was 5.58. The lowest mean pH was recorded in the Kuttanad (AEU 4) and highest in the Onattukkara sandy soils (AEU 3) on analysis after drying.

4.1.4.3.2. Electrical conductivity

The lowest mean EC of 0.056 dS m^{-1} was recorded in the Rice soils of Palakkad (Vadakkenchery) (AEU 22)and the highest of 1.29 dS m^{-1} was recorded in soils from Pokkali (AEU 5) in case of wet analysis. In case of dry analysis, the lowest mean EC of 0.063 dS m^{-1} was recorded in the Palakkad central plains (Vadakkenchery) (AEU 22) and the highest of 1.73 dS m^{-1} was recorded in soils from Pokkali (AEU5).

Table No. 13. Mean electrochemical properties during visual panicle initiation stage

AEU	pH		EC (dS m-^{1})		OC (%)		Tot C(%)		Tot N (%)		Av N (%)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Kuttanad	5.06	4.71	0.35	1.34	4.86	5.35	4.86	5.35	0.31	0.49	0.009	0.025
Onattukkara sandy plains	4.39	5.96	0.072	0.065	0.88	0.50	0.94	0.61	0.0056	0.053	0.096	0.007
Palakkad central plains	5.74	5.90	0.057	0.063	1.16	0.37	1.14	0.75	0.007	0.066	0.096	0.007
North central laterite	5.21	5.70	0.088	0.070	1.34	0.88	1.65	1.66	0.0087	0.133	0.150	0.0123
Palakkad eastern plains	7.59	5.58	0.37	0.27	1.02	0.40	1.15	1.36	0.0057	0.110	0.083	0.0085
Pokkali	5.74	4.18	1.29	1.73	1.30	1.05	1.48	2.29	0.0050	0.180	0.120	0.011
Kole lands	4.56	5.23	0.085	0.46	1.37	1.82	1.55	3.00	0.0063	0.150	0.120	0.012

Table No. 14. Mean carbon nitrogen (C:N) status during visual panicle initiation stage

AEU	(C:N)1 ratio		(C:N)2 ratio		(C:N)3 ratio		(C:N)4 ratio	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Kuttanad	17.70	22.62	594.94	426.76	15.71	11.76	526.48	220.75
Onattukkara sandy plains	9.32	11.62	165.00	90.52	8.66	11.08	153.85	72.14
Palakkad central plains	11.92	11.54	171.85	100.94	12.27	6.34	171.00	52.81
North central laterite	10.90	12.01	190.00	128.81	8.82	6.66	155.81	71.00
Palakkad eastern plains	14.33	12.74	201.40	153.34	12.86	3.46	178.46	44.43
Pokkali	12.32	12.56	301.41	207.88	11.04	6.06	265.34	96.55
Kole lands	13.05	20.93	244.28	264.71	11.64	13.08	316.35	158.20

4.1.4.3.3. Organic carbon

The mean organic carbon status of the soils varied from 0.88 to 4.86 percent when it was analyzed on wet condition while the same soils showed a range of 0.40 to 5.35 percent on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on wet analysis. Black cotton soils from Chittor taluk of Palakkad (AEU 23) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.1.4.3.4. Total carbon

The mean total carbon status of the soils varied from 0.94 to 4.86 percent when it was analyzed on wet condition while the same soils showed a range of 0.61 to 5.35 percent on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in both wet and dry analysis.

4.1.4.3.5. Total nitrogen

The lowest mean total nitrogen of 0.083 percent was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23) and the highest of 0.31 percent in Kuttanad (AEU 4) on wet analysis. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.1.4.3.6. Available nitrogen

The mean available nitrogen status of the soils varied from 0.0050 to 0.0092 percent when it was analyzed on wet condition while the same soils showed a range of 0.0070 to 0.0253 percent on analysis after drying. Soils from Pokkali (AEU 5) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. Soils from Onattukkara sandy soils (AEU 3) and Palakkad central plains (Vadakkenchery)(AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value of available nitrogen on dry analysis.

4.1.4.3.7. Total carbon :total nitrogen ratio (C:N)1

The mean carbon nitrogen ratio of the soils varied from 9.32 to 17.77 when it was analyzed on wet condition while the same soils showed a range of 11.54 to 22.62 on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on wet analysis. Palakkad central plains (Vadakkenchery) (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.1.4.3.8. Total carbon :available nitrogen ratio (C:N)2

The mean carbon nitrogen ratio of the soils varied from 165 to 594.94 when it was analyzed on wet condition while the same soils showed a range of 90.52 to 426.76 on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on wet and drynanalysis.

4.1.4.3.9. Organic carbon: total nitrogen ratio (C:N)3

The mean carbon nitrogen ratio of the soils varied from 8.66 to 15.71 when it was analyzed on wet condition while the same soils showed a range of 3.46 to 11.76 on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case wet analysis. While in case of dry analysis, Black soils from Chittor taluk of Palakkad (AEU 23) recorded the lowest and soils from Kolelands (AEU 6) recorded the highest value.

4.1.4.3.10. Organic carbon: available nitrogen ratio (C:N)4

The mean carbon nitrogen ratio of the soils varied from 153.85 to 526.48 when it was analysed on wet condition while the same soils showed a range of 44.43 to 220.75 on analysis after drying. Onattukara sandy plains (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on wet analysis. Palakkad eastern plains (AEU 23) recorded the lowest and Kuttanad (AEU 4) recorded the highest value on analysis after drying.

4.2. Available Nutrient status

The data on available P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B are given on table No. 15 to 20

4.2.1. Initial characterization

Initial characterization was done after air drying and sieving the sample through 2 mm sieve.

4.2.1.1. Available phosphorus

The available phosphorus ranged from 5.3 to 135.16 kg ha^{-1}.Wetland lateritic soils (Pattambi) (AEU 10, sample No. 12) recorded the lowest and soils from RRS, Vytilla (AEU 5, sample No. 16) recorded the highest value of available P.

4.2.1.2. Available potassium

Available potassium was observed to range from 12.32 to 463.68 kg ha^{-1}. The lowest available K was recorded in ORARS, Kayamkulam (AEU 3, sample No.4)and the highest in RRS, Vytilla (AEU 5, sample No. 16).

4.2.1.3. Available calcium

The highest available calcium content of 380.9 mg kg^{-1} soil was recorded in sample from Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) and the lowest of 54.2 mg kg^{-1} in soil from RRS, Vytilla (AEU 5, sample No. 16).

4.2.1.4. Available magnesium

Available magnesium content of soils found to range from 5.1 to 9.25 mg kg^{-1}soil. The lowest magnesium status was observed in ORARS, Kayamkulam(AEU 3, sample No. 4).Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) recorded the highest magnesium status.

4.2.1.5. Available sulphur

The available sulphur ranged from 10.45 to 1220.25 mg kg^{-1}soil. The lowest sulphur content was recorded in the soils of Pokkali(AEU 5, sample No.18) and the highest in Kuttanad soils from CKN Block, Vechoor(AEU 4,sample No. 2).

Table No. 15. Available nutrient status in soil before cropping season

Location	Parameter									
	Av. P	Av. K	Av. Ca	Av. Mg	Av. S	Av. Fe	Av. Mn	Av. Cu	Av. Zn	Av. B
	kg ha^{-1}		mg kg^{-1} soil							
1	13.43	310.24	280.25	8.80	247.26	11.18	9.99	3.65	2.99	0.59
2	9.32	198.24	189.00	8.20	1120.25	63.20	8.97	1.08	5.63	2.84
3	28.68	114.24	91.95	7.70	271.64	7.23	36.26	5.87	1.32	0.66
4	26.00	12.32	184.00	5.10	33.25	7.31	0.55	5.43	1.63	0.25
5	38.68	41.44	84.00	6.85	34.52	9.78	41.40	0.88	7.69	0.77
6	25.32	25.76	126.80	6.60	33.68	12.30	9.36	0.87	2.67	0.26
7	14.65	124.32	272.00	7.80	11.95	7.84	17.48	5.12	1.44	0.92
8	20.69	47.04	136.90	7.85	21.95	4.35	14.19	5.35	0.31	1.18
9	35.33	103.04	263.20	7.85	28.54	4.98	18.00	4.19	1.06	0.47
10	15.96	79.52	243.60	7.05	11.72	11.13	27.20	5.78	1.61	1.57
11	16.78	344.96	309.70	8.05	72.10	33.60	10.62	10.88	4.02	0.88
12	5.3	305.76	306.70	7.80	191.31	2.70	8.79	1.98	1.68	1.78
13	14.95	87.36	394.80	8.55	505.63	7.15	17.32	6.10	3.45	0.24
14	74.17	412.56	376.95	8.90	431.13	8.79	52.30	3.09	13.57	0.49
15	24.44	312.48	380.90	9.25	541.39	1.87	20.75	4.61	9.72	0.07
16	135.16	468.68	54.20	7.85	555.55	8.59	139.00	5.15	1.00	4.10
17	77.82	371.84	136.75	8.25	483.79	16.89	4.07	1.55	3.00	2.55
18	49.85	446.88	97.95	8.15	10.45	32.00	1.00	0.21	1.45	6.42
19	9.76	132.40	190.80	7.33	43.51	14.76	17.11	14.00	3.66	1.71
20	9.39	150.00	204.50	7.80	42.28	28.20	17.27	4.18	3.75	2.34
21	21.36	135.52	376.00	8.10	17.00	17.90	6.66	2.97	1.73	1.98

4.2.1.6. Available iron

The lowest iron content of 1.87 mg kg^{-1} soil was recorded in the Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) and the highest of 63.2 mg kg^{-1} soil was observed in Kuttanad soils from CKN Block, Vechoor(AEU 4, sample No. 2).

4.2.1.7. Available Manganese

Available Mn was found to range from 0.55 to 36.26 mg kg^{-1} soil. ORARS, Kayamkulam(AEU 3, sample No.4)recorded the lowest and soils from Karumadi (AEU 4, sample No.3) recorded the highest value of available Mn.

4.2.1.8. Available Copper

The lowest available Cu (0.21 mg kg^{-1}soil) was recorded in Pokkali soils from Kottuvalli (AEU 5, sample No.18) and the highest of (10.88 mg kg^{-1} soil) in wetland lateritic soil (Pattambi)(AEU 10,sample No. 11).

4.2.1.9. Available Zinc

The lowest available zinc(0.31 mg kg^{-1}soil) was recorded in rice soils of Palakkad (AEU22, sample No. 8)and highest value (13.57 mg kg^{-1}soil) in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14).

4.2.1.10. Available boron

The hot water extractable boron was found to vary from 0.079 to 6.42 mg kg^{-1} soil. The lowest boron content of 0.079 mg kg^{-1} soil was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) and the highest value was observed in soils of Pokkali, Kottuvalli(AEU 5, sample No. 18).

4.2.2. Active tillering stage

In active tillering, the samples collected under wet anaerobic conditions were analyzed both under the wet condition as well as after drying. In both cases the results are expressed on dry weight basis.The available nutrient status during active tillering stage are presented in table No.16 and 17.

Table No. 16. Available nutrient status in soil during active tillering stage

Location	Av. P		Av. K		Av. Ca		Av. Mg		Av. S	
	kg ha^{-1}				mg kg^{-1} soil					
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	27.90	6.94	375.4	286.7	387.5	219.3	15.81	9.48	270.40	468.6
2	23.72	3.53	411. 00	351.68	665.79	227.35	25. 00	9.15	235.77	1134
3	37.33	11.71	272.18	232.96	469.7	326.15	13.95	10. 00	14.07	186.99
4	32.50	22.18	36.64	25.76	173.36	162.9	8.63	8.10	18.90	18.09
5	68.00	90.65	143.37	80.64	130.79	116.85	8.42	7.35	2.90	30.74
6	44.86	21.56	56.14	58.24	165.60	161.85	8.27	6.80	11.40	15.97
7	19.21	8.38	98.44	78.40	252.75	192.75	11.09	8.65	14.47	16.82
8	23.41	12.31	33.29	35.84	177.67	164.25	8.57	8.70	12.15	15.47
9	33.80	9.91	33.89	35.84	100.84	103.3	8.53	8.45	17.80	10.26
10	16.06	10.30	182.11	114.24	376.22	263.5	11.64	8.15	4.30	7.29
11	64.66	7.68	185.49	174.72	398.67	266.8	12. 00	9.25	22.47	18.20
12	17.86	1.60	31. 00	66. 00	351.47	231.95	11.84	8.75	9.11	12.73
13	14.73	4.75	42.77	61.65	553.32	411.70	11.82	8.75	13.96	43.36
14	108.54	77.22	493.38	190.4	558.75	416. 00	13. 00	9.35	25.06	113.96
15	14.86	10.35	451.15	394.24	463.81	378.75	11.70	9.40	20.75	199. 00
16	129.00	139.44	346.74	481.6	193.88	164.35	12.53	9.10	46.52	387.73
17	41.39	16.73	987.3	661.92	337.35	262.65	12.50	9.15	259. 00	709.87
18	101.51	33.97	464.9	179. 00	343.27	186.95	16.96	8.60	338.16	948.88
19	15.78	1.99	162.48	189. 00	374.13	225.60	12.71	7.60	40.54	75.50
20	16.86	4.32	172.95	215. 00	441.32	250.60	13.49	7.35	14. 00	57.36
21	19.96	17.89	206.86	265.44	446.36	264.25	13.80	7.60	35.67	51.85

4.2.2.1. Available phosphorus

The available phosphorus ranged from 14.73 to 129 kg ha^{-1} when it was analysed on wet condition while the available P ranged from 1.6 to 139.44 kg ha^{-1} on analysis after drying. Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13) recorded the lowest and soils from RRS, Vytilla (AEU 5, sample No. 16) recorded the highest value in case of wet analysis. In case of dry analysis, available phosphorus observed in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13) was 4.75 kg ha^{-1} and in soils from RRS, Vytilla (AEU 5, sample No. 16) was 139.44 kg ha^{-1}. The value for available P was found to be considerably reduced to 4.75 in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13) when analysed after drying. While it increased to 139.44 kg ha^{-1} in case of Pokkali soils of RRS, Vytilla. When analysed after drying, the available P ranged from 1.6 kg ha^{-1} in wetland lateritic (Pattambi)(AEU 10) to 139.44 kg ha^{-1} in Pokkali soils of Vytilla. The available P content in most soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.2.2.2. Available potassium

Available potassium was observed to range from 31 to 493.38 kg ha^{-1} when it was analyzed on wet condition while the same soils showed an available K range from 25.76 to 661.92 kg ha^{-1} on analysis after drying. The lowest available K was recorded in Wetland lateritic soil(Pattambi)(AEU 10,sample No. 12) and the highest in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14) in case of wet analysis. On analysis after drying, available potassium observed in Wetland lateritic soil (Pattambi)(AEU 10,sample No. 12) was 66.08 kg ha^{-1} and in soils from Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14) it was 190.4 kg ha^{-1}.The lowest available K was recorded in ORARS, Kayamkulam(AEU 3, sample No. 4) and the highest in Pokkali (AEU 5, sample No. 17) in case of dry analysis. The value for available K was found to be considerably increased to 66.08

kg ha^{-1} in Wetland lateritic soil (Pattambi) (AEU 10, sample No. 12) when analysed after drying. While it decreased to 190.4 kg ha^{-1} in case of Black cotton soils of Chittor taluk of Palakkad (AEU 23, sample No.14). When analyzed after drying, the available K ranged from 25.76 in ORARS, Kayamkulam (AEU 3, sample No. 4) to 661.92 kg ha^{-1} in Pokkali soils of Vytilla (AEU 5, sample No.17). The available K content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.2.3. Available calcium

The highest available calcium content of 665.79 mg kg^{-1} soil was recorded in soils from Kuttanad ,CKN Block, Vechoor (AEU 4,sample No.2) and the lowest of 100.84 mg kg^{-1} soil in rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No. 9) in case of wet analysis. In case of dry analysis, available calcium observed in CKN Block, Vechoor (AEU 4,sample No.2) was 227.35 mg kg^{-1} soil and in rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No. 9) was 192.75 mg kg^{-1} soil. The highest available calcium content of 378.75 mg kg^{-1} soil was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15)and the lowest of 103.3 mg kg^{-1} soil from rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No. 9) in case of dry analysis. The value for available Ca was found to be considerably reduced to 227.35 mg kg^{-1} soil in CKN Block, Vechoor(AEU 4,sample No.2) when analysed after drying. While it increased to 192.75 mg kg^{-1} soil in case of rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No. 9). When analysed after drying, the available Ca ranged from 103.3 mg kg^{-1} soil in rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No. 9) to 378.75 mg kg^{-1} soil in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15). The available Ca content in most soil samples was found to be reduced when analysed after drying in comparison with the values obtained during wet analysis.

4.2.2.4. Available magnesium

Available magnesium content of soils was found to range from 8.27 to 25 mg kg^{-1} soil when it was analyzed on wet condition while the same soils showed an available Mg range from 7.35 to 10 mg kg^{-1}soil on analysis after drying. In case of wet analysis, the lowest magnesium status was observed in Chettikulangara (AEU 3, sample No. 6) and Kuttanad soils from CKN Block, Vechoor (AEU 4,sample No.2) recorded the highest magnesium status. In case of dry analysis, available magnesium observed in Chettikulangara (AEU 3, sample No. 6) was 6.8 mg kg^{-1} soil and in CKN Block, Vechoor (AEU 4,sample No.2) it was 9.15 mg kg^{-1} soil. The lowest magnesium status was observed in Chettikulangara (AEU 3, sample No. 5) and soils from Karumadi (AEU 4,sample No.3) recorded the highest magnesium status in case of dry analysis. The available Mg content in all the soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.2.2.5. Available sulphur

The available sulphur ranged from 2.9 to 338.16 mg kg^{-1} when it was analyzed on wet condition while the same soils showed an available S range from 7.29 to 1134 mg kg^{-1} soil on analysis after drying. The lowest sulphur content was recorded in the soils of Chettikulangara (AEU 3, sample No. 5) and the highest sulphur content was found in CKN Block, Vechoor (AEU 4,sample No. 2) in case of wet analysis. Available sulphur observed in soils of Chettikulangara (AEU 3, sample No. 5) was 30.74 mg kg^{-1} soil and in CKN Block, Vechoor (AEU 4,sample No.2)it was 1134 mg kg^{-1} soil on analysis after drying. In case of dry analysis, lowest sulphur content was recorded in the wetland lateritic soils(Pattambi)(AEU 10, sample No.10) and the highest sulphur content was found in CKN Block, Vechoor (AEU 4,sample No. 2). When analysed after drying, the lowest available S was observed in wetland lateritic soils (Pattambi) (AEU 10, sample No.10) and highest in CKN Block, Vechoor (AEU 4,sample No. 2). It is also clear from the table that available S content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.2.6. Available iron

The lowest iron content of 5.64 mg kg^{-1} soil was recorded in the Onattukkara sandy soils,ORARS, Kayamkulam (AEU 3, sample No.4) and the highest of 102.9 mg kg^{-1} soil was observed in CKN Block, Vechoor (AEU 4,sample No. 2) in case of wet analysis. In case of dry analysis, available iron observed in soils of ORARS, Kayamkulam (AEU 3, sample No. 4) was 7.04 mg kg^{-1} soil and in CKN Block, Vechoor (AEU 4,sample No.2)it was 66.24 mg kg^{-1} soil. In case of dry analysis, the lowest iron content of 7.04 mg kg^{-1} soil was recorded in the ORARS, Kayamkulam (AEU 3, sample No.4) and the highest of 66.24 mg kg^{-1} soil was found in CKN Block, Vechoor (AEU 4,sample No. 2). The available Fe content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.2.7. Available Manganese

Available Mn was found to range from 0.175 to 198.55 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed an available Mn range from 3.27 to 176.5 mg kg^{-1} on analysis after drying. In case of wet analysis, soils of Chettikulangara (AEU 3, sample No. 6) recorded the lowest and soils from Kottuvalli (AEU 5, sample No.18) recorded the highest value. On analysis after drying, the available manganese observed in soils of Chettikulangara (AEU 3, sample No. 6) was 4.46 mg kg^{-1} soil and in soils from Kottuvalli (AEU 5, sample No.18) it was 10.3 mg kg^{-1} soil. Soils of Karumadi (AEU 4, sample No.3) recorded the lowest and Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) recorded the highest value in case of dry analysis. The available Mn content in almost all the soil samples was found to be reduced when analysed after drying in comparison with the values obtained during wet analysis.

Table No. 17. Available nutrient status in soil during active tillering stage

Location	Av. Fe		Av. Mn		Av. Cu		Av. Zn		Av. B	
	mg kg^{-1} soil									
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	41.85	23.6	8.14	19.79	6.93	3.60	2.00	5.81	0.75	1.20
2	102.9	66.24	3.48	141.8	6.63	5.21	3.82	12.55	2.4	2.76
3	48.34	39.85	6.86	3.27	3.49	6.28	8.62	3.35	0.44	0.49
4	5.64	7.04	12.87	9.62	1.29	1.31	0.811	5.69	0.062	0.15
5	11.49	9.28	1.73	13.95	1.21	2.52	6.02	0.96	0.37	0.74
6	14.00	7.44	0.17	4.46	1.95	0.93	0.914	1.13	0.053	0.15
7	14.00	9.83	33.11	6.00	7.75	7.71	2.46	2.71	0.33	0.60
8	6.84	7.83	2.42	13.70	5.00	4.68	0.42	1.37	0.29	0.78
9	14.52	12.7	2.13	7.36	4.43	2.85	0.29	0.75	0.41	0.55
10	14.91	9.36	10.78	22.75	13.67	11.28	0.87	1.72	0.95	1.02
11	48.57	32.6	22.32	141.1	15.12	10.23	7.15	15.21	0.12	0.46
12	19.08	13.2	5.28	28.22	21.33	14.79	1.5	5.75	0.84	1.23
13	36.46	25.16	19.34	158.2	13.93	4.12	6.71	11.3	0.3	0.945
14	10.24	13.79	24.77	18.76	7.92	0.95	12	5.93	0.58	0.429
15	18.20	15.70	71.79	176.5	7.48	6.68	6.07	39.9	0.1	0.032
16	25.37	17.90	5.99	12.3	3.93	9.78	0.38	20.84	0.63	3.21
17	38.46	63.89	71.24	114.3	5.39	5.25	4.99	29.17	1.57	3.88
18	45.96	23.8	198.55	10.3	2.69	1.54	21.32	8.08	1.53	2.96
19	20.48	29.86	2.50	10.27	7.06	14.83	3.83	4.53	1.78	0.97
20	49.11	27.80	59.11	83.04	15.16	13.86	37.49	53.28	0.089	2.32
21	19.21	12.70	18.6	84.09	13.35	7.83	6.45	48	0.826	1.04

4.2.2.8. Available Copper

The lowest available Cu (1.21 mg kg^{-1} soil) was recorded in soil from Chettikulangara (AEU 3, sample No. 5) and the highest (21.33 mg kg^{-1} soil) in wetland lateritic soil (Pattambi)(AEU 10,sample No. 12) in case of wet analysis. On analysis after drying, available copper observed in soils of Chettikulangara (AEU 3, sample No. 5) was 2.52 mg kg^{-1} soil and in soils from wetland lateritic soil(Pattambi)(AEU 10,sample No. 12) it was 14.79 mg kg^{-1} soil. In case of dry analysis, the lowest available Cu(3.27 mg kg^{-1}) was recorded in soils of Karumadi(AEU 4, sample No. 3) and the highest (176.5 mg kg^{-1}) in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15.). It is also clear from the table that available Cu content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.2.9. Available Zinc

The lowest available zinc(0.29 mg kg^{-1}) was recorded in rice soils of Palakkad(AEU22, sample No. 9)and highest(37.49 mg kg^{-1}) in soils from Kolelands, Ponnamotha (AEU 6,sample No.20) in case of wet analysis. On analysis after drying, available zinc observed in rice soils of Palakkad (Vadakkenchery) (AEU22, sample No. 9)was 0.75 mg kg^{-1} soil and in soils from Ponnamotha (AEU 6,sample No.20) was 53.28 mg kg^{-1} soil. In case of dry analysis, the lowest available zinc(0.75 mg kg^{-1}) was recorded in rice soils of Palakkad (AEU22, sample No. 9)and highest(53.28 mg kg^{-1}) in Ponnamotha (AEU 6,sample No.20). The available Zn content in almost all the soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis

4.2.2.10. Available boron

The hot water extractable boron was found to vary from 0.053 to 2.4 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed an available range from 0.032 to 3.88 mg kg^{-1} soil on analysis after drying. The lowest boron content of 0.053 mg kg^{-1} soil was recorded in Chettikulangara (AEU 3, sample No. 6) and the highest value was observed in soils from Kuttanad (AEU 4, sample No. 2) in case of wet analysis. On analysis after drying, available boron observed in Chettikulangara (AEU 3, sample No. 6) was 0.158 mg kg^{-1} soil and in soils from Kuttanad (AEU 4, sample No. 2) it was 2.76 mg kg^{-1} soil. In case of dry analysis, the lowest boron content was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15.) and the highest value was observed in soils from Pokkali

(AEU 5, sample No.17). The available B content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.3. Visual panicle initiation

4.2.3.1. Available phosphorus

The available phosphorus ranged from 11.58 to 114.59 kg ha^{-1} when it was analysed on wet condition while the same soils showed an available P range from 1.53 to 131 kg ha^{-1} on analysis after drying. Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13) recorded the lowest and soils from RRS, Vytilla (AEU 5, sample No. 16) recorded the highest value in case of wet analysis. On analysis after drying, available phosphorus observed in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13) was 6.53 kg ha^{-1} soil and in soils from RRS, Vytilla (AEU 5, sample No. 16) it was 48.67 kg ha^{-1}. Wetland lateritic soil (Pattambi) (AEU 10,sample No. 11) recorded the lowest and soils from Chettikulangara (AEU 3, sample No. 5) recorded the highest value in case of dry analysis. The available P content in almost all the soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.2.3.2. Available potassium

Available potassium was observed to range from 25.18 to 479.76 kg ha^{-1} when it was analyzed on wet condition while the same soils showed an available K range from 33.6 to 305.76 kg ha^{-1} on analysis after drying. The lowest available K was recorded in soils from Chettikulangara (AEU 3, sample No. 5) and the highest in Kottuvalli (AEU 5, sample No. 18) in case of wet analysis. On analysis after drying, available potassium observed in Chettikulangara (AEU 3, sample No. 5) was 33.6 kg ha^{-1} and in soils from Kottuvalli (AEU 5, sample No. 18) it was 305.76 kg ha^{-1}. In case of dry analysis, the lowest available K was recorded in Chettikulangara (AEU 3, sample No. 5) and the highest in Kottuvalli (AEU 5, sample No. 18). The available K content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.3.3. Available calcium

The highest available calcium content of 788.55 mg kg^{-1} soil was recorded in soils from Kuttanad, CKN Block, Vechoor (AEU 4,sample No.2) and the lowest of 135 mg kg^{-1} in soil from Karumadi (AEU 4, sample No. 3) in case of wet analysis. On analysis after drying, available calcium observed in CKN Block, Vechoor (AEU 4,sample No.2) was 271.8 mg kg^{-1} soil and in soils from Karumadi (AEU 4, sample No. 3) it was 126.8 mg kg^{-1} .Whereas in case of dry analysis, the highest available calcium content of 426.85 mg kg^{-1} soil was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14)and the lowest of 117.8 mg kg^{-1} soil in soils from Pokkali, Kottuvalli (AEU 5, sample No. 16). It is also clear from the table that available Ca content in most soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.2.3.4. Available magnesium

Available magnesium content of soils found to range from 7.27 to 23.94 mg kg^{-1} soil when it was analyzed on wet condition while the available Mg ranged from 6.35 to 9.35mg kg^{-1} soil on analysis after drying. In case of wet analysis, the lowest magnesium status was observed in Chettikulangara (AEU 3, sample No. 6) and CKN Block, Vechoor (AEU 4,sample No.2) recorded the highest magnesium status. In case of dry analysis, available magnesium observed in Chettikulangara (AEU 3, sample No. 6) was 6.4 mg kg^{-1} soil and in soils from CKN Block, Vechoor (AEU 4,sample No.2) it was 8.95 mg kg^{-1} soil. The available Mg content in all the soil samples was found to be reduced when analyzed after drying in comparison with the values obtained during wet analysis.

4.2.3.5. Available sulphur

The available sulphur ranged from 8.11 to 431.46 mg kg^{-1} soil when it was analyzed on wet condition while the same soils showed an available S range from 9.56 to 1024 mg kg^{-1} soil on analysis after drying. The lowest sulphur content was recorded in the rice soils of Palakkad (AEU22, sample No. 9) and the highest sulphur content in Pokkali soils of Kottuvalli (AEU 5, sample No. 18) in case of wet analysis.On analysis after drying, available sulphur observed in rice soils of Palakkad (Vadakkenchery) (AEU22, sample No. 9)was 10.57 mg kg^{-1} soil and in soils from Kottuvalli (AEU 5, sample No. 18)it was 832.17 mg kg^{-1} soil. In case of dry analysis, lowest sulphur content was recorded in the rice soils of Palakkad (AEU22, sample No. 7) and the highest sulphur content was found in CKN Block, Vechoor (AEU 4,sample No. 2) in case of dry analysis. The available S content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

Table 18 Available nutrient status in soil during visual panicle initialtion stage

Location	Av P		Av K		Ca		Av Mg		Av S	
	kg ha^{-1}				(mg kg^{-1} soil)					
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	22.56	11.69	191.00	188.16	633.53	323.50	16.56	9.35	53.73	57.17
2	27.32	6.79	359.87	285.60	788.55	271.80	23.94	8.95	191.73	1024.88
3	18.97	15.82	96.73	144.48	135.00	126.80	10.54	9.30	39.22	270.83
4	24.37	22.06	25.18	33.60	126.54	147.80	7.46	7.10	21.50	20.87
5	89.00	131.00	143.00	151.2	155.65	141.80	7.92	6.35	9.85	42.82
6	46.83	19.88	54.73	56.00	155.67	131.75	7.27	6.40	11.76	16.66
7	23.72	9.91	156.95	131.04	309.71	243.60	10.21	8.25	17.75	9.56
8	29.27	1.56	71.29	59.36	309.28	241.80	10.54	8.25	14.32	13.34
9	11.58	6.53	58.11	30.24	242.26	243.30	8.11	8.00	8.11	10.57
10	52.48	28.19	131.15	60.48	242.66	176.80	11.18	8.5	75.08	11.99

Table 18 Available nutrient status in soil during visual panicle initialtion stage

Location	Av P		Av K		Ca		Av Mg		Av S	
	kg ha^{-1}				(mg kg^{-1} soil)					
	Wet	Dry	Wet	Dry	Wet		Wet	Dry	Wet	Dry
11	13.76	1.53	215.24	170.24	344.36	253	11.05	9	12.51	13.07
12	25.85	2.16	46.96	80.64	317.25	212.8	11.45	8.6	13.71	17.01
13	24.15	12.87	29.64	53.76	574.55	426.8	12.35	8.6	25	56.26
14	15.37	84.4	159.81	129.92	455.21	426.85	10	9.25	11.54	73.53
15	18.96	10.27	277.26	295.68	477.5	401.9	11	9.15	74.09	149.57
16	112.59	96.84	402.44	468.16	167.45	117.8	13.55	8.95	162.8	454.86
17	36.26	21.54	570	252	181.37	151.75	12.24	8.6	767.82	1454.47
18	114.59	48.67	479.76	305.76	289.69	176.65	15.23	8.55	431.46	832.17
19	21.56	16	115.52	193.76	312.76	193.9	12.41	7.45	29.18	36.22
20	27.36	9.48	165.96	206.9	366.53	217.8	13.3	7.15	13.09	35.95
21	25.75	19.81	229.97	235.52	349	276.75	9.26	7.15	28.79	36.8

Table 19 Available micronutrient status in soil during visual panicle initialtion stage

Location	Av Fe		Av Mn		Av Cu		Av Zn		Av B	
	(mg kg^{-1} soil)									
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	63.08	3.24	1.68	32.4	7.96	3.67	2.7	6.95	1.54	0.924
2	97.08	4.61	1.5	46.17	7.23	3.47	3.3	13.43	6.46	3.02
3	22.98	2.07	22.46	20.7	3.75	4.44	6.27	2.04	0.537	0.513
4	8.5	0.838	0.248	8.38	1.55	2.34	0.24	0.63	0.14	0.205
5	11.25	0.923	1.15	9.23	1.19	0.63	1.19	1.09	0.35	0.389
6	15.36	0.979	2.37	9.79	1.95	0.96	0.914	1.17	0.069	0.25
7	51.94	3.91	10.81	39	13.15	8.45	2.21	4	0.298	0.816
8	16.56	1.34	5.82	13.49	9.81	7.84	1.67	1.91	0.53	0.921
9	5.39	0.832	32.72	8.32	3.13	4.51	1.48	0.71	0.42	0.882
10	13.6	0.878	1.15	8.78	17.22	7.73	4.85	1.65	1.12	1.5

Table 19 Available micronutrient status in soil during visual panicle initialtion stage

Location	Av Fe		Av Mn		Av Cu		Av Zn		Av B	
	(mg kg^{-1} soil)									
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
11	14.92	1.23	6.63	12.3	18.95	12.77	4.04	9.53	0.344	0.65
12	38.82	3.56	3.94	35.6	14.05	15.15	3.58	7.47	0.527	1.47
13	47	2.82	77.11	28.21	12.64	7.41	9.36	5.55	0.543	0.28
14	10.64	0.731	7.66	7.31	4.39	4.83	6.51	6.89	0.038	0.32
15	9.39	0.879	14.37	8.79	7.14	4.73	3.32	20.49	0.069	0.061
16	42	3.23	1.25	32.3	8.22	3.63	0.83	6.19	2.04	5.32
17	37.33	5.97	0.853	59.7	5.68	4.28	8.94	10.49	0.839	1.48
18	23.26	2.51	2.07	25.11	3.22	1.45	4.87	19.43	1.1	2.63
19	33.93	2.51	1.53	25.13	15.96	17.17	8.67	14.45	0.041	1.9
20	35.55	1.93	59.31	19.3	16.9	9.78	18.59	10.39	0.7	1.77
21	11.89	0.975	12.92	9.75	6.68	6.6	5.66	10.33	0.493	1.83

4.2.3.6. Available iron

The lowest iron content of 5.39 mg kg^{-1} soil was recorded in the rice soils of Palakkad(AEU22, sample No. 9) and the highest of 97 mg kg^{-1} soil in Kuttanad soils, CKN Block, Vechoor (AEU 4,sample No. 2) in case of wet analysis. On analysis after drying,available iron observed in rice soils of Palakkad (Vadakkenchery) (AEU22, sample No. 9) was 0.832 mg kg $^{-1}$ soil and in soils from CKN Block, Vechoor (AEU 4,sample No. 2) it was 4.61 mg kg^{-1} soil. In case of dry analysis, the lowest iron content of 0.731 mg kg^{-1} was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14) and the highest of 5.97 mg kg^{-1} was found in Pokkali soils from Kottuvalli (AEU 5, sample No. 17). The available Fe content in most soil samples was found to be decreased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.3.7. Available Manganese

Available Mn was found to range from 0.24 to 77.11 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed an available S range from 7.31 to 46.17 mg kg^{-1} on analysis after drying. In case of wet analysis, Black cotton soils of Chittor taluk of Palakkad (AEU 23, sample No.13) recorded the highest and soils from Chettikulangara (AEU 3, sample No. 5) recorded the lowest value. On analysis after drying, available manganese observed in Black cotton soils of Chittor taluk of Palakkad (AEU 23, sample No.13) was 8.38 mg kg $^{-1}$ soil and in soils from Chettikulangara (AEU 3, sample No. 5) it was 28.21 mg kg^{-1} soil. Black cotton soils of Chittor taluk of Palakkad (AEU 23, sample No.14) recorded the lowest and soils from CKN Block, Vechoor (AEU 4,sample No. 2) recorded the highest value in case of dry analysis. The available Mn content in almost all the soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.3.8. Available Copper

The lowest available Cu (1.19 mg kg^{-1} soil) was recorded in soil from Onattukkara, Chettikulangara (AEU 3, sample No. 5) and the highest (18.95 mg kg^{-1} soil) in wetland lateritic soil (Pattambi) (AEU 10,sample No. 11) in case of wet analysis. On analysis after drying, available copper observed in Chettikulangara (AEU 3, sample No. 5) was 0.63 mg kg $^{-1}$ soil and in soils from wetland lateritic soil(Pattambi) (AEU 10,sample No. 11) it was 12.77 mg kg^{-1} soil. In case of dry analysis, the lowest available Cu (0.63 mg kg^{-1}) was recorded in soils of Chettikulangara (AEU 3, sample No. 5)and the highest (17.17 mg kg^{-1}) in soils from Kolelands, Vengidangu (AEU 6,sample No.19). The available Cu content in most soil samples was found to be decreased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.3.9. Available Zinc

The lowest available zinc (0.248 mg kg^{-1}) was recorded in Onattukkara sandy soils, ORARS, Kayamkulam (AEU 3, sample No.4) and highest(18.59 mg kg^{-1}) in soils from Kolelands, Ponnamotha (AEU 6,sample No.20) in case of wet analysis.On analysis after drying, available zinc observed in ORARS, Kayamkulam (AEU 3, sample No.4) was 0.63 mg kg $^{-1}$ soil and in soils from Ponnamotha (AEU 6,sample No.20) it was 12.77 mg kg^{-1} soil. In case of dry analysis, the lowest available zinc(0.63 mg kg^{-1}) was recorded in ORARS, Kayamkulam (AEU 3, sample No.4) and highest(20.49 mg kg^{-1}) in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15). The available Zn content in almost all the soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis

Table No.20. Mean available nutrient status on agro-ecological unit (AEU) basis before cropping season

AEU	Parameter									
	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	kg ha^{-1}		mg/kg soil							
Kuttanad	17.14	207.57	187.00	8.23	579.72	27.20	18.41	3.53	3.31	1.37
Onattukkara sandy plain	30.00	26.50	131.60	6.18	33.82	9.80	17.10	2.39	3.99	0.43
Palakkad central plains	23.55	91.46	224.00	7.83	20.81	5.72	16.56	4.89	0.94	0.86
North central laterite	38.04	243.41	286.66	7.63	91.71	15.81	15.54	6.21	2.44	1.41
Palakkad eastern plains	37.85	270.66	384.18	8.9	492.72	5.94	30.14	4.60	8.91	0.27
Pokkali lands	79.14	427.46	96.30	8.08	349.93	19.16	48.00	2.30	1.82	4.36
Kole lands	13.50	420.00	257.11	7.75	34.28	20.29	13.68	7.05	3.05	2.00

4.2.4.1. Available P

The mean values of available P of the soils ranged from 13.50 to 79.14 kg ha^{-1}. The lowest mean available P was recorded in the Kolelands (AEU 6) and highest in the Pokkali (AEU 5)

4.2.4.2. Available Potassium

The lowest mean available K of 26.50 kg ha^{-1}was recorded in the Onattukkara sandy soils(AEU 3) and the highest of 427.46 kg ha^{-1}was recorded in Pokkali(AEU 5).

4.2.4.3 Available Calcium

The mean calcium status of the soils varied from 96.3 to 384.18 mg kg^{-1} soil. Pokkali (AEU 5) recorded the lowest and Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the highest value.

4.2.3.10. Available boron

The hot water extractable boron was found to vary from 0.038 to 6.46 mg kg^{-1} soil when it was analyzed on wet condition while the same soils showed an available B range from 0.061 to 5.3 mg kg^{-1} on analysis after drying. The lowest boron content was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23, sample No.14) and the highest value was observed in soils from CKN Block, Vechoor(AEU 4, sample No. 2) in case of wet analysis. In case of dry analysis, available boron observed in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14) was 0.329 mg kg^{-1} soil and in soils from CKN Block, Vechoor (AEU 4, sample No. 2) was 3.026 mg kg^{-1} soil. Decreasing trend of available B in case of dry analysis was observed in soil types such as Kuttanad(AEU 4, sample Nos. 1, 2 and 3) and Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.13, 14 and 15). In case of dry analysis, the lowest boron content of 0.061 mg kg^{-1} was recorded in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15) and the highest value was observed in soils from Kottuvalli (AEU 5, sample No.17). The value for available B was found to be considerably increased to 0.329 mg kg^{-1} soil in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.14) when analysed after drying. While it decreased to 3.026 mg kg^{-1} soil in case of soils from CKN Block, Vechoor (AEU 4, sample No. 2).When analysed after drying, the available B ranged from 0.061 in Black cotton soils of Chittor taluk of Palakkad (AEU 23,sample No.15.) to 5.3 mg kg^{-1} soil in soils from Kottuvalli (AEU 5, sample No.17). It is also clear from the table that available B content in most soil samples was found to be increased when analysed after drying in comparison with the values obtained during wet analysis.

4.2.4. Mean values of initial characterization

The mean values of three locations each from 7 agro-ecological units (AEU's) are presented in table 20 to 22.

Table No.20. Mean available nutrient status on agro-ecological unit (AEU) basis before cropping season

AEU	Parameter									
	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	kg ha^{-1}		mg/kg soil							
Kuttanad	17.14	207.57	187.00	8.23	579.72	27.20	18.41	3.53	3.31	1.37
Onattukkara sandy plain	30.00	26.50	131.60	6.18	33.82	9.80	17.10	2.39	3.99	0.43
Palakkad central plains	23.55	91.46	224.00	7.83	20.81	5.72	16.56	4.89	0.94	0.86
North central laterite	38.04	243.41	286.66	7.63	91.71	15.81	15.54	6.21	2.44	1.41
Palakkad eastern plains	37.85	270.66	384.18	8.9	492.72	5.94	30.14	4.60	8.91	0.27
Pokkali lands	79.14	427.46	96.30	8.08	349.93	19.16	48.00	2.30	1.82	4.36
Kole lands	13.50	420.00	257.11	7.75	34.28	20.29	13.68	7.05	3.05	2.00

4.2.4.1. Available P

The mean values of available P of the soils ranged from 13.50 to 79.14 kg ha^{-1}. The lowest mean available P was recorded in the Kolelands (AEU 6) and highest in the Pokkali (AEU 5)

4.2.4.2. Available Potassium

The lowest mean available K of 26.50 kg $ha^{-1}$was recorded in the Onattukkara sandy soils(AEU 3) and the highest of 427.46 kg $ha^{-1}$was recorded in Pokkali(AEU 5).

4.2.4.3 Available Calcium

The mean calcium status of the soils varied from 96.3 to 384.18 mg kg^{-1} soil. Pokkali (AEU 5) recorded the lowest and Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the highest value.

4.2.4.4 Available Magnesium

The mean available magnesium status of the soils varied from 6.18 to 8.23 mg kg^{-1} soil. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.2.4.5. Available Sulphur

The lowest mean available S of 20.81 mg kg^{-1} soil was recorded in the rice soils of Palakkad (Vadakkenchery) (AEU 22) and the highest of 579.72 mg kg^{-1} soil in Kuttanad (AEU 4)

4.2.4.6. Available Iron

The mean available iron status of the soils varied from 5.72 to 27.20 mg kg^{-1} soil. Rice soils of Palakkad (Vadakkenchery) (AEU22) recorded the lowest and Kuttanad (AEU 4) recorded the highest value.

4.2.4.7 Available Manganese

The mean available manganese of the soils varied from 13.68 to 48 mg kg^{-1} soil. Kolelands (AEU 6) recorded the lowest and soils from Pokkali(AEU 5) recorded the highest value.

4.2.4.8 Available Copper

The mean available copper of the soils varied from 2.30 to 7 mg kg^{-1} soil. Soils from Pokkali (AEU 5) recorded the lowest and Kolelands (AEU 6) recorded the highest value.

4.2.4.9 Available Zinc

The mean available zinc of the soils varied from 0.94 to 8.91 mg kg^{-1} soil. Rice soils of Palakkad (Vadakkenchery) (AEU 22) recorded the lowest and Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the highest value.

4.2.4.10 Available Boron

The mean available B of the soils varied from 0.43 to 4.36 mg kg^{-1} soil. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Pokkali (AEU 5) recorded the highest value.

4.2.5. Active tillering stage

4.2.5.1 Available P

The mean values of available P of the soils ranged from 17.53 to 90.65 kg ha^{-1} when it was analysed on wet condition while the same soils showed a range of 6.53 to 63.38 kg ha^{-1} on analysis after drying. The lowest mean available P was recorded in the Kolelands (AEU 6) and highest in the Pokkali (AEU 5) in case of wet analysis. In case of dry analysis, mean available P observed in Kolelands(AEU 6) was 8.07 kg ha^{-1} soil and in soils from Pokkali(AEU 5) was 63.38 kg ha^{-1}.The lowest mean available P was recorded in the wetland lateritic soils(Pattambi) (AEU 10) and highest in the Pokkali (AEU 5) in case of dry analysis.

4.2.5.2. Available potassium

The lowest mean available potassium of 55.21 kg ha^{-1} was recorded in the Rice soils of Palakkad (Vadakkenchery) (AEU 22) and the highest value of 599.65 kg $ha^{-1}$was recorded in soils from Pokkali (AEU 5) in case of wet analysis. In case of dry analysis, mean available K observed in Rice soils of Palakkad (Vadakkenchery) (AEU 22) was 50 kg ha^{-1} soil and in soils from Pokkali(AEU 5) was 440.91 kg ha^{-1}. In case of dry analysis, the lowest mean available K (50 kg ha^{-1}) was recorded in the Rice soils of Palakkad (Vadakkenchery) (AEU 22) and highest (440.91 kg ha^{-1}) in the Pokkali (AEU 5).

Table No. 21. Mean available nutrient status on agro-ecological unit basis during active tillering stage

Parameter	Kuttanad		Onattukkara sandy plain		Palakkad central plains		North central laterite		Palakkad eastern plains		Pokkali lands		Kole lands	
	Type of analysis													
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P (kg ha^{-1})	29.55	7.39	48.47	44.80	25.47	10.2	32.86	6.53	46	30.77	90.65	63.38	17.53	8.07
K (kg ha^{-1})	352.87	290.45	78.72	54.88	55.21	50	132.89	118.35	329	215.43	599.65	440.91	180.76	223.25
Ca (mg kg^{-1} soil)	507.69	257.6	156.58	147.2	177	153.43	375.45	254	525.29	402.18	291.5	204.65	420.6	246.81
Mg (mg kg^{-1} soil)	18.25	9.55	8.44	7.42	9.4	8.6	11.86	8.72	12.17	9.17	13.99	8.95	13.33	7.52
S (mg kg^{-1} soil)	173.41	596.54	11.06	21.6	14.80	19.79	11.96	12.74	19.92	118.79	214.58	682.16	30.07	61.57
Fe (mg kg^{-1} soil)	64.36	43.23	10.38	7.92	11.81	10.12	27.52	18.38	21.63	18.21	36.59	35.19	29.6	23.45
Mn (mg kg^{-1} soil)	6.16	54.95	4.92	9.34	12.55	9.02	12.79	64	38.63	117.82	91.92	45.63	26.73	59.13
Cu (mg kg^{-1} soil)	5.68	5.03	1.48	2.02	5.73	5.08	16.7	12.1	9.77	3.91	4	5.52	11.85	12.17
Zn (mg kg^{-1} soil)	4.81	7.23	2.58	2.59	1.05	1.61	3.17	7.56	8.26	19.04	8.89	19.36	15.92	35.28

Table No. 21. Mean available nutrient status on agro-ecological unit basis during active tillering stage

Parameter	Kuttanad		Onattukkara sandy plain		Palakkad central plains		North central laterite		Palakkad eastern plains		Pokkali lands		Kole lands	
	Type of analysis													
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
B (mg kg^{-1} soil)	1.19	1.48	0.16	0.354	0.34	0.649	0.63	0.906	0.32	0.468	1.24	3.35	0.898	1.44

4.2.5.3. Available calcium

The mean available Ca of the soils varied from 156.58 to 507.69 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 147.2 to 402.18 mg kg^{-1} soil on analysis after drying. Rice soils of Palakkad (Vadakkenchery)(AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Ca observed in Rice soils of Palakkad(Vadakkenchery) (AEU 22) was 153.43 mg kg^{-1} soil and in soils from Kuttanad (AEU 4) was 147.2 mg kg^{-1} soil. In case of dry analysis, Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value on dry analysis.

4.2.5.4. Available magnesium

The mean available magnesium status of the soils varied from 8.44 to 18.25 mg kg^{-1} soil when it was analysed on wet condition while the soils showed a range of 7.42 to 9.55 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad(AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Mg observed in Onattukkara sandy soils(AEU 3) was 7.42 mg kg^{-1} soil and in soils from Kuttanad(AEU 4) was 9.55 mg kg^{-1} soil. In case of dry analysis, Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.2.5.5. Available sulphur

The lowest mean available sulphur of 11 mg kg^{-1} soil was recorded in the Onattukkara sandy soils (AEU 3) and the highest of 214.58 mg kg^{-1} in Pokkali (AEU 5) in case of wet analysis. In case of dry analysis, mean available S observed in Onattukkara sandy soils(AEU 3) was 2.14 mg kg^{-1} soil and in soils from Pokkali (AEU 5) was 682.16 mg kg^{-1} soil. In case of dry analysis, the lowest mean available sulphur of 12.74 mg kg^{-1} was recorded in wetland lateritic soils(Pattambi)(AEU 10) and the highest of 682.16 mg kg^{-1} soil in Pokkali (AEU 5).

4.2.5.6. Available iron

The mean available iron status of the soils varied from 10.38 to 64.36 mg kg^{-1} soil when it was analysed on wet condition while the available iron showed a range of 7.92 to 43.23 on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Fe observed in Onattukkara sandy soils(AEU 3) was 7.92 mg kg^{-1} soil and in soils from Kuttanad (AEU 4) was 43.23 mg kg^{-1} soil. In case of dry analysis, Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value.

4.2.5.7. Available manganese

The mean available manganese of the soils varied from 4.92 to 91.92 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 9.02 to 117.82 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Pokkali(AEU 5)recorded the highest value in case of wet analysis. In case of dry analysis, mean available Mn observed in Onattukkara sandy soils (AEU 3) was 9.34 mg kg^{-1} soil and in soils from Pokkali (AEU 5) was 45.63 mg kg^{-1} soil.In case of dry analysis, rice soils of Palakkad (Vadakkenchery)(AEU 22) recorded the lowest and Black cotton soils of Chittor taluk of Palakkad (AEU 23) recorded the highest value.

4.2.5.8. Available copper

The mean available copper of the soils varied from 1.48 to 16.70 mg kg^{-1}soil when it was analyzed on wet condition while the available copper showed a range of 2 to 12.17 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and wetland lateritic soil(Pattambi)(AEU 10)recorded the highest value in case of wet analysis. In case of dry analysis, mean available Cu observed in Onattukkara sandy soils (AEU 3) was 2.02 mg kg^{-1} soil and in soils from wetland lateritic soil(Pattambi)(AEU 10) was 12.1 mg kg^{-1} soil. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Kolelands (AEU 6) recorded the highest value in case of dry analysis.

4.2.5.9. Available zinc

The mean available zinc of the soils varied from 1 to 15.92 mg kg^{-1} soil when it was analysed on wet condition while the mean available zinc showed a range of 0.354 to 3.35 mg kg^{-1} soil on analysis after drying. Rice soils of Palakkad (Vadakkenchery)(AEU 22) recorded the lowest and soils from Kolelands(AEU 6) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Zn observed in Rice soils of Palakkad (Vadakkenchery)(AEU 22)was 1.61 mg kg^{-1} soil and in soils from Kolelands(AEU 6) was 35.28 mg kg^{-1} soil. Rice soils of Palakkad (Vadakkenchery)(AEU 22) recorded the lowest and soils from Kolelands (AEU 6) recorded the highest value in case of dry analysis.

4.2.5.10 Available Boron

The mean available Boron of the soils varied from 0.16 to 1.24 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 0.032 to 3.88 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and Pokkali(AEU 5)recorded the highest value in case of wet analysis. In case of dry analysis, mean available B observed in Onattukkara sandy soils(AEU 3) was 0.35 mg kg^{-1} soil and in soils from Pokkali(AEU 5) was 3.35 mg kg^{-1} soil. In case of dry analysis, Onattukkara sandy soils (AEU 3) recorded the lowest and soils from Pokkali(AEU 5) recorded the highest value.

Table No. 22. **Available nutrient status on agro-ecological unit basis during visual panicle initiation stage**

Parameter	Kuttanad		Onattukkara sandy plain		Palakkad central plains		North central laterite		Palakkad eastern plains		Pokkali lands		Kole lands	
	Type of analysis													
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P(kg ha^{-1})	22.95	11.43	53.4	57.64	21.52	6	30.69	10.62	19.49	35.84	87.81	55.68	24.89	15.09
K(kg ha^{-1})	215.86	206.08	74.30	80.26	95.45	73.54	131.11	103.78	155.57	159.78	484.06	341.97	170.48	212.06
Ca(mg kg^{-1} soil)	519.02	240.7	145.95	140.45	287.08	242.9	301.42	214.2	502.42	418.51	212.83	148.73	342.76	229.48
Mg (mg kg-1 soil)	17.01	9.2	7.55	6.61	9.62	8.16	11.22	8.7	11.11	9	13.67	8.7	11.65	7.25
S (mg kg^{-1} soil)	94.89	450.96	14.37	26.78	13.39	11.15	33.76	14.02	36.87	93.12	454.02	913.83	23.68	36.32
Fe (mg kg^{-1} soil)	61.04	3.30	11.70	0.91	24.63	2.02	22.44	1.88	22.34	1.47	34.19	3.90	27.12	1.805
Mn (mg kg^{-1} soil)	8.54	33.09	1.256	9.13	16.45	20.27	3.90	18.89	33.04	14.77	1.39	39.03	24.58	18.06
Cu (mg kg^{-1} soil)	6.31	3.86	1.56	1.31	8.69	6.93	16.74	11.88	8.05	5.65	5.70	3.12	13.18	11.18
Zn (mg kg^{-1} soil)	4.09	7.47	0.78	0.96	1.78	2.20	4.15	6.21	6.39	10.97	4.88	12.03	10.97	11.72
B (mg kg^{-1} soil)	2.84	1.48	0.18	0.28	0.41	0.87	0.66	1.20	0.21	0.22	1.32	3.14	0.41	1.83

4.2.6. Visual panicle initiation

4.2.6.1. Available phosphorus

The mean values of available P of the soils ranged from 19.37 to 87.81 kg ha^{-1} when it was analysed on wet condition while the same soils showed a range of 6 to 57.67 kg ha^{-1} on analysis after drying. The lowest mean available P was recorded in the soils of Chittor taluk of Palakkad (AEU 23) and highest in the Pokkali(AEU 5) in case of wet analysis. In case of dry analysis, mean available P of soils of Chittor taluk of Palakkad (AEU 23) was 35.85 kg ha^{-1} and that of Pokkali(AEU 5) was 55.69 kg ha^{-1} . The lowest mean available P was recorded in rice soils of Palakkad(Vadakkenchery)(AEU 22) and highest in the Pokkali(AEU 5) in case of dry analysis.

4.2.6.2. Available potassium

The lowest mean available K of 74.30 kg ha^{-1} was recorded in the Onattukkara sandy soils (AEU 3) and the highest of 484 kg $ha^{-1}$was recorded in soils from Pokkali (AEU 5) in case of wet analysis. In case of dry analysis, mean available K of Onattukkara sandy soils (AEU 3)was 80.27 kg ha^{-1} and that of Pokkali (AEU 5) was 342 kg ha^{-1}. The lowest mean available K of 73.55 kg ha^{-1} was recorded in the Rice soils of Palakkad(Vadakkenchery)(AEU 22)and the highest of 342 kg ha^{-1} was recorded in soils from Pokkali (AEU 5) in case of dry analysis.

4.2.6.3. Available Calcium

The mean available calcium status of the soils varied from 146 to 519 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 140 to 418.52 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Ca of Onattukkara sandy soils(AEU 3)was 140.5 mg kg^{-1} soil and that of Kuttanad (AEU 4) was 242.40 mg kg^{-1} soil. Onattukkara sandy soils(AEU 3) recorded the lowest and soils of Chittor taluk of Palakkad (AEU 23) recorded the highest value in case of dry analysis.

4.2.6.4. Available Magnesium

The mean available magnesium status of the soils varied from 7.55 to 17 mg kg^{-1} soil when it was analyzed on wet condition while the same soils showed a range of 6.62 to 9.2 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Mg of Onattukkara sandy soils(AEU 3)was 6.62 mg kg^{-1} soil and that of Kuttanad (AEU 4) was 9.2 mg kg^{-1} soil. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.2.6.5. Available sulphur

The lowest mean available S of 13.4 mg kg^{-1} soil was recorded in Rice soils of Palakkad (Vadakkenchery) (AEU 22)and the highest of 454.40 mg kg^{-1} soil in Pokkali(AEU 5) in case of wet analysis. In case of dry analysis, mean available S of Rice soils of Palakkad (Vadakkenchery) (AEU 22)was 11.16 mg kg^{-1} soil and that of Pokkali (AEU 5) was 913.80 mg kg^{-1} soil. Rice soils of Palakkad (Vadakkenchery) (AEU 22) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.2.6.6. Available iron

The mean available iron status of the soils varied from 11.71 to 61 mg kg^{-1} soil when it was analyzed on wet condition while the soils showed a range of 0.91 to 3.90 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Fe of Onattukkara sandy soils(AEU 3) was 0.91 mg kg^{-1} soil and that of Kuttanad (AEU 4) was 3.31 mg kg^{-1} soil. Soils from Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kuttanad (AEU 4) recorded the highest value in case of dry analysis.

4.2.6.7. Available manganese

The mean available Mn of the soils varied from 1.25 to 33 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 9.13 to 33 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and Black soils from Chittor taluk of Palakkad(AEU 23) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Mnof Onattukkara sandy soils(AEU 3) was 9.13 mg kg^{-1} soil and that of Black soils from Chittor taluk of Palakkad(AEU 23) was 14.77 mg kg^{-1} soil. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Pokkali (AEU 5) recorded the highest value on dry analysis.

4.2.6.8. Available Copper

The mean available copper of the soils varied from 1.56 to 16.74 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 1.31 to 11.88 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and soils from wetland lateritic (Pattambi)(AEU 10) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Cu of Onattukkara sandy soils(AEU 3) was 1.31mg kg^{-1} soil and that of wetland lateritic (Pattambi)(AEU 10) was 11.88 mg kg^{-1} soil. Onattukkara sandy soils(AEU 3) recorded the lowest and wetland lateritic soils(AEU 10) recorded the highest value on dry analysis.

4.2.6.9. Available Zinc

The mean available zinc of the soils varied from 0.784 to 10.97 mg kg^{-1} soil when it was analysed on wet condition while the soils showed a range of 0.963 to 12 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Kolelands (AEU 6) recorded the highest value in case of wet analysis. In case of dry analysis, mean available Zn of Onattukkara sandy soils (AEU 3) was 0.963 mg kg^{-1} soil and that of Kolelands (AEU 6) was 11.72 mg kg^{-1}

soil.Onattukkara sandy soils(AEU 3) recorded the lowest and soils from Pokkali(AEU 5) recorded the highest value on dry analysis.

4.2.6.10. Available Boron

The mean available boron of the soils varied from 0.19 to 2.84 mg kg^{-1} soil when it was analysed on wet condition while the same soils showed a range of 0.28 to 3.15 mg kg^{-1} soil on analysis after drying. Onattukkara sandy soils (AEU 3) recorded the lowest and Kuttanad (AEU 4) recorded the highest value in case of wet analysis. In case of dry analysis, mean available B of Onattukkara sandy soils (AEU 3) was 0.28 mg kg^{-1} soil and that of Kuttanad (AEU 4) was 1.48 mg kg^{-1} soil. Onattukkara sandy soils (AEU 3) recorded the lowest and Pokkali(AEU 5) recorded the highest value on dry analysis.

4.3. Nutrient content in plant

The nutrient content in rice in various plant parts during active tillering and visual panicle initiation stages are given in table Nos. 23 to

4.3.1. Active tillering stage

4.3.1.1. Total nitrogen

The total nitrogen in shoot varied 0.88 to 2.75 percent.The lowest value was observed in soils from Karumadi (AEU 4, sample No.3) and in Pokkali soils from Kottuvalli (AEU 5 , sample No.18) and the highest percent total nitrogen in, wetland lateritic soils of Palakkad (Pattambi) (AEU 10, sample No.10).The percent total nitrogen in root varied from 0.46 in Pokkali soils from Kottuvalli (AEU 5 , sample No.18) and 1.69 percent in Pokkali soils of RRS, Vytilla (AEU 5, sample No.16)

4.3.1.2. Total phosphorus

The total phosphorus in shoot varied 0.023 to 0.25 percent.The lowest value was observed in wetland lateritic soils of Palakkad (Pattambi)(AEU 10, sample No.11) and the highest percent total phosphorus in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.7).The percent total phosphorus in root varied from 0.004 in

Pokkali soils from Kottuvalli (AEU 5 , sample No.17) and 0.13 percent in Kuttanad soils from Poovathikkari(AEU 4, sample No.1).

4.3.1.3. Total potassium

The total potassium in shoot varied 0.268 to 0.91 percent. The lowest value was observed in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 13)and the highest percent total K in Ponnamotha(AEU 6, sample No.20).The percent total K in root varied from 0.021 in Pokkali soils from Kottuvalli (AEU 5 , sample No.18) and 0.32 percent in Manalurthazhum (AEU 6, sample No.21).

4.3.1.4. Total calcium

The total calcium in shoot varied 0.023 to 0.132 percent. The lowest value was observed in wetland lateritic soils of Palakkad (Pattambi)(AEU 10, sample No.11) and the highest percent total Ca in Kuttanad soils from Poovathikkari (AEU 4, sample No.1).The percent total Ca in root varied from 0.026 Pokkali soils from Kottuvalli (AEU 5 , sample No.18) and 0.26 percent in soils from Karumadi (AEU 4, sample No.3).

4.3.1.5. Total magnesium

The total magnesium in shoot varied 0.011 to 0.012 percent. The lowest value was observed in Onattukkara sandy soils from Chettikulangara (AEU 3, sample No.6) and the highest percent total Mg in in Pokkali soils of RRS, Vytilla (AEU 5, sample No.16) .The percent total Mg in root varied from 0.0011 in ORARS, Kayamkulam (AEU 3, sample No.4) and 0.012 percent in soils from rice soils of Palakkad (Vadakkenchey)(AEU 22, sample No.9) and in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 13).

Table No. 23. Nutrient content in rice during active tillering stage

Location	Tot N (%)		Tot P (%)		Tot K (%)		Tot Ca (%)		Tot Mg (%)		Tot S (%)	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
1	1.1	0.9	0.24	0.13	0.78	0.316	0.13	0. 09	0.012	0.0118	0.14	0.048
2	0.96	0.68	0.189	0.09	0.74	0.237	0.10	0.075	0.0126	0.012	0.11	0.06
3	0.88	0.78	0.078	0.023	0.44	0.085	0.37	0.26	0.0118	0.0111	0.09	0.034
4	1.14	0.89	0.21	0.12	0.675	0.171	0.124	0.045	0.0119	0.0011	0.18	0.044
5	1.83	1.01	0.21	0.008	0.779	0.029	0.093	0.039	0.0126	0.0034	0.1	0.022
6	1.17	0.68	0.098	0.027	0.456	0.06	0.10	0.034	0.0116	0.0113	0.027	0.012
7	1.65	0.98	0.25	0.016	0.767	0.022	0.093	0.054	0.0127	0.0035	0.17	0.02
8	1.58	0.86	0.12	0.052	0.781	0.157	0.11	0.056	0.0123	0.0115	0.13	0.04
9	1.18	1.02	0.23	0.1	0.783	0.159	0.092	0.049	0.0125	0.0128	0.17	0.056
10	2.75	1.65	0.12	0.041	0.72	0.182	0.09	0.056	0.0127	0.0111	0.11	0.067
11	2.28	1.45	0.023	0.015	0.675	0.227	0.023	0.035	0.0121	0.0023	0.077	0.024
12	2.12	1.38	0.14	0.037	0.673	0.226	0.113	0.057	0.0125	0.0036	0.15	0.08
13	2.07	1.22	0.076	0.035	0.268	0.217	0.37	0.042	0.01273	0.0128	0.04	0.023
14	2.62	1.58	0.073	0.036	0.312	0.31	0.081	0.066	0.012	0.0127	0.049	0.041
15	1.52	0.75	0.232	0.019	0.875	0.229	0.116	0.035	0.0125	0.0118	0.13	0.02
16	1.96	1.69	0.19	0.036	0.789	0.075	0.095	0.058	0.0129	0.0116	0.17	0.024
17	1.82	1.56	0.14	0.004	0.811	0.025	0.11	0.089	0.01262	0.0113	0.13	0.023
18	0.88	0.46	0.19	0.017	0.769	0.021	0.128	0.026	0.0127	0.0035	0.17	0.021
19	1.03	0.63	0.13	0.1	0.896	0.248	0.102	0.059	0.0126	0.0111	0.16	0.081
20	1.56	0.84	0.17	0.082	0.911	0.256	0.114	0.061	0.0127	0.0115	0.12	0.075
21	2.65	1.54	0.2	0.092	0.82	0.325	0.127	0.07	0.0126	0.0118	0.16	0.066

4.3.1.6. Total sulphur

The total magnesium in shoot varied 0.027 to 0.17 percent. The lowest value was observed in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.6) and highest value in rice soils of Palakkad(Vadakkenchey)(AEU 22, sample No.7 and 9)and in Pokkali soils of RRS, Vytilla and Kottuvalli(AEU 5, sample No.16 and 18 and) .The percent total S in root varied from 0.012 in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.6) and 0.018 percent in soils from Vengidangu(AEU 6, sample No.19)

4.3.1.7. Total iron

The total iron in shoot varied 250 to 1290 ppm. The lowest value was observed in Karumadi (AEU 4, sample No.3)and in black soils of Chittor taluk of Palakkad (AEU 23, sample No. 14) and the highest total iron in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.7). The total iron content in root varied from 10 in Pokkali soils from Kottuvalli (AEU 5, sample No.18) and 620 ppm in Onattukara sandy soils (AEU 3 , sample No.5).

4.3.1.8. Total manganese

The total manganese in shoot varied 4.7 to 220 ppm. The lowest value was observed in Chittor taluk of Palakkad (AEU 23, sample No. 14) and the highest in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.9).The total Mn in root varied from 0.0001 in Pokkali soils from RRS, Vytilla (AEU 5 , sample No.16) and 0.012 percent in Manalurthazhum (AEU 6, sample No.21).

4.3.1.9. Total copper

The total copper in shoot varied 1.4 to 20 ppm. The lowest value was observed in wetland lateritic soils of Palakkad (Pattambi) (AEU 10, sample No.11) and the highest total copper in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No. 7). The percent total Cu in root varied from 0.9 in Onattukkara sandy soils from Chettikulangara (AEU 3, sample No.5) and 10 ppm in Kutanad soils from CKN Block, Vechoor (AEU 4, sample No.2).

Table No. 24. Nutrient content in rice during active tillering stage

Location	Tot Fe (ppm)		Tot Mn (ppm)		Tot Cu (ppm)		Tot Zn (ppm)		Tot B (ppm)	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
1	1030.00	43.00	216.00	27.00	19.80	6.70	21.00	10.00	95.45	104
2	860.00	39.00	106.00	19.00	15.20	10.00	30.00	6.10	98.00	166.00
3	250.00	20.00	77.00	21.00	5.70	3.20	9.00	5.30	32.72	110.00
4	1160.00	16.00	200.00	16.00	20.00	1.40	28.00	7.10	85.97	169.00
5	1010.00	21.00	95.00	2.00	15.00	0.90	26.00	9.50	94.94	20.88
6	1110.00	620.00	87.00	23.00	14.00	2.10	26.00	3.50	74.89	201.46
7	1290.00	31.00	160.00	29.00	22.00	2.50	33.00	8.00	170.79	15.66
8	930.00	22.00	350.00	28.00	14.00	2.10	39.00	6.10	92.33	323.32
9	1800.00	14.00	220.00	30.00	20.00	4.40	33.00	8.30	85.66	167.37
10	960.00	14.00	107.00	27.00	13.00	1.50	19.00	2.80	71.77	127.56
11	151.00	89.00	107.00	32.00	1.40	1.00	5.10	2.30	30.67	170.31
12	960.00	48.00	104.00	67.00	16.00	1.50	5.60	4.30	71.45	220.55
13	180.00	12.00	168.00	66.00	6.50	4.50	6.10	5.40	32.13	172.43
14	250.00	20.00	47.00	27.00	5.60	5.40	7.30	6.70	14.84	114.90
15	1130.00	22.00	200.00	5.50	15.00	1.80	18.00	4.00	100.97	12.88
16	1010.00	54.00	45.00	1.00	10.00	6.70	38.00	12.00	64.27	32.34
17	860.00	14.00	130.00	1.10	17.00	2.00	40.00	1.00	61.99	16.31
18	1160.00	10.00	130.00	1.90	18.00	2.60	32.00	1.70	70.14	19.73
19	890.00	32.00	67.00	41.00	17.00	6.90	2.80	2.00	78.89	384.00
20	1120.00	38.00	210.00	100.00	16.00	6.70	45.00	8.00	90.56	440.00
21	880.00	39.00	199.00	120.00	13.0	3.50	25.00	7.10	83.84	527.24

4.3.1.10. Total zinc

The total zinc in shoot varied 2.8 to 45 ppm. The lowest value was observed Vengidangu (AEU 6, sample No. 19) and the highest in Ponnamotha (AEU 6, sample No.20).The total Zn in root varied from 1 in Pokkali soils fromKottuvalli (AEU 5 , sample No.17) and 12 ppm in Pokkali soils from RRS, Vytilla (AEU 6, sample No. 16).

4.3.1.11. Total boron

The total boron in shoot varied 1.48 to 17.07 ppm. The lowest value was observed in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 14) and the highest total B in rice soils from Palakkad (AEU 22, sample 7).The total B content in root varied from 1.28 ppm in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 15) to 52.72 ppm in soils from Manalurthazhum (AEU 6, sample No. 21)

4.3.2. Visual panicle initiation stage

4.3.2.1. Total nitrogen

The total nitrogen in shoot varied 0.64 to 2.81 percent. The lowest value was observed in Kuttanad soils of Poovathikkari (AEU 4, sample No.1)and the highest percent total nitrogen in Onattukkara sandy soils from Chettikulangara (AEU 3, sample No.6).The percent total nitrogen in root varied from 0.54 in Kuttanad soils of Poovathikkari (AEU 4, sample No.1)and 1.58 percent in soils from Pattambi (AEU 10, sample No.11) and Kozhinjampara (AEU 23 sample No. 14). Percent total nitrogen in panicle portion ranged from 0.94 percent in Pokkali soils from Kottuvalli (AEU 5, sample No.18) to 1.45 percent in soils from Karumadi(AEU 4, sample No. 3).

4.3.2.2. Total phosphorus

The total phosphorus in shoot varied from 0.078 to 0.27 percent. The lowest value was observed in soils from Karumadi(AEU 4, sample No. 3) and the highest percent total phosphorus in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.5).The percent total phosphorus in root varied from 0.0019 in Black soils of

Chittor taluk of Palakkad(AEU 23, sample No. 14) and 0.14 percent in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.5). Total P in panicle ranged from 0.003 percent in rice soils of Palakkad(Vadakkenchey)(AEU 22, sample No.8) to 0.18 in soils from Karumadi(AEU 4, sample No. 3).

4.3.2.3. Total potassium

The total potassium in shoot varied 0.068 to 0.89 percent. The lowest value was observed in Black soils of Chittor taluk of Palakkad(AEU 23, sample No. 13)and the highest percent total K in Black soils of Chittor taluk of Palakkad(AEU 23, sample No. 14).The percent total K in root varied from 0.00015 in Pokkali soils fromKottuvalli (AEU 5 , sample No.17) and 0.32 percent in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.5). Total potassium in panicle was found to range from 0.001 in soils from Chettikulangara (AEU 3, sample No.6) and rice soils of Palakkad(Vadakkenchey)(AEU 22, sample No.7) to 0.48 percent in wetland lateritic soils of Palakkad(Pattambi)(AEU 10, sample No.12).

4.3.2.4. Total calcium

The total calcium in shoot varied 0.077 to 0.132 percent. The lowest value was observed in Pokkali soils from Kottuvalli (AEU 4, sample No.18) and the highest in Kuttanad soils from Poovathikkari (AEU 4, sample No.1) and in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 15). The total Ca in root varied from 0.010 in Onattukara sandy soils (sample No. 5) to 0.087 percent in Onattukara (AEU 3, sample No.4). Total Ca in panicle ranged from 0.043 in Pokkali soils from Kottuvalli (AEU 5, sample No. 18) to 0.54 in Onattukara (sample No. 5)

Table No. 25. Nutrient content in rice during visual panicle initiation stage

Location	Tot N (%)			Tot P (%)			Tot K (%)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
1	0.64	0.54	1.09	0.23	0.061	0.046	0.84	0.16	0.13
2	0.96	0.68	1.17	0.167	0.118	0.064	0.77	0.23	0.16
3	2.02	1.1	1.45	0.078	0.036	0.182	0.41	0.088	0.42
4	2.58	1.09	1.18	0.16	0.017	0.021	0.74	0.3	0.098
5	1.83	1.23	1.14	0.27	0.141	0.0305	0.85	0.32	0.39
6	2.81	1.17	1.12	0.2	0.027	0.065	0.19	0.087	0.001
7	1.06	1.04	0.97	0.21	0.0595	0.0215	0.73	0.108	0.001
8	1.58	1.23	1.02	0.21	0.064	0.003	0.83	0.241	0.36
9	1.18	1.02	0.96	0.12	0.062	0.06	0.71	0.095	0.132
10	1.23	1.08	1.04	0.18	0.005	0.028	0.69	0.056	0.231

Table No. 25. Nutrient content in rice during visual panicle initiation stage

Location	Tot N (%)			Tot P (%)			Tot K (%)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
11	2.28	1.58	1.1	0.13	0.044	0.0205	0.63	0.087	0.123
12	2.12	1.56	1.15	0.126	0.065	0.067	0.65	0.17	0.48
13	2.07	1.22	1.2	0.16	0.0035	0.012	0.068	0.002	0.085
14	2.62	1.58	1.6	0.098	0.0019	0.176	0.89	0.089	0.292
15	1.52	1.2	1.35	0.17	0.042	0.0075	0.79	0.17	0.23
16	0.89	0.59	1.05	0.102	0.0365	0.018	0.45	0.028	0.071
17	1.82	1.21	0.98	0.096	0.0055	0.009	0.44	0.00015	0.056
18	0.88	0.68	0.94	0.12	0.002	0.025	0.44	0.006	0.087
19	2.56	1	1.39	0.13	0.091	0.1	0.46	0.087	0.092
20	2.62	1.05	1.08	0.12	0.087	0.098	0.48	0.13	0.19
21	2.65	0.95	1.1	0.162	0.106	0.101	0.6	0.3	0.35

4.3.2.5. Total magnesium

The total magnesium in shoot varied 0.0089 to 0.0145 percent. The lowest value was observed in Black soils of Chittor taluk of Palakkad(AEU 23, sample No. 13)and the highest percent total Mg in Ponnamotha(AEU 6, sample No. 20).The percent total Mg in root varied from 0.0011 in rice soils of Palakkad(Vadakkenchey)(AEU 22, sample No.8) and 0.0137 percent in Ponnamotha(AEU 6, sample No. 20). The total Mg content in panicle ranged from 0.0012 in Onattukkara sandy soils from Chettikulangara (AEU 3, sample No.6) and 0.0128 in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 14)

4.3.2.6. Total sulphur

The total sulphur in shoot varied 0.042 to 0.23 percent. The lowest value was observed in soils from Karumadi(AEU 4, sample No.3) and highest value in Black soils of Chittor taluk of Palakkad(AEU 23, sample No. 15).The percent total S in root varied from 0.0094 in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.8) and 0.087 percent in soils from Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.5). Total sulphur in panicle ranged from 0.020 in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.8) and 0.115 in Manalurthazhum (AEU 6, sample No.21)

4.3.2.7. Total boron

The total boron in shoot varied 38.82 to 107.99 ppm. The lowest value was observed in soils from Karumadi(AEU 4, sample No.3) and highest value in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.5).The percent total B in root varied from 28.30 ppm in Onattukkara sandy soils from Chettikulangara(AEU 3, sample No.6)and 319 ppm in wetland lateritic soils from Palakkad(Pattambi)(AEU 10, sample No.11). Total boron in panicle ranged from 14.51 in rice soils of Palakkad (Vadakkenchery) (AEU 22, sample No.7) and 98.69 ppm in wetland lateritic soils from Palakkad(Pattambi)(AEU 10, sample No.1

4.3.2.8. Total iron

The total iron in shoot varied 250 to 3415 ppm. The lowest value was observed in Karumadi (AEU 4, sample No.3) and the highest total iron in Pokkali soils from Kottuvalli(AEU 5 , sample No.18). The total iron content in root varied from 21 in Black soils of Chittor taluk of Palakkad (AEU 23, sample No. 13) and 2900 ppm in Manalurthazhum (AEU 6, sample No.21). The total Fe content in panicle ranged from 21 in Pokkali soils from Kottuvalli (AEU 5, sample No.17) and 826 ppm in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.9).

4.3.2.9. Total manganese

The total manganese in shoot varied 28 to 419 ppm. The lowest value was observed in Pokkali soils from RRS, Vytilla (AEU 5 , sample No.16) and the highest percent total manganese in rice soils of Palakkad (Vadakkenchey) (AEU 22, sample No.7).The percent total Mn in root varied from 1.3 in Pokkali soils from Kottuvalli (AEU 5, sample No.17) and 84 ppm in Karumadi(AEU 4, sample No.3).The manganese content in panicle ranged from 2.5 in wetland lateritic soils of Palakkad (Pattambi)(AEU 10, sample No.10) to 34 ppm in soils from Karumadi (AEU 4, sample No.3).

4.3.2.10. Total copper

The total copper in shoot varied 5.7 to 26.5 ppm. The lowest value was observed in soils from Karumadi (AEU 4, sample No.3) and the highest total copper in Onattukara sandy soils from Chettikulangara (AEU 3, sample No.5). The percent total Cu in root varied from 0.1 in rice soils of Palakkad (Vadakkenchey)(AEU 22, sample No.7) and in soils from Pokkali (AEU 5, sample Nos. 16 and 17) and 16 ppm in Manalurthazhum (AEU 6, sample No.21). Total copper in panicle was found to range from 0.11 in Pokkali soils from Kottuvalli (AEU 5 , sample No.17) and 17.2 ppm in soils from Karumadi(AEU 4, sample No.3)

Table No. 26. Nutrient content in rice during visual panicle initiation

Location	Tot Ca (%)			Tot Mg (%)			Tot S (%)			Tot B (mg kg $^{-1}$)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
1	0.132	0.058	0.21	0.0123	0.01263	0.0127	0.188	0.048	0.0335	10.78	10.4	2.61
2	0.106	0.067	0.27	0.0126	0.01277	0.0127	0.13	0.0609	0.0373	10.5	16.6	2.87
3	0.13	0.026	0.069	0.0127	0.0115	0.0125	0.042	0.0348	0.0874	3.88	1.26	7.83
4	0.122	0.087	0.21	0.0125	0.0123	0.0016	0.161	0.0288	0.111	8.9	7.9	6.9
5	0.12	0.01	0.54	0.0128	0.0128	0.0126	0.189	0.0877	0.0315	10.79	10.97	4.24
6	0.112	0.067	0.45	0.0124	0.0126	0.0012	0.154	0.0282	0.0238	9.3	2.83	1.84
7	0.119	0.067	0.2	0.0128	0.0117	0.0046	0.173	0.0371	0.0224	7.43	20.5	1.45
8	0.094	0.034	0.25	0.0123	0.0011	0.0355	0.18	0.0094	0.0209	8.89	12.08	2.15
9	0.121	0.018	0.2	0.0129	0.0123	0.0127	0.143	0.0335	0.0371	10.66	15.6	2.51
10	0.121	0.023	0.32	0.0128	0.0111	0.0076	0.145	0.0293	0.0522	9.28	21.9	9.86

Table No. 26. Nutrient content in rice during visual panicle initiation

Location	Tot Ca (%)			Tot Mg (%)			Tot S (%)			Tot B (mg kg $^{-1}$)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
11	0.109	0.086	0.26	0.013	0.0124	0.015	0.12	0.038	0.0318	9.67	31.9	3.44
12	0.105	0.065	0.35	0.0126	0.0126	0.016	0.11	0.0468	0.0648	8.72	13.86	2.35
13	0.105	0.062	0.3	0.0089	0.00369	0.00567	0.14	0.021	0.022	9.45	11.6	1.94
14	0.123	0.075	0.36	0.0134	0.0089	0.01288	0.18	0.059	0.073	9.34	8.6	5.62
15	0.132	0.023	0.38	0.0128	0.0125	0.0029	0.231	0.0541	0.0212	9.1	10.75	0.88
16	0.103	0.058	0.28	0.0128	0.0078	0.011	0.124	0.0242	0.0294	6.42	3.99	1.85
17	0.108	0.06	0.31	0.0127	0.0056	0.007	0.139	0.0212	0.0215	8.15	3.14	1.63
18	0.077	0.034	0.043	0.0126	0.0035	0.0125	0.142	0.0219	0.029	4.45	14.6	2.2.5
19	0.100	0.034	0.35	0.0132	0.0123	0.012	0.12	0.0609	0.037	6.88	11.0	4.5
20	0.092	0.046	0.25	0.0145	0.0137	0.012	0.112	0.0807	0.087	9.23	27.5	6.5
21	0.131	0.068	0.27	0.0128	0.0127	0.0123	0.104	0.106	0.115	9.78	28.54	6.11

4.3.2.11. Total zinc

The total zinc in shoot varied 9 to 49 ppm. The lowest value was observed in Karumadi (AEU 4, sample No.3) and the highest total Zn in Pokkali soils from RRS, Vytilla(AEU 6, sample No. 16) .The total Zn in root varied from 2 in Pokkali soils from Kottuvalli (AEU 5 , sample No.17) and 37 ppm in Manalurthazhum (AEU 21, sample No.21). The total zinc in panicle ranged from 0.7 in Pokkali soils from Kottuvalli (AEU 5, sample No.17) and 21 ppm in Vengidangu (AEU 6, sample No. 19).

Table No. 27.Micronutrient content in rice during visual panicle initiation stage

Location	Tot Fe (ppm)			Tot Mn (ppm)			Tot Cu (ppm)			Tot Zn (ppm)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
1	1030	1630	102	216	19	10.6	19.0	6.7	3.6	21	10	7.4
2	860	2250	137	106	27	10.5	15.0	10.6	5.4	21	6.1	9.3
3	250	1660	731	77	84	34.8	5.7	7.9	17.2	9	5.3	14.4
4	840	210	140	208	28	8.9	15.0	1.4	0.3	29	18.8	1.5
5	1220	520	523	198	24	2.7	26.5	12.4	3.2	47	11.3	5.2
6	940	870	44	210	30	8.5	14.5	2.7	0.6	27	6.3	1.2
7	1120	1920	31	419	40	4.3	22.0	0.1	1.7	39	6.5	1.1
8	1030	1340	50	136	46	2.6	24.0	0.2	0.33	30	5.8	3.6
9	898	1620	826	149	10.6	16.9	15.4	4.9	4.46	22	3.3	5.8
10	1245	1960	366	164	43	2.5	15.3	0.8	0.42	17	2.3	8.6

Table No. 27. Micronutrient content in rice during visual panicle initiation stage

Location	Tot Fe (ppm)			Tot Mn (ppm)			Tot Cu (ppm)			Tot Zn (ppm)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
11	1000	2116	218	210	56	6.7	12.6	0.6	0.58	18	14.6	16.2
12	1027	1752	31	171	49	2.9	12.7	8.2	0.6	17	7.4	12.3
13	340	21.1	268.6	140	21.1	33	20.0	0.2	0.22	16	2.6	0.2
14	780	560	341	120	21	25.4	19.0	0.4	12.3	15	2.7	9.3
15	948	933	15	177	47.1	8	20.18	0.3	0.17	22	4.4	5.9
16	745	350	136	28.8	22	6.5	10.4	0.1	6.04	49	12.9	14.7
17	609	22.8	21.2	144	1.3	2.9	12.3	0.1	0.11	14	2	0.7
18	3415	85.7	55	10	10	4.4	23.2	0.03	0.22	4	5.4	6.6
19	3200	670	54	150	30	5.6	13.0	0.35	0.45	18	33.3	21.3
20	1200	567	210	120	23	4.3	13.5	0.32	0.48	24	36.5	19.8
21	691	2900	1360	94	70	30	15.2	16.0	13.0	23	37.6	24.7

4.3.3. Mean values of nutrient status in rice based on agroecological unit basis

4.3.3.1. Active tillering stage

The total carbon content varied between 34.22 at Palakkad central plains (AEU 22) to 39.92 percent in Onattukara (AEU 3) in shoot. While the values in root ranged from 23.65 in Kole lands to 39.57 percent in Black soils. The total nitrogen content in shoot at active tillering stage was lowest in Kuttanad (0.98 %) and highest (2.38 %) in north central laterites (AEU 10). In root the total nitrogen content varied from 0.78 in Kuttanad to 1.49 % at Pattambi. However, the soils from Palakkad recorded the lowest mean total nitrogen at active tillering stage and highest total nitrogen was recorded in Kuttanad. The phosphorus content at active tillering stage was lowest in lateritic soil in shoot (0.094 %) and the highest in Onattukara and Pokkali (0.17 %). In root it ranged from 0.019 in Pokkali to 0.091 % in Kole lands. The total potassium content in shoot varied from 0.48 % in Palakkad eastern plains to 0.87 % in Kole lands. While in root it ranged from 0.040 in Pokkali to 0.25 % in Palakkad eastern plains. The total Ca content in shoot was found to vary from 0.098 in Palakkad central plains to 0.18 percent in Palakkad eastern plains. While in root the lowest Ca content was observed in 0.039 in Onattukara and highest of 0.16 % in Kuttanad. The mean total magnesium content in shoot was 0.012 % in all the agroecological units. While in root it was lowest (0.005 %) in Onattukara and north central laterites and highest (0.012 %) in Palakkad eastern plains. The total sulphur content in shoot ranged from 0.012 in Palakkad eastern plains to 0.15 % in Palakkad central plains and Pokkali lands. While in root the lowest total S (0.022 %) was observed in Pokkali and highest of 0.074 % in Kole lands.The total iron in shoot varied from 520 ppm in Chittor to 1300 ppm in Palakkad central plains. While in root the Fe content ranged from 18 ppm in Palakkad eastern plains to 210 ppm in Onattukara. The total Mn content in shoot ranged from 100 ppm in north central laterites to 240 ppm in Palakkad central plains. While in the root the lowest value of 12 ppm was found in Kuttanad and highest of 87 ppm in Kole lands. The total Cu content in shoot ranged from 9 in Chittor to 18 ppm in Palakkad plains. While in root it varied from 1.3 in Pattambi to 6.6 ppm in Kuttanad region. The total Zn in shoot was highest (36 ppm) in Pokkali and lowest (9 ppm) in north central laterites (AEU 10). While in root the lowest value (3.1 ppm) was observed in Pattambi and the highest value of 7.4 ppm in Palakkad central plains. The shoot boron ranged from 4.9 ppm in Chittor to 11.6 ppm in Palakkad central plains. While in root the lowest value of 2.27 ppm was observed in Pokkali and highest of 17.28 ppm in north central laterites (AEU 10).

Table No. 28. Nutrient status in plant on agro-ecological unit basis during active tillering stage

AEU	Parameters											
	Tot N		Tot P		Tot K		Tot Ca		Tot Mg		Tot S	
	%											
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Kuttanad	0.98	0.78	0.16	0.08	0.65	0.21	0.2	0.16	0.012	0.011	0.11	0.047
Onattukkara sandy plains	1.38	0.86	0.17	0.051	0.63	0.086	0.1	0.039	0.012	0.005	0.102	0.026
Palakkad central plains	1.47	0.95	0.2	0.056	0.77	0.11	0.098	0.053	0.012	0.009	0.156	0.038
North central laterites	2.38	1.49	0.094	0.031	0.68	0.21	0.14	0.049	0.012	0.005	0.11	0.057
Palakkad eastern plains	2.07	1.18	0.12	0.03	0.48	0.25	0.18	0.047	0.012	0.012	0.012	0.073

Table No. 28. Nutrient status in plant on agro-ecological unit basis during active tillering stage

AEU	Parameters											
	Tot N		Tot P		Tot K		Tot Ca		Tot Mg		Tot S	
	%											
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Pokkali lands	1.55	1.23	0.17	0.019	0.78	0.04	0.11	0.057	0.012	0.0088	0.15	0.022
Kolelands	1.74	1	0.16	0.091	0.87	0.27	0.11	0.063	0.012	0.011	0.14	0.074

Table No. 29.Nutrient status in plant on agro-ecological unit basis during active tillering stage

AEU	Parameter(ppm)									
	Tot Fe		Tot Mn		Tot Cu		Tot Zn		Tot B	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Kuttanad	710	34	130	22	13	66	20	7.1	7.53	12.66
Onattukkara sandy plains	1000	210	120	13	16	14	26	6.7	8.52	13.04
Palakkad central plains	1300	22	240	29	18	30	35	7.4	11.62	16.87
North central laterites	690	50	100	42	10	13	9	3.1	5.79	17.28
Palakkad eastern plains	520	18	130	32	9	39	10	5.3	4.93	10.00
Pokkali lands	1010	26	100	1.3	15	37	36	4.9	6.54	2.27
Kole lands	960	36	158	87	15.3	57	24	5.7	8.44	45.04

4.3.3.2. Visual panicle initiation

Mean total carbon in shoot ranged from 33.07 % in Kuttanad to 41.88 % in Onattukara sandy soils. While in root it ranged from 22.42 % in Kole lands to 40.13 % in Palakkad eastern plains. In panicle, the lowest total carbon (38.24 %) was found in north central laterites and highest of 40.78 in Kole lands. The total nitrogen in shoot was found to range from 1.19 % in Pokkali to 2.61 % in Kole lands. In root it was lowest (0.77 %) in Kuttanad and highest in Pattambi (1.40 %). In panicle the lowest nitrogen (0.98 %) was found in Palakkad central plains and highest (1.38 %) in Chittor. In shoot the total P ranged from 0.10 in Pokkali to 0.21 % in Onattukara sandy plains. While in root the lowest P content (0.014 %) was recorded in Pokkali and the highest of 0.094 % in Kole lands. Same trend was observed in panicle also. The shoot K content varied from 0.44 % in Pokkali to 0.75 % in Palakkad central plains. While in root it ranged from 0.011 % in Pokkali to 0.23 % in Onattukara. In panicle the total K was lowest (0.07 %) in Pokkali and highest (0.27 %) in Pattambi. The shoot Ca content was found to range from 0.096 % in Pokkali to 0.12 % in Kuttanad and Palakkad eastern plains. In root it was highest (0.058 %) in north central laterite and lowest (0.039 %) in Palakkad central plains. While in panicle Ca varied from 0.18 in Kuttanad to 0.34 % in Chittor. Lowest shoot Mg content (0.011 %) was recorded in Palakkad eastern plains (AEU 23) and highest (0.013 %) in Kole lands (AEU 6). While in root it ranged from 0.0056 % in Pokkali to 0.012 % in Kuttanad, Onattukara and Kole lands. In panicle, the lowest Mg content (0.0051 %) was recorded in Onattukara and the highest (0.017 %) in Palakkad central plains. The total S content in shoot ranged from 0.11 % in Kole lands to 0.18 % in Palakkad eastern plains. In root it was lowest (0.022 %) in Pokkali and highest (0.082 %) in Kole lands. In panicle S content varied from 0.026 in Pokkali and Palakkad central plains to 0.079 % in Kole lands. Lowest shoot B (6.3 ppm) was recorded in Pokkali and highest (9.6 ppm) in Onattukara sandy plains. In root the lowest B content (7.23 ppm) was observed in Onattukkara and highest (22.55 ppm) in north central laterites

Table No. 30. Nutrient status in rice on agro ecological unit basis during visual panicle initiation stage

AEU	Total N (%)			Tot P (%)			Tot K (%)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
Kuttanad	1.20	0.77	1.23	0.15	0.071	0.097	0.67	0.150	0.230
Onattukkara	2.40	1.16	1.14	0.21	0.061	0.038	0.59	0.230	0.160
Vadakkenchery	1.27	1.09	0.98	0.18	0.061	0.028	0.75	0.140	0.160
Pattambi	1.87	1.40	1.09	0.14	0.038	0.038	0.65	0.100	0.270
Chittoor	2.07	1.33	1.38	0.14	0.015	0.065	0.58	0.087	0.200
Pokkali	1.19	0.82	0.99	0.10	0.014	0.017	0.44	0.011	0.071
Kolelands	2.61	1.00	1.19	0.13	0.094	0.099	0.51	0.170	0.210

Table No. 31. Nutrient status in rice on agroecological unit basis during visual panicle initiation stage

AEU	Parameter (ppm)											
	Tot Ca (%)			Tot Mg (%)			Tot S (%)			Tot B(ppm)		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
Kuttanad	0.12	0.050	0.18	0.012	0.012	0.012	0.12	0.047	0.052	8.38	13.2	4.43
Onattukkara	0.11	0.054	0.4	0.0125	0.012	0.0051	0.16	0.048	0.055	9.66	7.23	4.32
Vadakkenchery	0.11	0.039	0.21	0.0126	0.0083	0.017	0.16	0.026	0.026	8.99	16.06	2.03
Pattambi	0.11	0.058	0.31	0.0128	0.0120	0.0128	0.125	0.038	0.049	9.22	22.55	5.22
Chittoor	0.12	0.053	0.34	0.011	0.0083	0.0071	0.18	0.044	0.038	9.29	10.31	2.81
Pokkali	0.096	0.050	0.21	0.012	0.0056	0.010	0.13	0.022	0.026	6.34	7.27	1.91
Kole lands	0.10	0.049	0.29	0.013	0.012	0.012	0.11	0.082	0.079	8.63	22.34	5.70

In panicle boron content ranged from 1.9 ppm in Pokkali to 5.7 ppm in Kole lands. The shoot Fe content ranged from 680 ppm in Palakkad eastern plains to 1600 ppm in Kole lands. In root it varied from 150 ppm in Pokkali to 1940 in north central laterites. In panicle the lowest value was observed in Pokkali and highest of 540 ppm in Kole lands. The lowest Mn content (60 ppm) was recorded in Pokkali and highest of 230 ppm in Palakkad central plains. In root it varied between 11 in Pokkali to 49 ppm in north central laterites. In panicle, the lowest value of 4 ppm was recorded in north central laterites and highest value of 22 ppm in Palakkad eastern plains. The total copper in shoot ranged from 13.2 ppm in Kuttanad to 20.4 ppm in Palakkad central plains. In root it was 1.7 ppm in Palakkad central plains the highest value of 8.4 ppm in Kuttanad. In panicle it ranged from 1.3 ppm in Onattukara to 8.7 ppm in Kuttanad. The total Zn in shoot ranged from 17 to 34 ppm. While in root it ranged from 3.2 ppm in Palakkad eastern plains to 35 ppm in Kole lands. In panicle it varied between 2.6 ppm in Onattukara to 21 ppm in Kole lands.

Table No. 32. Nutrient status in rice on agro-ecological unit basis during visual panicle initiation

AEU	Parameter(ppm)											
	Tot Fe			Tot Mn			Tot Cu			Tot Zn		
	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle	Shoot	Root	Panicle
Kuttanad	710	1800	320	130	43	18	13.2	8.4	8.7	1.7	0.71	1.0
Onattukkara	1000	530	230	200	27	6.7	18.0	5.5	1.3	3.4	1.2	0.26
Vadakkenchery	1000	1600	300	230	32	7.9	20.4	1.7	2.1	3.0	0.52	0.35
Pattambi	1090	1940	200	181	49	4	13.5	3.2	0.53	1.7	0.81	1.2
Chittoor	680	500	208	140	29	22	19.0	0.3	4.2	1.7	0.32	0.51
Pokkali	1500	150	70	60	11	4.6	15.3	0.23	2.1	2.2	0.67	0.73
Kolelands	1600	1300	540	121	41	13	13.9	5.5	4.6	2.1	3.5	2.1

4.4.1. Dry analysis

The correlation coefficients between electrochemical properties and nutrient status in soils of 7 AEU's of Kerala in case of dry analysis are given in the table No. 33

The pH had significant negative correlation with EC (-0.31*), organic carbon (-0.36**) and available S (-0.37**). Organic carbon (0.52**), available N (0.42**), K (0.61**), Mg (0.26*), S (0.75**), Fe (0.42**), Cu (0.27*) and B (0.65**) had significant positive correlations with EC. Organic carbon had significant positive correlations with available N (0.62**), K (0.27*) S (0.44**) and Fe (0.35**). In case of available N, significant positive correlations was obtained with available K (0.28*), S (0.44**), Fe (0.51**) and B (0.38**). Available P showed significant positive correlations with available K (0.35**) and B (0.29*) and significant negative correlations with Ca (-0.25*) and Cu (-0.30*) respectively. Available Mg (0.40**), S (0.49**), Fe (0.40*), Mn (0.36**), Zn (0.43**) and B (0.61**) had significant positive correlations with available K. Available Ca had significant positive correlations with available Mg (0.44**) and Zn (0.25*). Significant negative correlations was obtained by available Ca with available B (-0.38**). Available Mg had significant positive correlation with available S (0.33**) and Mn (0.25*). Available S showed significant positive correlation with available Fe (0.39**) and B (0.40**) and significant negative correlation with available Cu (-0.26*). Available Fe had significant positive correlation with available Mn (0.37**) and B (0.37**). Available Cu had significant positive correlation with Zn (0.27*).

Table No. 33. Correlations between different soil parameters and nutrient contents in soils of 7 AEU's in case of dry analysis

	pH	EC	OC	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
pH	1													
EC	-.319*	1												
OC	-.366**	.525**	1											
N	-.221	.429**	.623**	1										
P	.169	.199	-.174	-.006	1									
K	-.011	.614**	.271*	.280*	.356**	1								
Ca	.171	-.199	.099	-.032	-.254*	.088	1							
Mg	.068	.269*	.204	.111	.059	.408**	.443**	1						
S	-.377**	.750**	.441**	.444**	.109	.491**	-.065	.334**	1					
Fe	-.232	.425**	.350**	.517**	-.146	.401**	.031	.231	.393**	1				
Mn	.021	.119	.080	.105	-.028	.362**	.165	.257*	.247	.371**	1			
Cu	.176	.270*	-.101	-.059	-.306*	-.035	.136	.060	-.262*	.006	.131	1		
Zn	-.035	.088	.055	.049	-.075	.431**	.259*	.179	.161	.233	.554	.272*	1	
B	-.073	.650**	.215	.384**	.299*	.618**	-.388**	.096	.406**	.378**	.140	-.046	.123	1

4.4.2. Wet analysis

The correlation coefficients between electrochemical properties and nutrient status in soils of 7 AEU's of Kerala in case of wet analysis are given in the table No. 34

The pH had significant positive correlation with available Ca (0.35**) and significant negative correlation with available S (-0.28*). Organic carbon (0.30*), available N (0.47**), K (0.47**),S (0.84**), Mn (0.25*), Zn (0.28*) and B (0.44**) had significant positive correlations with EC. EC had significant negative correlations with Cu (-0.28*). Organic carbon had significant positive correlations with available N (0.69**), Ca (0.43**), Mg (0.61**), Fe (0.56**) and B (0.47**). In case of available N, significant positive correlations was obtained with available S (0.36**) and B (0.46**). Available P showed significant positive and negative correlations with available K (0.36**) and Cu (-0.31*) respectively. Available Mg (0.45**), S (0.41**), Fe (0.32**) and Mn (0.31*) had significant positive correlations with available K. Available Ca had significant positive correlations with available Mg (0.73**), Fe (0.64**) and Cu (0.33**). Available Mg had significant positive correlation with available Fe (0.89**) and B (0.38**). Available S showed significant positive correlation with available Zn (0.26*) and B (0.40**) and significant negative correlation with available Cu (0.26*). Available Fe had significant positive correlation with available B (0.29*). Available Mn had significant positive correlation with Zn (0.51**).

Table No. 34. Correlations between different soil parameter and nutrient contents in soils of 7 AEU's of Kerala in case of wet analysis

	pH	EC	OC	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
pH	1													
EC	-0.123	1												
OC	-0.225	0.306*	1											
N	-0.238	0.472**	0.698**	1										
P	-0.010	0.144	-0.155	-0.232	1									
K	0.165	0.479**	0.245	0.102	0.369**	1								
Ca	0.353**	-0.043	0.437**	0.074	-0.155	0.228	1							
Mg	0.079	0.132	0.615**	0.119	0.121	0.450**	0.731**	1						
S	-0.282*	0.847**	0.199	0.362**	0.086	0.415**	-0.144	0.070	1					
Fe	0.002	-0.004	0.568**	0.057	0.075	0.327**	0.645**	0.890**	0.002	1				
Mn	0.200	0.254*	-0.016	0.022	0.064	0.311*	0.114	0.140	0.244	0.098	1			
Cu	0.225	-0.285*	0.003	0.001	-0.314*	-0.138	0.332**	0.209	-0.261*	0.222	0.006	1		
Zn	-0.056	0.283*	-0.005	0.119	-0.050	0.236	0.209	0.119	0.266*	0.095	0.519**	.21	1	
B	-0.209	0.443**	0.473**	0.466**	0.102	0.391**	0.177	0.389**	0.407**	0.296*	0.084	-0.043	0.083	1

4.5. Correlation between carbon nitrogen status (C:N ratios) and total N and available N in soil during active tillering

4.5.1. Dry analysis

Correlation coefficients between carbon nitrogen status (C:N ratios) and total N and available N in soil during active tillering in case of dry analysis are presented in table No. 28.Significant positive correlations was obtained between $(C:N)_1$ with total (0.68*)and available nitrogen (0.69*), $(C:N)_2$ with total (0.95*) and available nitrogen (0.58*), $(C:N)_3$ with total (0.44*) and available nitrogen (0.48*) and $(C:N)_4$ with total nitrogen(0.58*) in soil. (Table No. 35)

Table No. 35. Correlation coefficients between carbon nitrogen status (C: N ratios) and total and available N in soil during active tillering stage in case of dry analysis

Carbon nitrogen status	Correlation coefficients	
	Total N	Available N
(C:N)1	0.68*	0.69*
(C:N)2	0.95*	0.58*
(C:N)3	0.44*	0.48*
(C:N)4	0.58*	0.32

4.5.2. Wet analysis

Correlation coefficients between carbon nitrogen status (C: N ratios) and total N and available N in soil during active tillering in case of wet analysis are presented in table No. 29. Significant positive correlations was obtained between $(C:N)_1$ with total (0.40*) and available nitrogen (0.57*), $(C:N)_2$ with total nitrogen (0.42*) and $(C:N)_3$ with total (0.46*)and available nitrogen (0.60*).(Table No.36)

Table No. 36. Correlation coefficients between carbon nitrogen status (C: N ratios) and total and available N in soil during active tillering stage in case of wet analysis.

Carbon nitrogen status	**Correlation coefficients**	
	Total N	Available N
(C:N)1	0.40*	0.57*
(C:N)2	0.42*	0.33
(C:N)3	0.46*	0.60*
(C:N)4	0.057	0.011

4.6. Correlation between carbon nitrogen status (C: N ratios) and total N and available N in soil during visual panicle initiation

4.6.1. Dry analysis

Correlation coefficients between carbon nitrogen status (C: N ratios) and total N and available N in soil during visual panicle initiation in case of dry analysis are presented in table No. 30. Significant positive correlations was obtained between $(C: N)_1$ with total(0.66*) and available nitrogen (0.71*), $(C:N)_2$ with total (0.86*) and available nitrogen (0.69*) and $(C:N)_4$ with total (0.52*) and available nitrogen (0.41*) in soil.(Table No.37)

Table No. 37.Correlation coefficients between carbon nitrogen status (C: N ratios) and total and available N in soil during visual panicle initiation stage in case of dry analysis

Carbon nitrogen status	Correlation coefficients	
	Total N	Available N
(C:N)1	0.66*	0.71*
(C:N)2	0.86*	0.69*
(C:N)3	0.042	0.18
(C:N)4	0.52*	0.41*

4.6.2. Wet analysis

Correlation coefficients between carbon nitrogen status (C: N ratios) and total N and available N in soil during visual panicle initiation in case of wet analysis are presented in table No. 31. Significant positive correlations was obtained between $(C:N)_1$ with total nitrogen (0.48*), $(C:N)_2$ with total nitrogen (0.89*) and $(C:N)_4$ with total nitrogen (0.87*) in soil.(Table No.38).

Table No. 38. Correlation coefficients between carbon nitrogen status (C: N ratios) and total and available N in soil during visual panicle initiation stage in case of wet analysis

Carbon nitrogen status	Correlation coefficients	
	Total N	Available N
(C:N)1	0.48*	0.33
(C:N)2	0.89*	0.28
(C:N)3	0.27	0.25
(C:N)4	0.87*	0.26

4.7. Spearman's ranked correlation between various soil parameters and plant N content

As extreme variation was noticed within each parameter computation of correlation based on exact values gave spurious correlation. The value of a soil parameter at a particular sample site may sometimes be quite accidental. As such it is better that the soil parameters may be indexed in the range 0 to 1 based on the existing range of concerned parameter that was observed as such corresponding index value was prepared for each nutrient status in the sampling site. As the indexing was only a rank order of the nutrient status of a particular site, Spearman's ranked order coefficient will measure the degree of association among the different parameters. Accordingly, Spearman's ranked correlation was calculated between total carbon, organic carbon, total nitrogen, available nitrogen and carbon ratio computed on the basis of total carbon and total nitrogen (C:N)1 with N content in plant during active tillering and visual panicle initiation stages. Significant Spearman's correlation coefficients are given in table No. 32. Significant correlation was obtained with total carbon, organic carbon and C:N ratio based on total carbon and total nitrogen with plant nitrogen at active tillering and visual panicle initiation stages significant at 1 and 5 % levels.

Table No. 39. Spearman's ranked correlations between various soil parameters and plant N content

Parameter	Spearman's correlation coefficient
Between total carbon and shoot N at AT stage	0.55**
Between total carbon and root N at VPI stage	0.46*
Between total carbon and panicle N at VPI stage	0.58**
Between OC and shoot N at AT stage	0.57**
Between OC and root N at VPI stage	0.49*
Between OC and panicle N at VPI stage	0.60**
Between (C:N)1 and panicle N at VPI stage	0.63**

4.8. Incubation experiment

An incubation experiment was conducted in the laboratory using 4 soil types namely, Onattukara sandy soils (S_1), Kari soils from Kuttanad (S_2), Wetland lateritic soil (Pattambi) (S_3) and Black soil from Chittor Taluk of Palakkad (S_4) to study the pattern of decomposition of added organic matter and to identify the corresponding variations and stabilization of C:N ratio at equilibrium. For this, the above four soils were incubated under submerged conditions with (5 t ha^{-1}(O_1)) and without (0 t ha^{-1} (O_2)) incorporation of paddy straw as the source of organic matter. The total carbon, total nitrogen, organic carbon and available nitrogen were estimated at fortnightly interval. C:N ratios viz., (C:N)1(Total carbon: Total nitrogen), (C:N)2 (Total carbon: Available nitrogen), (C:N)3 (Organic carbon: Total nitrogen) and (C:N)4 (Organic carbon : Available nitrogen) were also calculated.

4.8.1. Changes in pH, Eh, total C, total nitrogen, available nitrogen and C:N ratios with respect to days of submergence

Changes in pH, Eh, total C, total nitrogen, available nitrogen and C:N ratios with respect to days of submergence are given in table Nos. 40-51.

4.8.1.1. pH

The initial pH ranged from 3.83 in Kari soils from Kuttanad to 5.68 in black soils from Chittor. The pH in wetland lateritic soils from Pattambi was 4.67 and in Onattukara sandy soils was 5.56. With the addition of organic matter the pH recorded in Onattukara soil (T1) was 5.90 after 15 days and it was 5.29 in the treatment without the addition of organic matter (T2). In Kuttanad soils, with the addition of organic matter (T3) the pH after 15 days was 2.88 while it was 2.55 in the treatment without organic matter addition (T4). In Pattambi soils the pH recorded after 15 days was 5.40 in the treatment without addition of organic matter (T5) and it was 5.89 in the treatment without organic matter addition. In Chittor black soils, the pH recorded in treatment without the addition of organic matter (T7) was 6.24 and it was 5.76 without organic matter addition (T8). In Onattukkara sandy soils with the addition of organic matter (T1) the pH was 6.08 after 15 days of incubation and it was 4.08 after 105 days of incubation. In sandy soils of Onattukkara, in the treatment without addition of organic matter (T2) it varied from 5.44 to 4.18 during the period of incubation experiment (105 days). In Kari soils from Kuttanad with the addition of organic matter (T3) the pH was 2.95 after 15 days of incubation and it was 2.95 after 105 days of incubation. While in the same soils without incorporation of organic matter (T4) the total carbon content varied from 2.70 to 2.10 during the period of submergence. In wetland lateritic soils with the addition of organic matter (T5) it was 4.35 after 15 days of incubation and it was 4.65 after 105 days of incubation and in the same soils without addition of organic matter (T6) the pH recorded was 4.46 after 15 days of incubation and it was 5.67 after 105 days of incubation. In black soils from Chittor the pH in the treatment with the addition of organic matter ranged from 5.28 to 5.56 and in the treatment without the addition of organic matter it was 5.21 to 5.85 during the period of submergence.

Table No.40. Changes of pH with days of submergence

Days of submergence	T1	T2	T3	T4	T5	T6	T7	T8
0	5.75	5.56	2.95	3.83	4.67	4.67	5.68	5.68
1	5.68	5.39	2.80	2.60	4.60	4.54	5.56	5.55
2	5.61	5.61	2.71	2.50	4.57	4.86	5.54	5.90
3	5.83	5.79	3.00	2.53	4.75	5.05	5.78	6.07
4	5.61	5.42	2.87	2.48	4.52	5.84	5.50	6.38
5	5.84	5.68	3.32	2.94	4.78	5.97	5.76	6.40
6	6.05	5.78	3.30	2.85	4.92	6.07	6.03	6.48
7	6.07	5.88	3.09	2.75	4.97	6.16	6.10	6.56
8	6.17	5.96	3.07	2.73	5.07	6.29	6.18	6.58
9	5.87	6.00	3.02	2.65	4.87	6.32	5.88	5.86
10	6.07	5.67	2.93	2.50	4.97	6.38	5.96	5.98
11	5.57	5.61	3.10	2.79	4.86	6.29	5.84	5.86
12	5.52	5.46	3.09	2.75	4.82	6.04	5.76	5.79
13	5.70	5.26	2.59	2.65	5.21	5.85	6.06	5.68
14	5.90	5.29	2.88	2.55	5.40	5.89	6.24	5.76

Table No. 41. Changes of pH with respect to days of submergence

Treatments	Initial	Days of submergence						
		15	30	45	60	75	90	105
T1	5.56	6.08	5.15	4.54	4.24	4.23	4.08	4.02
T2	5.56	5.44	5.03	4.48	4.24	4.28	4.23	4.18
T3	3.83	2.95	2.49	2.23	2.08	2.29	2.24	2.18
T4	3.83	2.70	2.29	2.28	2.03	2.26	2.16	2.10
T5	4.67	4.35	4.27	4.20	4.18	4.48	4.74	4.65
T6	4.67	4.46	4.21	4.09	5.63	6.03	6.23	5.67
T7	5.68	5.28	5.2	5.56	5.78	6.35	5.73	5.56
T8	5.68	5.21	5.18	5.38	5.82	6.46	6.27	5.85

4.8.1.2. Redox potential

The initial redox potential ranged from 454 in Onattukkara sandy soils to 874 mV in Kari soils from Kuttanad. In Onattukkara sandy soils with the addition of organic matter (T1) the redox potential was -6 mV after 15 days of incubation and it was 134 mV after 105 days of incubation. In sandy soils of Onattukkara, in the treatment without addition of organic matter (T2) it varied from 74 to 34 mV during the period of incubation experiment (105 days). The Eh recorded in the soils from Kuttanad with the addition of organic matter (T3) was 374 after 15 days of incubation and it was 136 mV after 105 days of incubation. In soils from Kuttanad without incorporation of organic matter (T4) the Eh varied from 574 to -26 mV during the period of submergence.

Table No. 42. Changes in redox potential with respect to days of submergence

Days of submergence	T1	T2	T3	T4
	mV			
0	454	634	874	784
1	254	394	594	754
2	674	554	554	714
3	614	194	494	694
4	554	154	494	674
5	434	114	494	674
6	494	114	494	674
7	394	134	454	654
8	294	114	434	654
9	114	114	434	634
10	114	94	434	614
11	94	94	414	614
12	14	94	414	614
13	14	74	414	614
14	-6	74	394	594

Table No. 43. Changes of redox potential with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
	mV							
T1	454	-6	-26	14	34	154	134	134
T2	454	74	74	34	34	34	34	34
T3	874	374	314	214	114	154	136	136
T4	874	574	514	374	94	-6	-26	-26

4.8.1.3. Total carbon

The initial total carbon ranged from 0.44 in Onattukkara sandy soils to 7.88 percent in Kari soils from Kuttanad. The total carbon in Wetland lateritic soils from Pattambi was 1.92 and in Black cotton soils from Chittor Taluk of Palakkad it was 1.12 percent. The total carbon was found to be highest in all the treatments where organic matter was applied than in the treatments without organic matter addition. In Onattukkara sandy soils with the addition of organic matter (T1) the total carbon content was 0.28 percent after 15 days of incubation and it was 0.44 percent after 105 days of incubation. In sandy soils of Onattukkara, in the treatment without addition of organic matter (T2) it varied from 0.25 to 0.31 percent during the period of incubation experiment (105 days). The highest total carbon recorded in the soils from Kuttanad with the addition of organic matter (T3) was 7.74 after 45 days of incubation and it was 5.98 percent after 105 days of incubation. In soils from Kuttanad without incorporation of organic matter (T4) the total carbon content varied from 5.87 to 5.06 during the period of submergence. In wetland lateritic soils with the addition of organic matter (T5) it was 2.36 percent after 15 days of incubation and it was 1.52 percent after 105 days of incubation and in the same soils without addition of organic matter (T6) the total carbon content recorded was 1.67 after 15 days of incubation and it was 1.36 percent after 105 days of incubation. In black soils from Chittor the total carbon content in the treatment with the addition of organic matter ranged from 1.97 to 1.20 and in the treatment without the addition of organic matter it was 1.07 to 0.49 percent during the period of submergence.

Table No. 44. Changes of total carbon with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
	%							
T1	0.44	0.28	0.91	0.96	0.84	0.90	0.84	0.44
T2	0.44	0.25	0.25	0.85	0.80	0.50	0.79	0.31
T3	7.88	6.1	7.26	7.74	5.79	8.81	5.80	5.98
T4	7.88	5.87	5.67	5.84	5.50	5.52	5.55	5.06
T5	1.92	2.36	2.36	5.08	1.77	1.79	1.84	1.52
T6	1.92	1.67	2.11	2.13	1.35	1.36	1.74	1.36
T7	1.12	1.97	0.93	1.01	1.03	0.92	1.03	1.20
T8	1.12	1.07	0.57	0.89	0.87	0.92	0.86	0.49

4.8.1.4. Total nitrogen

The initial total nitrogen value varied from 0.09 in Onattukkara sandy soils to 0.24 percent in Wetland lateritic soils from Pattambi. The percent total nitrogen in soils from Kuttanad was 0.13 and in Black cotton soils from Chittor it was 0.19. The total nitrogen was found to be highest in all the treatments where organic matter was applied than in the treatments without organic matter addition. (Table No.). In Onattukkara sandy soils with the addition of organic matter (T1) the total nitrogen value was increased to 0.1 percent after 15 days of incubation while it was 0.04 percent after 105 days of incubation. While in the same soils without the addition of organic matter the value of total nitrogen varied from 0.08 to 0.04 percent during the period of submergence (105 days). The total nitrogen was highest in Kari soils from Kuttanad. The total nitrogen was 0.36 after 15 days of incubation and after 105 days it was 0.32 percent in the Kari soils with the addition of organic matter (T3). In the treatment without the addition of organic matter (T4) it ranged from 0.42 to 0.29 percent during the period of incubation. In wetland lateritic soils from Pattambi with the addition of organic matter (T5) the total nitrogen content increased to 0.29 percent after 15 days of incubation and it was 0.11 percent at the end of incubation study. While in the same soils without organic matter addition (T6) total nitrogen varied from 0.21 to 0.09 percent during the course of incubation study. In black cotton soils from Chittor with the addition of organic matter (T7) the total nitrogen was 0.29 after 15 days of incubation and it decreased to 0.12 percent after 105 days of incubation whereas in the same soils without the addition of organic matter (T8) the total nitrogen varied from 0.12 to 0.04 percent during the period of submergence.

Table No. 45. Changes of total nitrogen with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
	%							
T1	0.09	0.1	0.16	0.17	0.11	0.076	0.11	0.046
T2	0.09	0.08	0.073	0.11	0.10	0.039	0.1	0.043
T3	0.13	0.36	0.38	0.35	0.30	0.42	0.31	0.32
T4	0.13	0.42	0.34	0.38	0.26	0.32	0.26	0.29
T5	0.24	0.29	0.23	0.34	0.12	0.13	0.12	0.11
T6	0.24	0.21	0.22	0.16	0.096	0.083	0.12	0.09
T7	0.19	0.29	0.14	0.11	0.12	0.1	0.12	0.12
T8	0.19	0.12	0.1	0.11	0.10	0.086	0.096	0.04

4.8.1.5. Organic carbon

Organic carbon in the incubated soils varied from 0.42 in Onattukkara sandy soils to 4.83 percent in Kari soils from Kuttanad. The percent organic carbon in Wetland lateritic soils from Pattambi was 0.81 and in Black cotton soils from Chittor Taluk of Palakkad it was 0.60 percent. The organic carbon status in the above soils was greater in the treatments with the addition of organic matter against the treatments without addition of organic matter. In sandy soils of Onattukkara with the addition of organic matter (T1) the organic carbon was 0.24 after 15 days of incubation and it was 0.37 percent after 105 days of incubation. In the same soils without the addition of organic matter (T2) organic carbon content varied from 0.22 to 0.08 percent during the course of incubation study. The organic carbon content was highest in Kari soils from Kuttanad. In these soils, in the treatment with the addition of organic matter (T3) the organic carbon content was 4.13 after 15 days of incubation and it were 2.85 percent at the end of incubation study. The organic carbon status in Kari soils without the addition of organic matter (T4) varied from 3.59 to 2.73 during the period of submergence. In wetland lateritic soils from Pattambi with the addition of organic matter (T5) the organic carbon increased to 1.48 after 15 days of submergence and it was 1.42 percent after 105 days of incubation. While in the same soils without incorporation of organic matter (T6) it varied from 1.25 to 1.22 percent during the period of incubation. The organic carbon status in black soils from Chittor with the addition of organic matter varied from 1.67 after 15 days of incubation to 0.76 percent after 105 days of incubation. While in the same soils without addition of organic matter (T8) the organic carbon varied from 1.04 to 0.68 percent during the period of submergence.

Table No. 46. Changes of organic carbon with respect to time of submergence

Treatment	**Initial**	**Days of submergence**						
		15	**30**	**45**	**60**	**75**	**90**	**105**
	%							
T1	0.42	0.24	0.89	0.91	0.74	0.44	0.74	0.37
T2	0.42	0.22	0.23	0.8	0.71	0.63	0.71	0.08
T3	4.83	4.13	3.75	3.73	4.03	3.77	4.03	2.85
T4	4.83	3.59	3.3	3.24	3.77	3.28	3.77	2.73
T5	0.81	1.48	1.13	2.66	1.29	1.12	1.29	1.42
T6	0.81	1.25	1.04	1.02	0.97	0.99	0.97	1.22
T7	0.6	1.67	0.82	0.89	0.99	0.76	0.99	0.93
T8	0.6	1.04	0.56	0.84	0.82	0.23	0.82	0.32

4.8.1.6. Available nitrogen

The initial available nitrogen was found to vary from 0.0056 in Onattukkara sandy soils to 0.019 percent in Black cotton soils from Chittor Taluk of Palakkad. In Wetland lateritic soils from Pattambi it was 0.0083 and in Kari soils from Kuttanad it was 0.0084 percent. In sandy soils from Onattukkara with the addition of organic matter (T1) the available nitrogen increased to 0.016 percent after 15 days of incubation and it was 0.014 percent after 105 days of incubation.

While in the same soils without the addition of organic matter (T2) it varied from 0.013 to 0.014 percent during course of incubation study. The available nitrogen content in wetland lateritic soils from Pattambi with the addition of organic matter (T5) was 0.019 after 15 days of incubation and it was 0.016 percent at the end of incubation study. While in the same soils without the addition of organic matter (T6) the available nitrogen content varied from 0.011 to 0.0112 percent during the period of submergence. In black cotton soils from Chittor with the addition of organic matter (T7) the available nitrogen was 0.019 after 15 days of incubation and it was 0.011 percent after 105 days of incubation. While in the same soils without the addition of organic matter (T8) the available nitrogen varied from 0.019 to 0.014 percent during the period of incubation study.

Table No. 47. Changes of available nitrogen with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
	%							
T1	0.0056	0.016	0.0083	0.0083	0.0084	0.017	0.0084	0.014
T2	0.0056	0.013	0.0083	0.0080	0.0084	0.014	0.0084	0.014
T3	0.0084	0.016	0.016	0.0160	0.011	0.025	0.011	0.027
T4	0.0084	0.013	0.0083	0.0083	0.011	0.0083	0.011	0.022
T5	0.0083	0.019	0.013	0.0083	0.016	0.0084	0.0083	0.016
T6	0.0083	0.011	0.0083	0.0083	0.014	0.0224	0.0083	0.011
T7	0.019	0.019	0.0160	0.0084	0.014	0.0084	0.0084	0.011
T8	0.019	0.019	0.0130	0.016	0.011	0.0084	0.016	0.014

4.8.1.7. (C: N) 1 ratio (Total carbon: Total nitrogen)

The initial (C: N) 1 varied from 5.01 in Onattukkara sandy soils to 60.87 in Kari soils from Kuttanad. The ratio was 8 in wetland lateritic soils from Pattambi and it was 5.82 in black cotton soils from Chittor. In Onattukkara sandy soils with the addition of organic matter (T1) the C: N ratio was decreased to 2.84 after 15 days of incubation study and it was stabilized at 9.6 after 105 days of incubation. While in the same soils without the addition of organic matter (T2) the C: N ratio varied from 2.96 to 7.6 during the course of incubation study. The C: N ratio was highest in

Kari soils from Kuttanad. In these soils with the addition of organic matter (T3) the ratio was 16.94 after 15 days of incubation and it were 18.32 after 105 days of incubation. The C: N ratio varied from 13.98 to 17.26 during the period of submergence in Kari soils without addition of organic matter (T4). In wetland lateritic soils from Pattambi the C: N ratio was 8.15 after 15 days of incubation and it was 13.81 after 105 days of incubation with the addition of organic matter (T5). In the same soils without the addition of organic matter (T6) C: N ratio varied from 7.99 to 15.14 during the period of incubation. The carbon nitrogen ratio in black soils of Chittor with the addition of organic matter (T7) was 6.67 after 15 days of incubation and it was 12.33 after 105 days of incubation. While in the same soils without the addition of organic matter (T8) the ratio varied from 8.96 to 12.33 during the period of incubation study.

Table No. 48. Changes of (C: N) 1 with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
T1	5.01	2.84	5.6	5.69	7.26	11.18	7.48	9.6
T2	5.01	2.96	3.5	7.57	7.81	12.75	7.93	7.6
T3	60.87	16.94	18.95	22.14	19.12	21.09	18.52	18.32
T4	60.87	13.98	16.55	15.13	20.91	17.23	21.11	17.26
T5	8.00	8.15	10.14	14.8	13.99	13.11	15.32	13.81
T6	8.00	7.99	9.47	13.09	13.69	16.52	14.55	15.14
T7	5.82	6.67	6.4	8.72	8.48	9.26	8.25	9.91
T8	5.82	8.96	5.76	7.93	8.27	10.74	8.94	12.33

4.8.1.8. (C: N) 2 ratio (Total carbon: Available nitrogen)

The initial (C: N) 2 ratio varied from 56.97 in black soils from Chittor to 936.64 in Kari soils from Kuttanad. It was 78.22 in Onattukkara sandy soils and 229.11 in wetland lateritic soils from Pattambi. In Onattukkara sandy soils with the addition of organic matter (T1) the C: N ratio was 16.90 after 15 days of incubation and it was 31.66 after 105 days of incubation. While in the same soils without the addition of organic matter (T2) the ratio ranged from 18.39 to 22.37 during the period of incubation study. The (C: N) 2 was highest in Kari soils from Kuttanad. In these soils with the addition of organic matter (T3) the ratio was 363.63 after 15 days of incubation and it were 213.71 at the end of incubation experiment. The C: N ratio varied from 420.51 to 225.81 during the period of submergence in Kari soils without the addition of organic matter (T4). In wetland lateritic soils from Pattambi with the addition of organic matter (T5) the ratio was 120.86 after 15 days of incubation and it were 90.47 after 105 days of incubation. While in same soils it varied from 150.47 to 121.72 during the course of incubation without incorporation of organic matter (T6). In black soils from Chittor with the addition of organic matter (T7) the C: N ratio was 101.08 after 15 days of incubation and it was 107.74 after 105 days of submergence. While in the same soils without the addition of organic matter (T8) the ratio varied from 54.92 to 35.23 during the period of incubation study.

Table No. 49.Changes of (C: N) 2 with respect to time of submergence

Treatment	Initial	Days after submergence						
		15	30	45	60	75	90	105
T1	78.22	16.90	109.18	115.12	100.79	50.75	100.39	31.66
T2	78.22	18.39	30.33	106	96.035	36.19	94.44	22.37
T3	936.64	363.63	433.34	462.07	517.56	349.60	518.45	213.71
T4	936.64	420.51	678.21	696.89	491.36	663.62	495.83	225.89
T5	229.11	120.86	169.55	604.97	105.75	213.48	219.12	90.47
T6	229.11	150.47	252.63	255.08	96.42	60.71	208.86	121.72
T7	56.97	101.08	55.98	121.03	73.57	110.32	123.01	107.74
T8	56.97	54.928	41.17	54.17	78.27	109.52	52.35	35.23

4.8.1.9. (C: N) 3 ratio (Organic carbon: Total nitrogen)

The initial carbon nitrogen ratio varied from 3.10 in black soils of Chittor to 37.15 in Kari soils of Kuttanad. The ratio was 4.66 in sandy soils from Onattukkara and it was 3.37 in wetland lateritic soils from Pattambi. In Onattukkara sandy soils with the addition of organic matter (T1) the ratio was 2.4 after 15 days of incubation and it was 7.92 after 105 days of incubation. While in the same soils without the addition of organic matter (T2) the ratio varied from 2.75 to 1.84 during the period of incubation study. The C: N ratio was highest in Kari soils from Kuttanad. In these soils with the addition of organic matter (T3) the ratio was 11.47 after 15 days of incubation and it was 8.72 at the end of incubation experiment. In Kari soils without the addition of organic matter (T4) the C: N ratio varied from 8.54 to 9.30 during the period of submergence. In wetland lateritic soils from Pattambi with the addition of organic matter (T5) the C: N ratio was increased to 5.10 after 15 days of incubation and it was 12.90 after 105 days of incubation. While in the same soils without the addition of organic matter (T6) the ratio varied from 5.95 to 13.55 during the period of incubation. In black soils from Chittor with the addition of organic matter (T7) the ratio was 5.62 after 15 days of incubation and it was 8.66 after 105 days of incubation. While in these soils without the addition of organic matter (T8) the ratio increased to 8.66 to 17 during the period of incubation study.

Table No. 50. Changes of (C: N) 3 with respect to time of submergence

Treatment	Initial	Days of submergence						
		15	30	45	60	75	90	105
T1	4.66	2.40	5.45	5.35	6.34	5.73	6.53	7.92
T2	4.66	2.75	3.13	7.06	6.87	15.86	7.10	7.84
T3	37.15	11.47	9.78	10.65	13.28	8.97	12.86	8.72
T4	37.15	8.54	9.61	8.37	14.31	10.25	14.31	9.30
T5	3.37	5.10	4.84	7.74	10.18	8.19	10.75	12.90
T6	3.37	5.95	4.65	6.24	10.03	11.88	8.08	13.55
T7	3.10	5.62	5.58	7.60	8.02	7.60	7.813	7.80
T8	3.10	8.66	5.6	7.41	7.68	2.65	8.47	8.23

4.8.1.10. (C: N) 4 Organic carbon: Available nitrogen

The initial carbon nitrogen ratio in the above incubated soils varied from 30.52 in black soils from Chittor to 574.11 in Kari soils from Kuttanad. The ratio was 74.66 in Onattukkara sandy soils and it was 96.65 in wetland lateritic soils from Pattambi. In sandy soils from Onattukkara with the addition of organic matter (T1) the C: N ratio was 14.31 after 15 days of incubation and it was 26.42 after 105 days of incubation. While in the same soils without the addition of organic matter (T2) the ratio varied from 15.76 to 5.71 during the period of submergence. The highest carbon nitrogen ratio was observed in Kari soils from Kuttanad. In Kari soils with the addition of organic matter (T3) the ratio varied from 246.19 to 101.79 during the period of submergence.

While in the same soils without incorporation of organic matter (T4) the ratio was 257 after 15 days and it was 121.87 after 105 days of incubation. In wetland lateritic soils from Pattambi with the addition of organic matter (T5) the ratio varied from 75.68 to 84.52 during the incubation period. In the same soils without the addition of organic matter (T6) the ratio was 112.17 after 15 days of incubation and it was 108.92 after 105 days of incubation. In black cotton soils from Chittor the ratio increased to 85.60 after 15 days of incubation and it was 67.85 after the end of incubation study. While in the same soils without the addition of organic matter (T8) the ratio varied from 53.22 to 48.57 during the period of submergence.

Table No. 51. Changes of (C: N) 4 with respect to time of submergence

Treatment	Initial	Days after submergence						
		15	30	45	60	75	90	105
T1	74.66	14.31	106.39	108.37	88.09	24.81	88.09	26.42
T2	74.66	15.76	27.54	99.37	84.52	45	84.52	5.71
T3	574.11	246.19	223.73	222.48	359.82	149.60	359.82	101.79
T4	574.11	257.03	394.50	386.63	336.60	394.32	336.60	121.87
T5	96.65	75.68	81.07	316.77	76.78	133.33	153.62	84.52
T6	96.65	112.17	124.32	121.96	69.28	44.19	115.98	108.92
T7	30.52	85.40	49.18	105.95	70.71	90.47	117.85	67.85
T8	30.52	53.22	40.22	50.94	73.21	27.38	49.73	48.57

Discussion

5. Discussion

The results presented in chapter 4 are discussed here under with the support of available literature wherever possible.

5.1. Initial characterization

5.1.1. Electrochemical properties and carbon nitrogen status

The pH was lowest in Kari soils (Poovathikkari, Vechoor) of Kuttanad. This is as expected since the soil is potentially acid sulphate and hence when analyzed after drying resulted in very low pH (2.86). The black cotton soils from Chittoor recorded near neutral pH (7.14) which is highest among the collected samples (Table No.4). The electrical conductivity was lowest for sandy soils of Onattukara tract whereas it was highest in acid saline soils from Pokkali tract (3.18 dS m^{-1}). This is due to influence of sea water inundation in Pokkali soils (table No. 4 and 5).

The organic carbon, total carbon and total nitrogen were found to be highest in Kari soils from Vechoor whereas the corresponding values were lowest in the Onattukara sandy soils. The Kuttanad soils in general are high in organic matter content and since more than 95 % of nitrogen in soils are associated with organic pool the soils from Kuttanad since high in organic matter are expected to have high carbon and nitrogen content. In contrast, the soils of Onattukara which are sandy in texture having low organic matter content and hence have low total nitrogen content.

The available nitrogen content did not follow the same trend as that of total nitrogen, total carbon and organic carbon. The available nitrogen content (mineralizable N) estimated by alkaline permanganometry largely depends on mineralization rate in the soil which in turn is a function of microbial population (ammonifiers and nitrifiers) the activity of which is restricted both due to low pH and submergence. This might be the reason for reduced available nitrogen content in Kuttanad, Kole and Pokkali soils inspite of higher total carbon, organic carbon and total nitrogen content. (Table No. 4 and 5).

The carbon nitrogen ratio were computed based on total carbon : total nitrogen (C: N) 1, total carbon : available nitrogen (C: N) 2, organic carbon : total nitrogen (C: N) 3 and organic carbon : available nitrogen (C: N) 4. (C: N) 1 and (C: N) 3 showed the same trend where (C: N) 1 varied between 8 to 26, the lowest being in Pokkali and the highest in Kari soils of Vechoor. The carbon nitrogen ratio's computed based on available nitrogen also showed the same trend but showing abnormally wide values (high C: N ratios) in Kari soils of Vechoor which was 576 for (C: N) 2 and 535 for (C: N) 4. However, the lowest values in both cases were in Pokkali soils from Kottuvalli which was 15 for (C: N) 2 and 12 for (C: N) 4 (table No. 4 and 5).

The different values for carbon nitrogen ratios clearly showed that it varied widely and depending on the nitrogen content values ranged between 5 to 25 in case of (C: N) 1 and (C: N) 3 . This would mean that in all the soils it is not stabilized in the range of 10-12:1. This result would further indicate that the present N recommendation data based on organic carbon content assuming C: N ratio being stabilized at 10:1 definitely requires a re-look.

5.2. Active tillering stage

5.2.2. Electrochemical properties and carbon nitrogen status

The pH in general increased from the initial pH irrespective of the type of analysis i.e. whether it is wet or dry analysis during active tillering stage. The result is as expected since submergence causes a rise in pH (Ponnamperuma, 1972). Comparison of the wet and dry analysis showed that the pH were higher in wet analysis in case of Kuttanad, lateritic soils of Pattambi, black soils of Chittor, Pokkali soils as well as in Kole lands. However, lower values were recorded in wet analysis only in the case of Onattukara and Vadakkenchery. Thus, in majority of the soils flooding caused an increase in pH and when analyzed as such without drying showed the same value. The same sample when dried resulted in oxidized condition causing a reduction in pH (Table No. 6 and 7).

The electrical conductivity estimated at active tillering stage indicated a decrease in all cases at active tillering stage. This is due to the dilution effect due to flooding. No clear trends were obtained in the case of EC between wet and dry analysis data of soil samples.

Comparison of data on organic carbon at active tillering stage indicated that the values for organic carbon were higher when analysed under wet condition than that obtained from dry analysis. Drying and transformation of soil into aerobic condition might have resulted in oxidation of carbon which ultimately caused to record low values during dry analysis. The same trend observed in the case of total carbon analysis in some of the soils also points to this fact. However, a substantial increase in total carbon content in some other soils needs further investigations.

The available nitrogen content was higher in majority of the soils when they were analyzed after drying. The total nitrogen also showed almost the same trend. The nitrogen associated with organic matter is not soluble in water and hence when analyzed on wet basis quantity of soil solids will be less in comparison with samples taken for analysis on dry basis. This might be the reason for higher values in dry analysis (table No. 6 and 7)

A perusal of the data on C: N ratio's lead to the following conclusions. The carbon nitrogen ratio based on total carbon and total nitrogen (C: N) 1 varied from 9.64 to 22.87 on wet analysis while it was 10.25 to 29.09 on analysis after drying. Among the soils the ratio was higher on dry analysis in case of Kuttanad, Onattukara, black soils of Chittor and Kole lands. Whereas in other soils, it was lower in comparison with wet analysis. (C: N) 2 and (C: N) 4 did not show any specific trend probably because of the inclusion of available nitrogen in computing C: N ratio the values of which is widely varying. The data on (C: N) 3 i.e. organic carbon: total nitrogen ratio indicated lower values when analyzed on dry basis in most of the samples. This is the direct reflection of higher values of total nitrogen when soil is analyzed on dry basis (Table No. 7).

5.3. Visual panicle initiation

5.3.1. Electrochemical properties and carbon nitrogen status

The pH in general showed an increasing trend when compared with the corresponding values at initial and active tillering stage. This clearly indicated the effect of submergence in increasing the pH values as reported by Ponnamperuma (Ponnamperuma, 1972). Comparison of wet and dry analysis showed that in most of the soil samples pH values were lower on dry analysis. On flooding H+ ions were consumed for reduction which resulted in an increase in pH. The wet samples when dried led to oxidation and resulted in a decrease in pH (Table 8 and 9).

The electrical conductivity did not show any clear trend of change in comparison with active tillering stage. However, it was higher when analyzed after drying than that obtained during wet analysis.

The organic carbon did not show any notable change from that at active tillering stage. However, the values were notably lower in majority of the soils when analyzed after drying. As in the case at active tillering stage the decrease is attributed to loss of organic carbon as CO_2 when dried due to oxidation. Total carbon also showed lower values in dry analysis due to same reason explained above. Total nitrogen in majority of the samples recorded a higher value when analyzed after drying. Available nitrogen did not show any definite trend.

The (C: N) 1 ratio was found to decrease in comparison with the corresponding values during active tillering stage which means that the higher carbon nitrogen ratio's at active tillering stage is being stabilized at a slower pace during visual panicle initiation stage. However, in Kuttanad the ratio was tending to stabilize at a value around 19.88 when analyzed on wet basis. In all other cases, it was found to stabilize at a range of 7 to 17.77. The (C: N) 1 ratio computed on dry analysis basis resulted in an entirely different picture where the ratio's were found to vary from 9.53 in black soils of Chittor to as high as 30.76 in Kuttanad. The (C: N) 3 ratio on the basis of wet analysis tend to stabilize at about 16 in Kuttanad soil. However it was found to be as low as 6 in Onattukara (sample No. 5) and attained a value of 8 in lateritic soils from Pattambi (sample Nos. 11 and 12). In all other cases, it ranged between 10 to 12. The corresponding values obtained after dry analysis was lower to a tune of even 4.75 in Kuttanad soil (sample No. 3). It was found to be as low as 2.38 in Chittor soil (sample No. 15). In majority of the soils this (C: N) 3 ratio on dry analysis basis was in the range of 4 to 7. The (C: N) 2 and (C: N) 4 computed on the basis of available nitrogen in soil were found to be abnormally high and without any conclusive trends. This is as expected since the available nitrogen (mineralizable N) is always changing based on pH, redox potential as well as plant uptake (Table No. 9).

5.4. Mean values of initial characterization

5.4.1. Electrochemical properties and carbon nitrogen status

The pH varied between 3.20 in Kuttanad (AEU 4) and 6.39 in black cotton soils from Chittor (AEU 23). The values indicated that Kuttanad and Onattukara soils are extremely acidic, Palakkad central plains and north central laterite are very strongly acidic, Kole lands are medium acidic, Palakkad eastern plains and Pokkali are slightly acidic. (Table No. 10) (Figure 1).

The EC was highest in Pokkali (2.75 dS m^{-1}) and lowest in agroecological unit number 22 (Palakkad central plains). (Figure 2). The organic carbon content was also highest in Kuttanad and lowest in Onattukara. (Figure 3). The total carbon, total nitrogen and available nitrogen also showed the same trend. (Figure 4; 5; 6). The (C: N) 1 ratio varied between 9.43 in Palakkad central plains (AEU 22) to 21.53 in Kuttanad (AEU 4). Whereas (C: N) 2 varied between 17.65 in Palakkad central plains (AEU 22) to 174.78 in Kuttanad (AEU 4). The (C: N) 3 ratio ranged from 6.35 in Pokkali lands (AEU 5) to 19.89 in Kuttanad (AEU 4). (C: N) 4 again varied from 16.38 in Pokkali lands (AEU 5) to 161.44 in Kuttanad (AEU 4). (Figure 7; 8; 9; 10).

Figure 1. Changes in pH in different stages of soil sampling

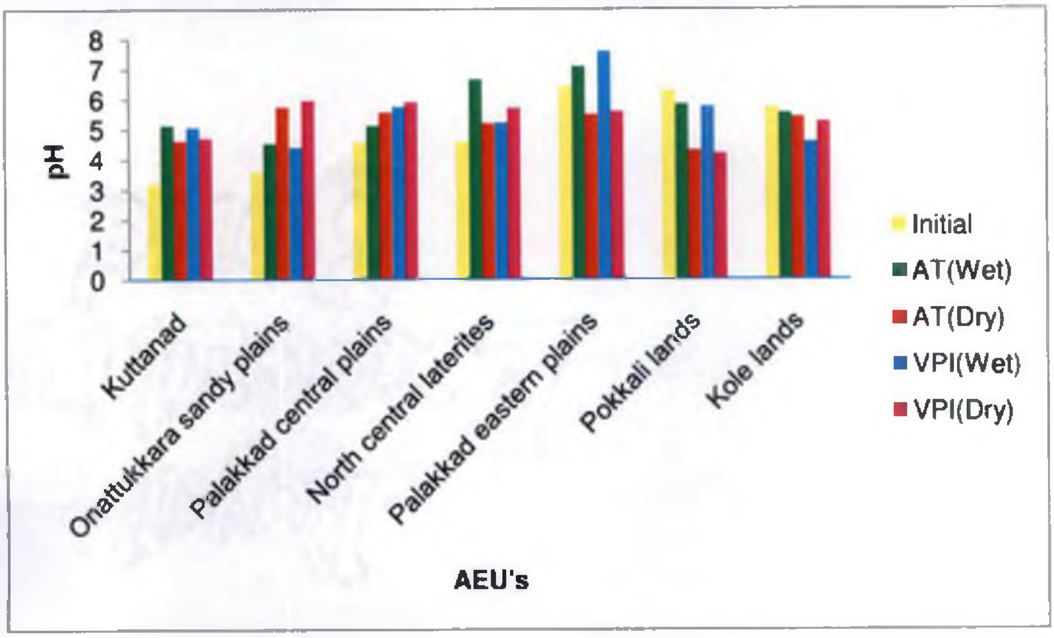
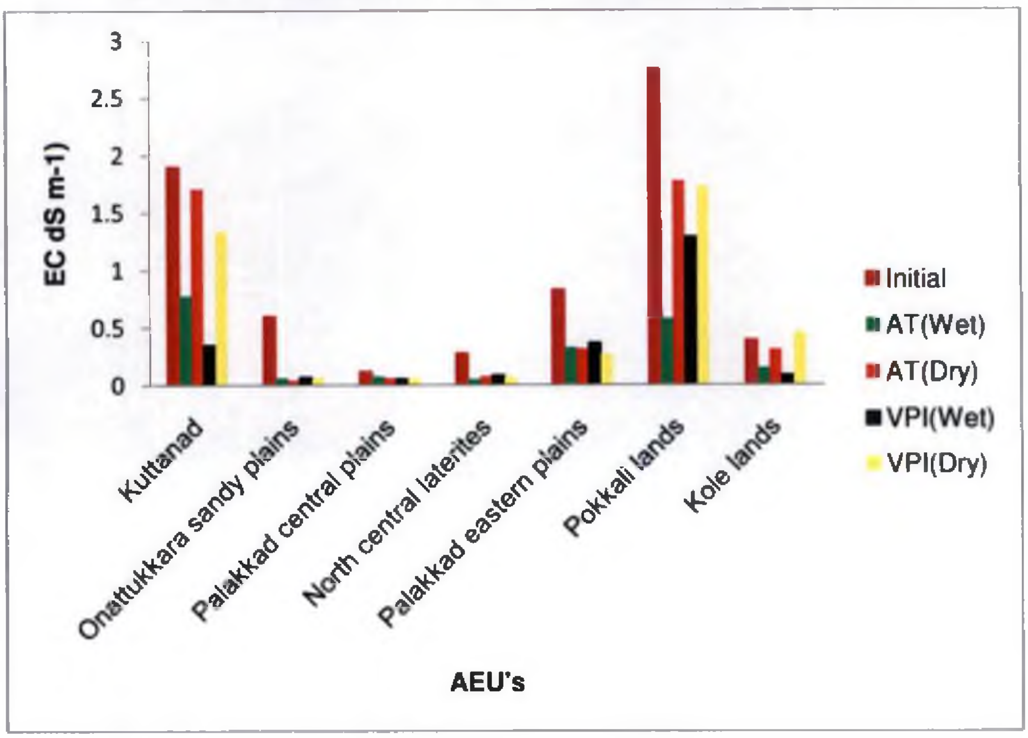


Figure 2. Changes in EC in different stages of soil sampling



5.5. Mean values of active tillering stage

The data on the electrochemical properties and carbon nitrogen status based on wet and dry analysis on agroecological unit basis are presented in table No. 11 and 12.

The pH was found to increase both in wet and dry analysis when compared with the corresponding values of pH obtained initially. The initial pH was based on dry soil analysis which upon flooding during rice cultivation resulted in increase in pH as reported by Ponnamperuma due to consumption of H^+ ions for reduction in anaerobic soil environment. On comparison of data on pH under wet and dry analysis indicated that in most of the agro ecological unit pH was lower when analyzed after drying. This would mean that when flooded soil is dried, oxidized environment prevailed causing a decrease in pH values (Figure 1).

Electrical conductivity was generally found to decrease at active tillering stage from that at initial characterization. This clearly indicates the dilution effect of flooded water during cultivation on salinity. Between the values of wet and dry analysis at active tillering stage in soils with high salinity (Kuttanad, Pokkali and Kole) dry analysis recorded higher values because of concentration of salts during drying (Figure 2).

The organic carbon content were found to decrease in soils from AEU's of Kuttanad, Palakkad eastern plains and Kole lands whereas it was found to increase in Onattukara soil, north central laterite and soils from Pokkali lands from the initial values of organic carbon before starting rice culture (table No. 7). The corresponding data based on dry analysis showed that organic carbon content was lower at active tillering stage than at initial levels in all soils except Onattukara sandy plains and Kole lands. A comparison of data on organic carbon based on wet and dry analysis reveals that it was lower when analyzed after drying probably because of loss of carbon due to oxidation on drying (Figure 3).

Figure 3. Changes in organic carbon in different stages of soil sampling

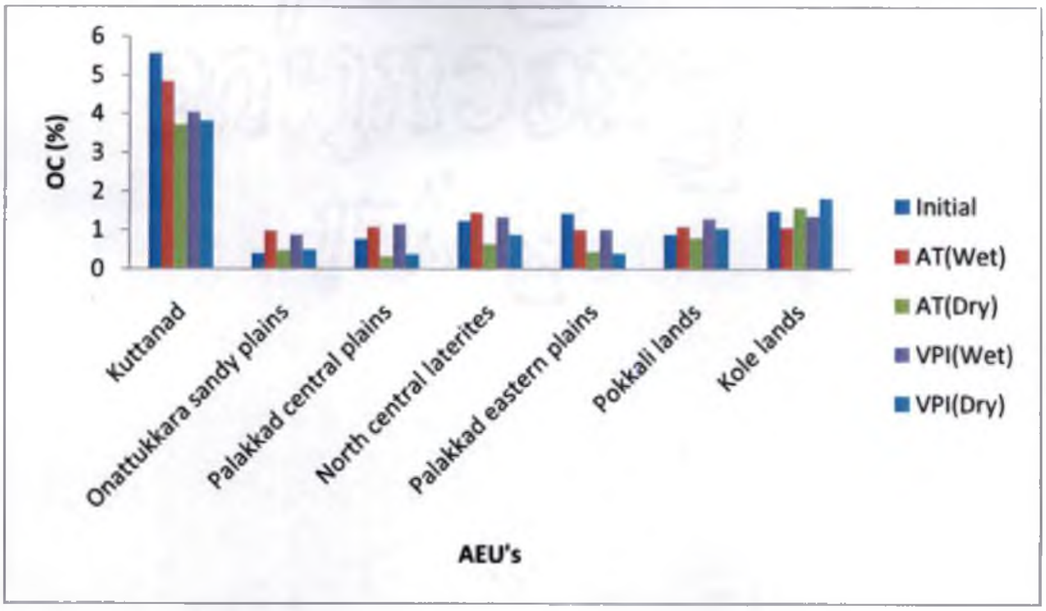
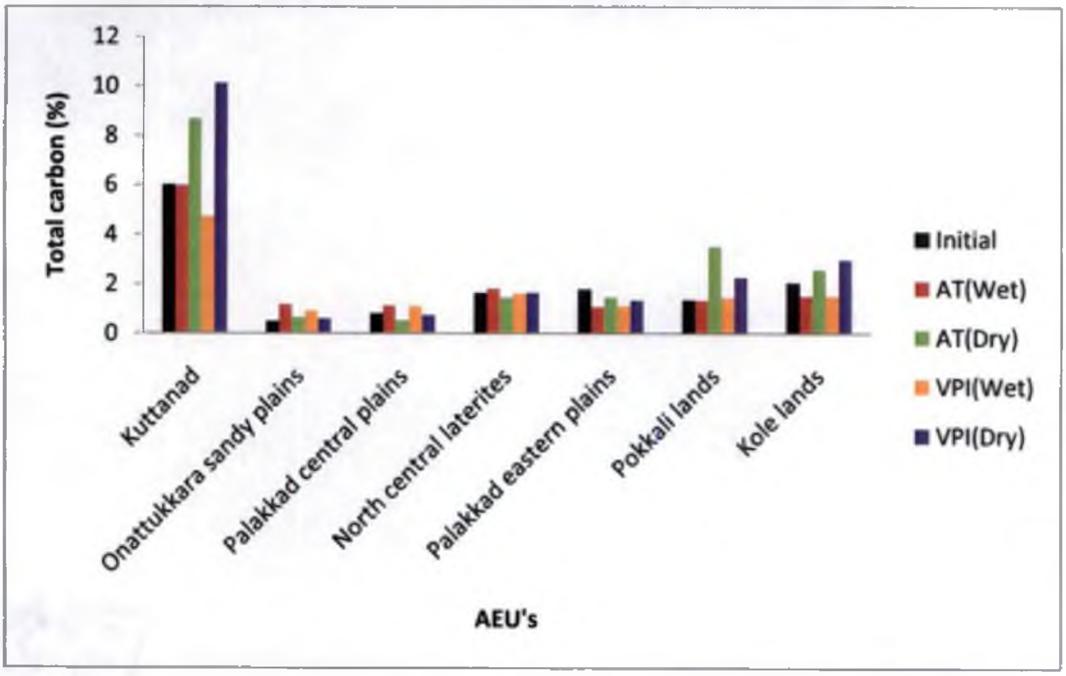


Figure 4. Changes in total C in different stages of soil sampling



The total carbon content was found to decrease at active tillering stage from the initial values in Kuttanad, Palakkad eastern plains and Kole lands while it registered an increase when analyzed on wet basis in all other soils. Total carbon estimated after drying the soil samples showed an increase in Kuttanad, Pokkali and Kole lands. The values were considerably higher than their corresponding counterparts during wet analysis (Figure 4).

The above results on organic carbon and total carbon points to the following facts: When organic carbon was estimated by Walkley and Black method, the extent of extraction of carbon are definitely varying whereas the entire carbon content is being estimated during total carbon determination. Similarly, the amount of carbon lost during dry analysis also varied depending on the type of soil. In light textured soil where the organic matter content is low, the carbon loss is found to be much more as in Onattukara sandy plains whereas such losses are not observed in soils of Kuttanad, Pokkali and Kole lands.

The total nitrogen content on wet analysis basis did not give any clear trend with respect to corresponding content during initial stage. However, the data of total N on the basis of dry analysis shows that the total nitrogen decreased in all the agroecological zones from the initial content except in Kuttanad and Onattukara sandy plains (Figure 5).

The (C: N) 1 ratio was wider in all the soils when analysed dry. In wet analysis, the trend was same except in Kuttanad and Onattukara soils. The increase in (C: N) 1 ratio is the resultant effect of increase in total carbon content during the period of crop growth upto active tillering stage.

A perusal of data on (C: N) 1 ratio from wet and dry analysis showed that the ratio was wider in dry analysis in Kuttanad, Onattukara, Palakkad eastern plains and Kole lands, while it was narrower in soils of Palakkad central plains, north central laterite and Pokkali soils.

Figure 5. Changes in total N in different stages of soil sampling

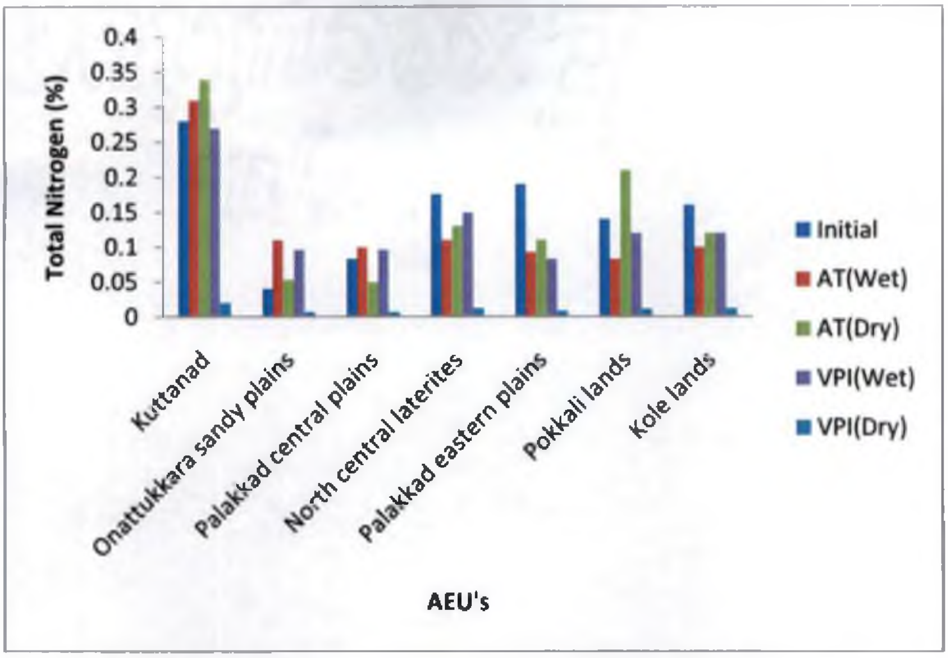
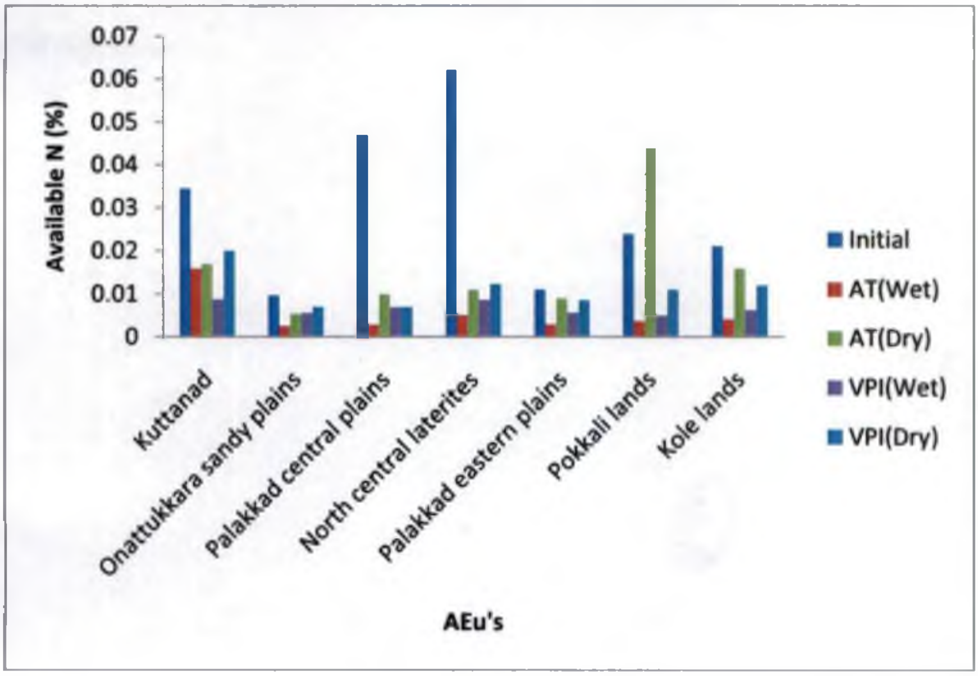


Figure 6. Changes in available N in different stages of soil sampling



The (C: N) 3 ratio on the basis of wet analysis showed narrower values than the initial ones in all soils except Kuttanad and Onattukara sandy plains which is similar to the trend shown by (C: N)

1 ratio. While the (C: N) 3 ratio on the basis of dry analysis was found to be very narrow compared to initial values. In comparison with (C: N) 1 ratio on the basis of dry analysis, (C: N) 3 ratio recorded considerably lower values. The above data clearly indicate lower recovery of carbon by the wet oxidation method resulting in narrower carbon nitrogen ratio. The abnormally varying and wider values of (C: N) 2 and (C: N) 4 points towards the fact that the mineralizable nitrogen and hence the carbon nitrogen ratio based on this nitrogen is short lived in the soil system either due to plant absorption or due to leaching losses (Figure 7 to 10).

5.6. Mean values of visual panicle initiation stage

The data on the electrochemical properties and carbon nitrogen status based on wet and dry analysis on agroecological unit basis are presented in table No. 13 and 14.

The pH in general recorded higher values at active tillering and visual panicle initiation stages in comparison with initial values except in Pokkali and Kole lands. This is due to continuous submergence during paddy cultivation. In Pokkali and Kole soils de-watering before sowing might have resulted in a slight decrease from initial values. At active tillering, dry analysis resulted in lower pH values in all soils except in Onattukara and Palakkad plains. The decrease in pH is attributed to reduction of soil under anaerobic condition due to consumption of H^+ ions for reduction (Figure 1).

The electrical conductivity was generally found to decrease at visual panicle initiation stage from that at initial and active tillering stage. This clearly indicates the dilution effect of flooded water during cultivation on salinity. Between the values of wet and dry analysis at visual panicle initiation stage in soils with high salinity (Kuttanad, Pokkali and Kole lands) dry analysis recorded higher values because of concentration of salts during drying (Figure 2).

The organic carbon content was found to decrease in soils from AEU's of Kuttanad, Palakkad eastern plains and Kole lands. Whereas it was found to increase in Onattukara, Palakkad central plains, north central laterites and Pokkali lands from initial values of organic carbon before starting rice culture. The corresponding data based on dry analysis showed that organic carbon content was lower at active tillering stage in comparison with initial values but later increased in visual panicle initiation stage except in Palakkad eastern plains (Figure 3).

The total carbon content was found to decrease in soils from AEU's of Kuttanad, north central laterites, Palakkad eastern plains and Kole lands. Whereas it was found to increase in Onattukara, Palakkad central plains and Pokkali lands from initial values of total carbon before starting rice culture. Total carbon estimated after drying the soil samples showed an increase in Kuttanad, Palakkad eastern plains, Pokkali and Kole lands. The values were considerably higher than their corresponding counterparts during wet analysis (Figure 4).

The total nitrogen content on wet analysis basis did not give any clear trend with respect to corresponding content during initial stage. However, the data of total N on the basis of dry analysis shows that the total nitrogen decreased in all the agroecological zones from the initial content except in Kuttanad, Palakkad eastern plains, Pokkali and Kole lands as in the case of total carbon content (Figure 5).

The available nitrogen was found to decrease from values obtained during initial characterization before start of rice culture (Figure 6).

The (C: N) 1 ratio was found to be lower in Kuttanad soil when computed on wet analysis basis in comparison with initial and at active tillering stage which means that the ratio was found to steadily and slowly decreasing from 21.53 to 17.3 during the period of crop growth. The same trend was shown by Onattukara soil also.

Figure 7. Changes in total carbon: total N ratio (C: N) 1 in different stages of soil sampling

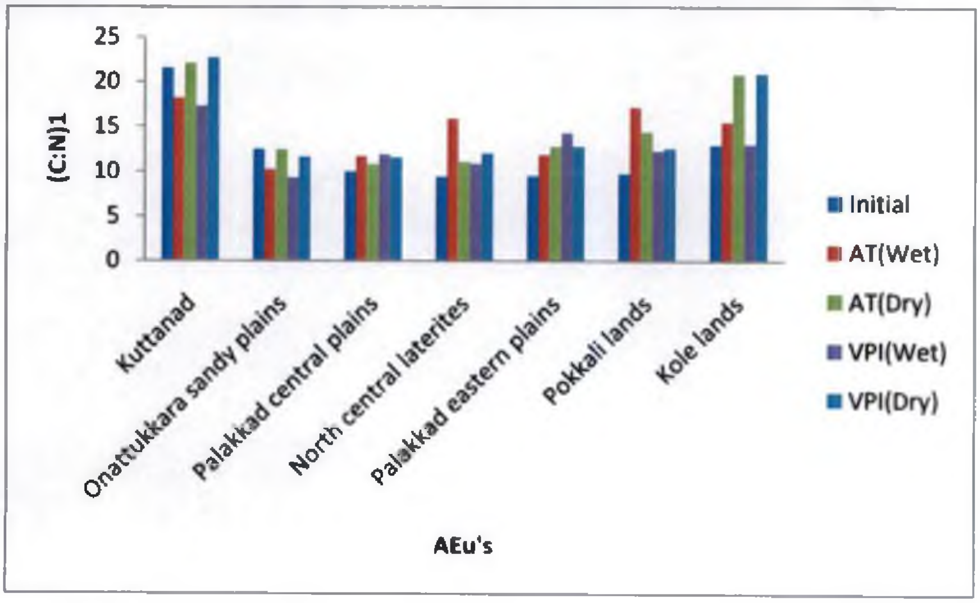
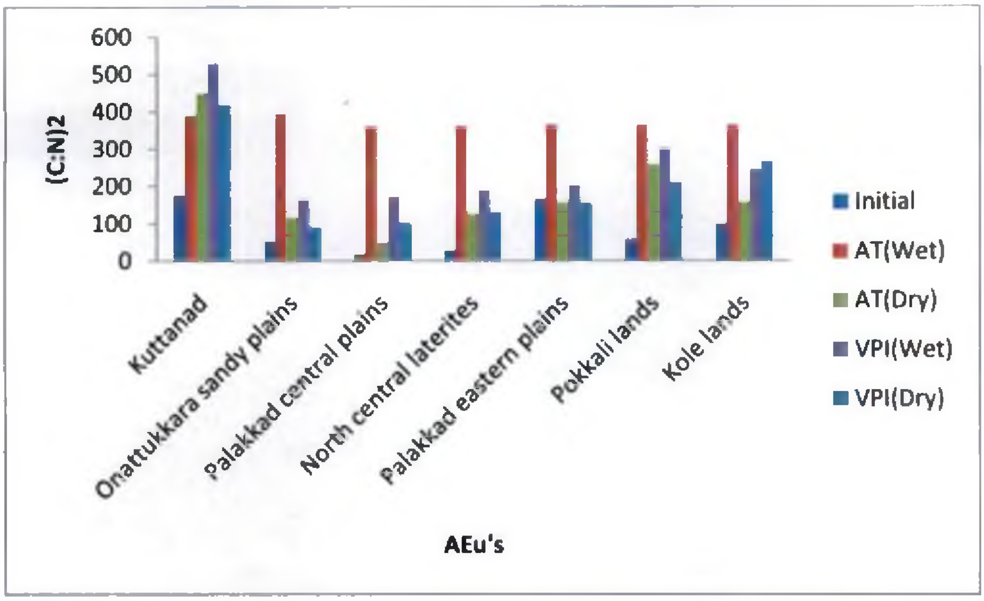


Figure 8. Changes in total C: available N ratio (C: N) 2 in different stages of soil sampling



However, the ratio was between 17 to 22.70 in Kuttanad but it was only 9.3 to 12 in Onattukara sandy plains. The (C: N) 1 ratio showed a slight increase in Palakkad central plains (AEU 22) from an initial value of 10 through 11.72 at active tillering stage to 11.92 at panicle initiation stage. This would mean the ratio being stabilized at about 11.70 in this soil. In north central lateritic soils, the data on (C: N) 1 ratio increased to 15 at active tillering stage from 9.42 (initial) and came down to 10.90 at visual panicle initiation stage i.e. the ratio tends to stabilize at around 10. In Palakkad eastern plains (AEU 23), the ratio showed a gradual and steady increase from 9.52 through 11.87 to 14.33. The (C: N) 1 ratio in Pokkali on wet basis showed a sudden increase from 9.78 (initial) to 17.2 (active tillering stage) and further reduced to 12.30 in visual panicle initiation. Here, the ratio may stabilize in and around 12. In Kole lands the trend was very similar to Pokkali soil but the increase was only marginal and the ratio maintained stability from initial to visual panicle initiation stage.

The (C: N) 1 ratio was found to be higher in Kuttanad when computed on dry analysis basis in comparison with initial and at active tillering which would mean that for analysis on dry basis more soil solids without moisture was included causing higher amount of carbon and nitrogen. The percent increase in carbon content was much higher than nitrogen causing a higher (C: N) 1 ratio. Inspite of the above fact in Onattukara sandy soils a decrease in the ratio was noticed which of course is not substantial in comparison with Kuttanad soil because of lower carbon and nitrogen content and their percent increases were also lower. In all other soils, the trend was similar to that in Kuttanad soils. However, an examination to values of carbon nitrogen ratio's at initial, active tillering and visual panicle initiation indicated the ratio's were to the tune of 20 or above in Kuttanad and Kole soils whereas it was in the range of 11 to 12 in all other soils (Figures 7 to 10).

Figure 9. Changes in organic C: total N ratio (C:N)3 in different stages of soil sampling

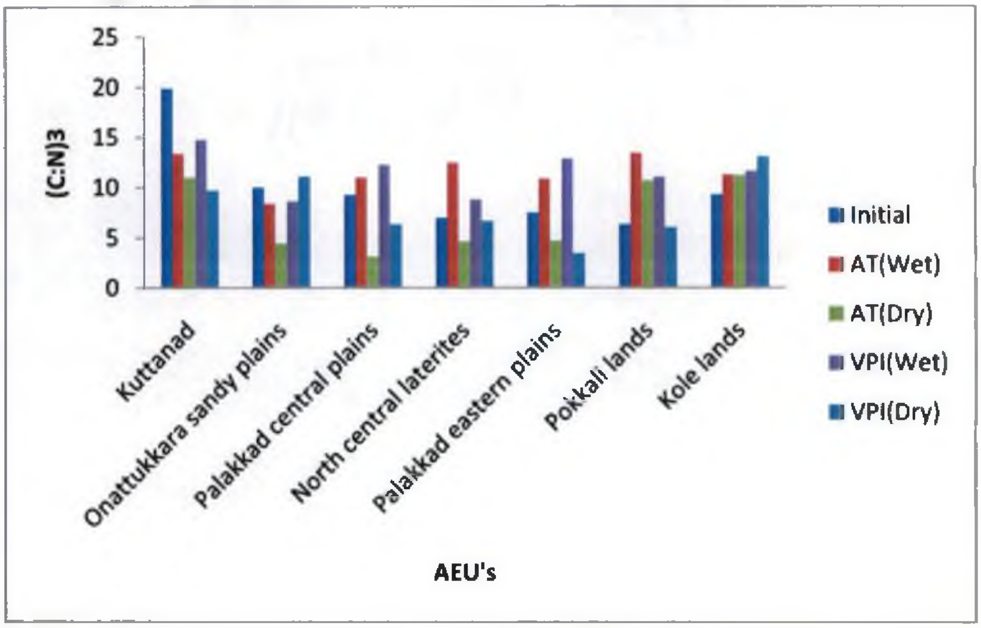
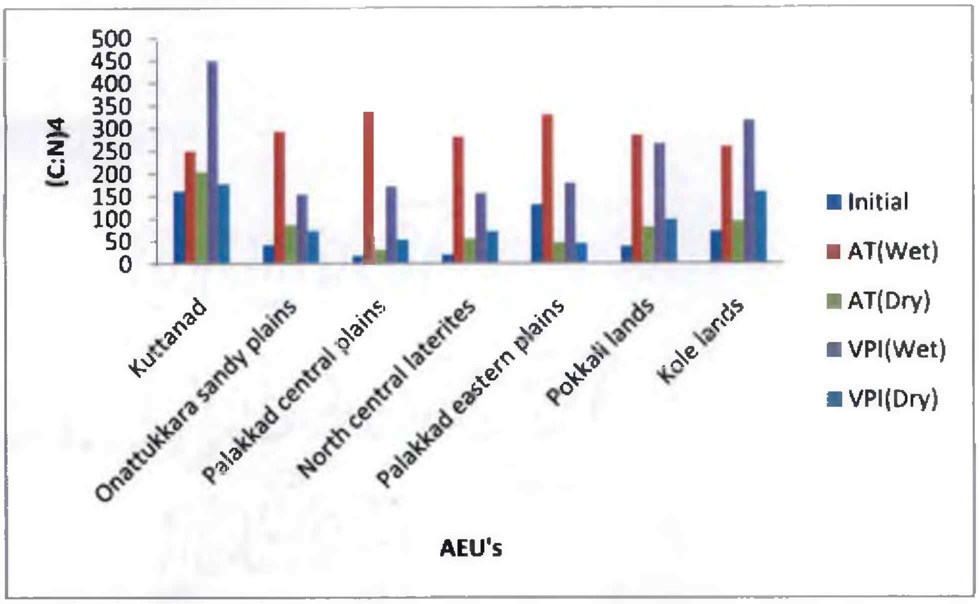


Figure 10. Changes in organic C: available N ratio (C: N) 4 in different stages of soil sampling



The practical significance of this result is that in routine soil testing programmes the recommendation for nitrogen based on organic carbon estimation is on the assumption that C: N ratio stabilizes at 10:1. But it was observed in the present study that C: N ratio computed on total carbon and total nitrogen basis i.e. (C: N) 1 stabilizes in and around 20:1 in Kuttanad and Kole soils whereas in other soils it was near 11 to 12. The data on (C: N) 1 ratio computed on wet analysis basis during visual panicle initiation stage was narrowest in coarse textured sandy soils of Onattukara (9.3) and soils from north central laterites (10.9). Here also higher values of 17.30 were recorded in Kuttanad. Further, comparison of C: N ratio's computed on organic carbon and total nitrogen i.e. (C: N) 3 basis was found to stabilize at 10 to 15 in Kuttanad, Pokkali and Kole soils whereas it was much narrower to the tune of only 3 to 4 in other soils when computed on the basis of dry analysis (figures 7 to 10)

5.7. Mean available nutrient status

The available P status of different agroecological units ranged between 13.50 in Kole lands to 79.14 in Pokkali on dry analysis basis. The data at active tillering and panicle initiation stage on available P was consistently high when analyzed as such on wet basis. While lower values were obtained in all the soils on analysis after drying. When the soil is submerged, reduction occurs, pH increases in acid soils attaining near neutrality; availability of P will be maximum at near neutral pH. This is clearly depicted by higher available P values when analyzed on wet basis maintaining the anaerobic situation in the field. On the other hand, when the soil is dried pH decreases as depicted in table No.5 which causes precipitation of phosphorus into unavailable forms resulting in low available P status (Figure 11).The deficiency and sufficiency ranges of available P is different in wet and dry soil analysis. In Kuttanad, the available P during active tillering was 7.39 kg ha^{-1} in case of dry analysis which is deficient whereas available P recorded in case of wet analysis was 29.55 kg ha^{-1} which comes under sufficiency range of available P.

Figure 11. Changes in available P in different stages of soil sampling

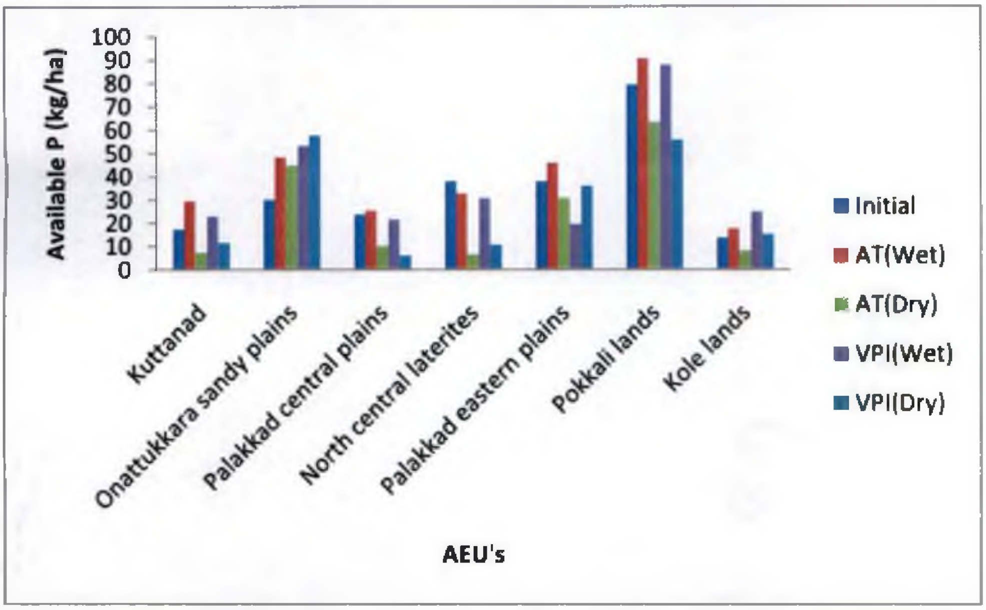
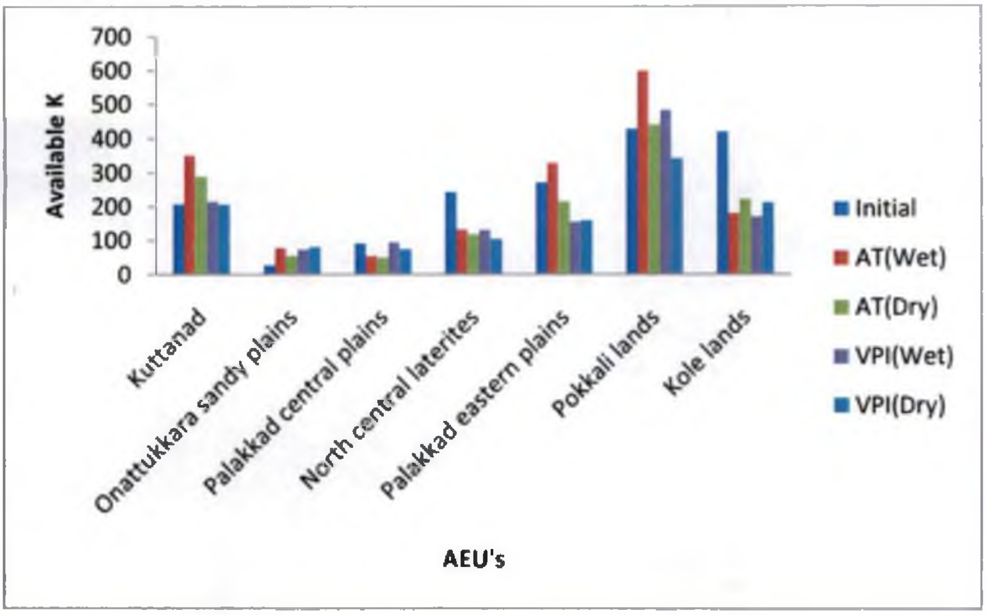


Figure 12. Changes in available K in different stages of soil sampling



Hence, nutrient prescriptions based on wet analysis helps in need based recommendations for paddy. Similar trend was observed with respect to calcium also in Kuttanad.

The initial K status varied between 26.50 in Onattukara to as high as 427 kg ha^{-1} in Pokkali soils. At active tillering stage K content recorded lower values when analyzed after drying in comparison with those obtained on wet analysis. This increase is attributed to the relative concentration of K in comparison with other cations in the solution which is an indirect effect of submergence and consequent changes in pH and redox potential. From the data it is clear that a decrease in available K content during dry analysis was followed by a corresponding increase in Mn and Zn content which might reduce the active concentration of potassium (Figure 12).

The Ca and Mg content also showed similar trends. (Figure 13 and 14). The available S content showed a reverse trend i.e. available S content was higher when analyzed on dry basis. This is due to the oxidation of otherwise unavailable forms of sulphur mainly sulphides under anaerobic condition to sulphates which naturally increase the sulphur content when soil is dried and analyzed (Figure 15).

The available iron content was found to register lower values when analyzed after drying due to oxidation of ferrous (Fe^{2+}) forms to ferric (Fe^{3+}) forms which is not soluble. However, the values of available Mn were found to be higher in dry analysis so also the case of Zn. This is attributed in relation with the status of sulphur. When anaerobic condition prevailed during wet analysis maintained the sulphur as sulphides especially of that of Mn and Zn. When it is dried and analyzed these sulphides are oxidized to sulphates of the same cations Mn and Zn making them soluble resulting in recording high values. But in the case of Fe and Cu this trend is not manifested probably because of formation of sulphides of Mn and Cu prior to formation of ferrous sulphides. However, this needs further detailed investigation (Figure 16 to 19)

Figure 13. Changes in available Ca in different stages of soil sampling

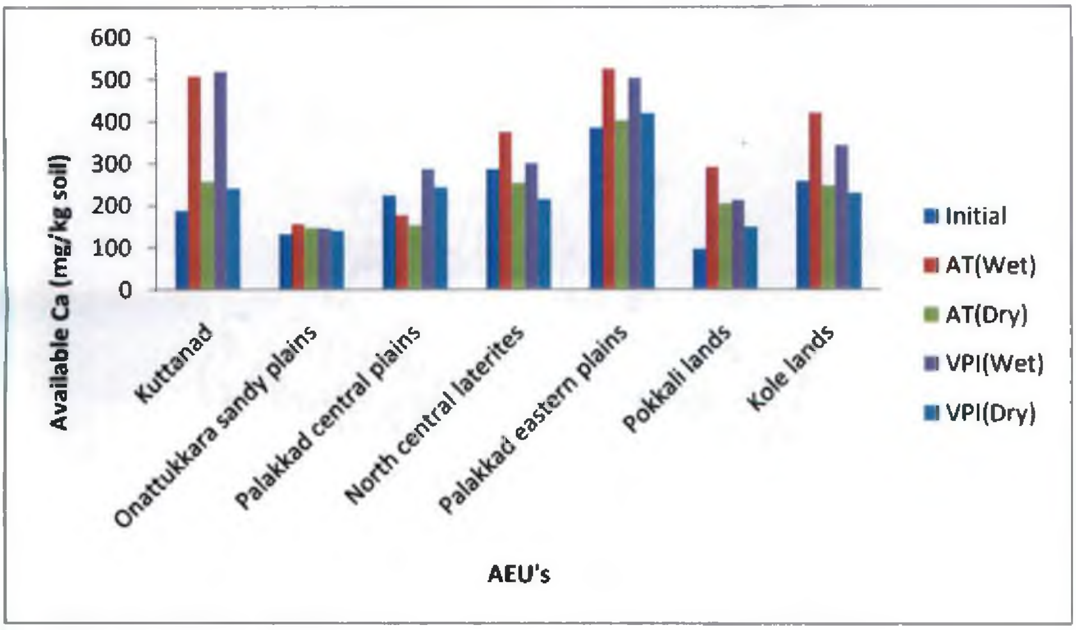
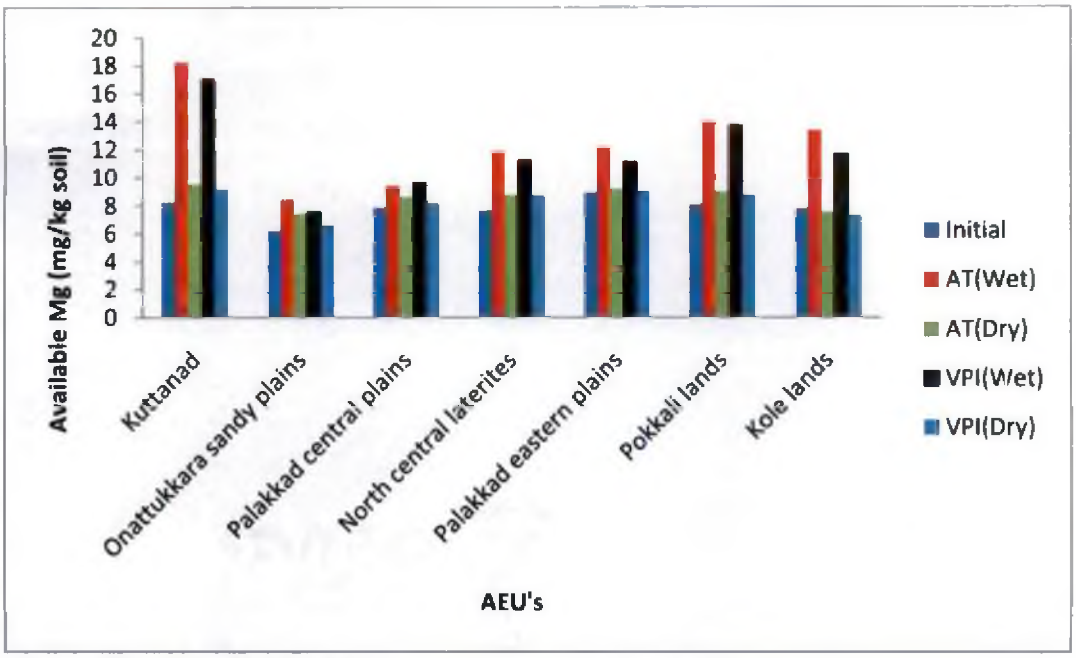


Figure 14. Changes in available Mg in different stages of soil sampling



The hot water extractable boron recorded higher values both at active tillering and panicle initiation stages in dry analysis. This is also an indirect effect of pH on available B. In general, it was observed by many workers that pH has negative correlation with available B. So, when the soils are dried as explained earlier, pH get reduced resulting in recording of higher values for available B (Figure 20). In Palakkad central plains available boron recorded during active tillering in case of dry analysis recorded high values of available B whereas it was lower in case of wet analysis. Hence, nutrient prescriptions based on wet analysis helps in need based recommendations for paddy.

The above results on available nutrient status estimated both under wet and dry analysis opened up the following points: In paddy soils since anaerobic flooded conditions prevail the sampling and analysis by maintaining the same chemical environment (as done in wet analysis) will give more realistic and useful values. When the samples are dried and analyzed the values obtained may not be real in the rhizosphere which in turn causes misinterpretation in fertility status.

5.8. Mean values of nutrient content in rice

5.8.1. Active tillering stage

The data on agroecological unit based mean values of nutrient content in rice at active tillering stage is given in table No. 28 and 29.

The total nitrogen content in shoot at active tillering stage was lowest in Kuttanad (0.98 %) and highest (2.38 %) in north central laterites (AEU 10). In root the total nitrogen content varied from 0.78 in Kuttanad to 1.49 % at Pattambi. However, the soils from Palakkad recorded the lowest mean total nitrogen at active tillering stage and highest total nitrogen was recorded in Kuttanad. These results points that there are definitely some unknown interactions governing N absorptions which is not found to be a function of nitrogen in soil under flooded condition. This requires detailed investigations.

Figure 15. Changes in available S in different stages of soil sampling

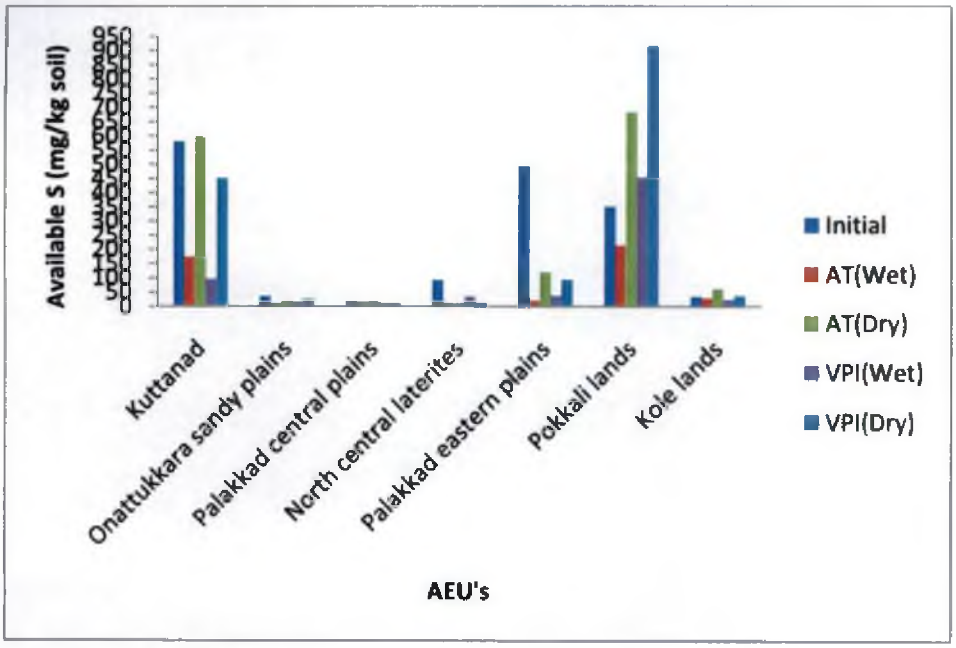


Figure 16. Changes in available Fe in different stages of soil sampling

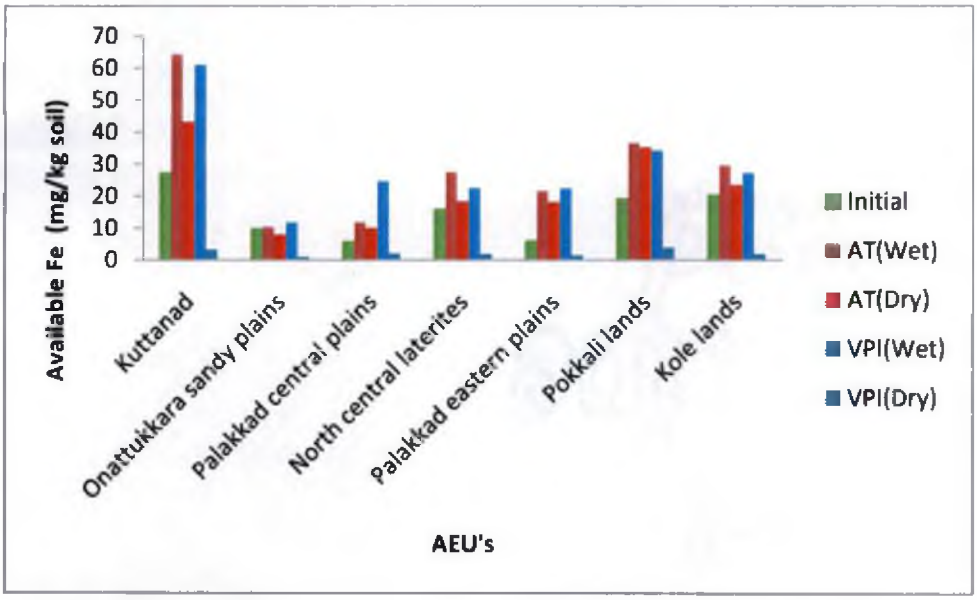


Figure 17. Changes in available Mn in different stages of soil sampling

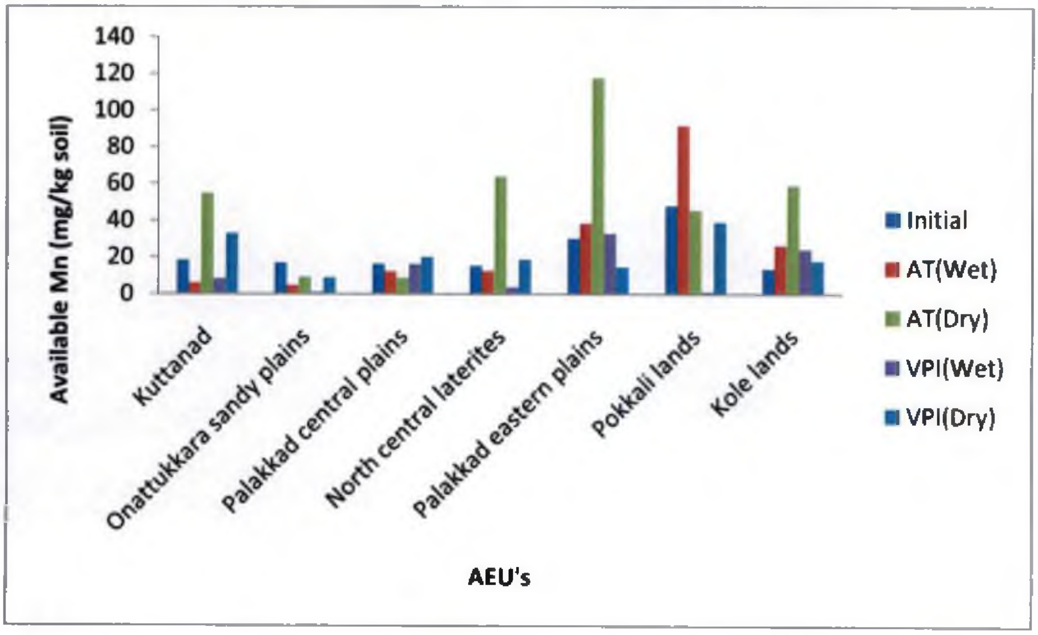
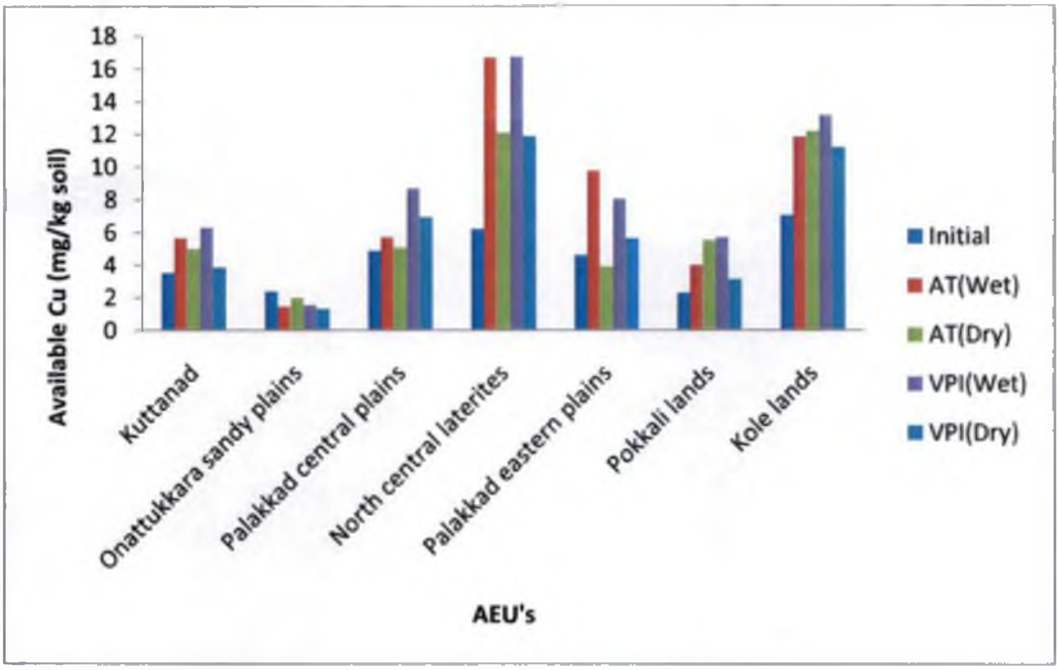


Figure 18. Changes in available Cu in different stages of soil sampling



Highest N content both in shoot and root at active tillering stage revealed that maximum nitrogen absorption took place in lateritic soils where the texture is sandy loam and organic carbon content is low which in turn must have resulted in less immobilization, fixation of plant available form (NH_4^+ and NO_3^-) resulting in maximum absorption. On the other hand, in Kuttanad where the texture is clayey and organic carbon content was the highest, major fraction of nitrogen must have got immobilized and remained in unavailable organic forms resulting in lesser absorption by plants.

The phosphorus content at active tillering stage was lowest in lateritic soil in shoot (0.094 %) and the highest in Onattukara and Pokkali (0.17 %). In root it ranged from 0.019 in Pokkali to 0.091 % in Kole lands. The P content in plant was lowest in north central lateritic soils from Pattambi which is dominated by 1:1 kaolinitic type of clay which has got highest P fixing capacity. This must have resulted in lower availability of P in soil solution which in turn might have affected P absorption in plant. The lowest mean available P recorded in north central laterites also supports the above findings.

The total potassium content in shoot varied from 0.48 % in Palakkad eastern plains to 0.87 % in Kole lands. While in root it ranged from 0.040 in Pokkali to 0.25 % in Palakkad eastern plains. The highest K content was observed in shoot from Kole lands and lowest was recorded by shoot in Palakkad eastern plains. The soils from Palakkad eastern plains (AEU 23) dominated by 2:1 type clay minerals which has got K fixing capacity in comparison with other AEU's.

The total Ca content in shoot was found to vary from 0.098 in Palakkad central plains to 0.18 percent in Palakkad eastern plains. While in root the lowest Ca content was observed in 0.039 in Onattukara and highest of 0.16 % in Kuttanad. The Palakkad eastern plains with near neutral pH dominated by higher exchangeable Ca which in turn lead to higher absorption. However, the data on initial Ca content in soil also lead to confirmation of this conclusion

Figure 19. Changes in available Zn in different stages of soil sampling

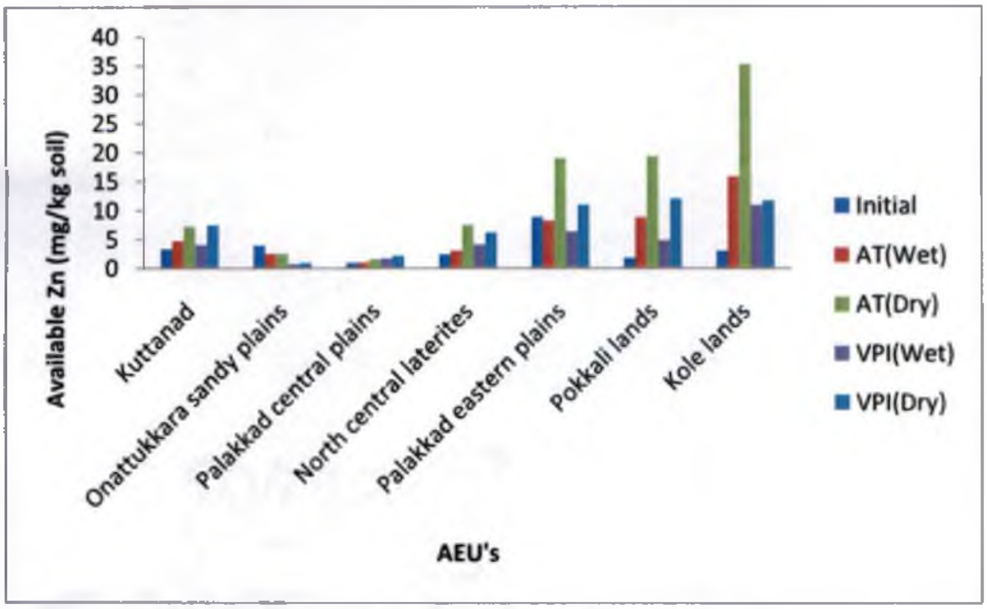
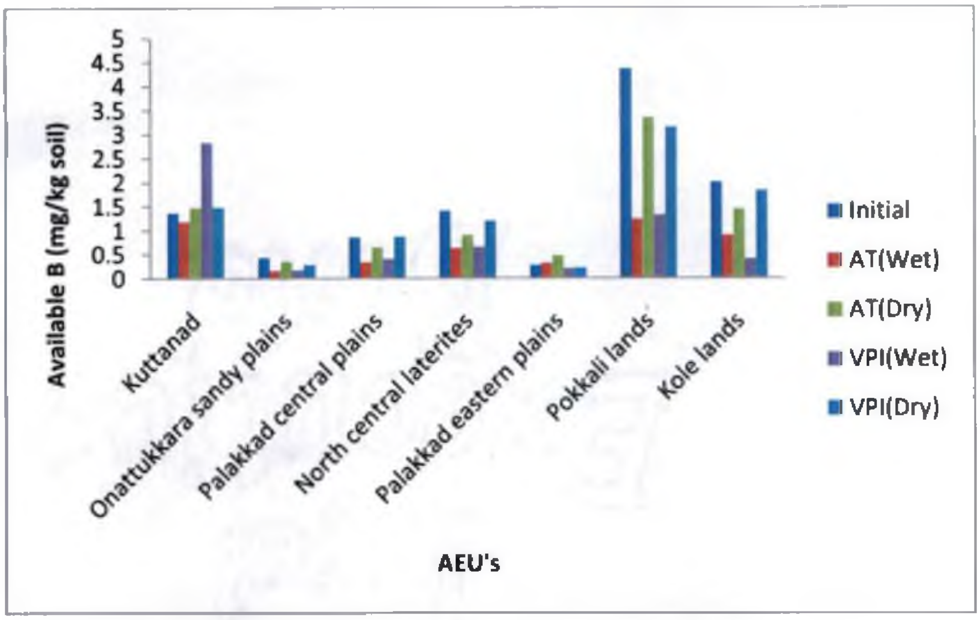


Figure 20. Changes in available B in different stages of soil sampling



The mean total magnesium content in shoot was 0.012 % in all the agroecological units. While in root it was lowest (0.005 %) in Onattukara and north central laterites and highest (0.012 %) in Palakkad eastern plains. In case of Mg shoot content recorded the very same values in all the AEU's. However, the content of Mg in root was lowest in Onattukara and north central laterites (Pattambi) and highest in Palakkad eastern plains (AEU 23). The initial available Mg content which was lowest in Pattambi and highest in Chittor indicated the root content was dependent on available Mg content in soil in a direct proportion.

The total sulphur content in shoot ranged from 0.012 in Palakkad eastern plains to 0.15 % in Palakkad central plains and Pokkali lands. While in root the lowest total S (0.022 %) was observed in Pokkali and highest of 0.074 % in Kole lands.

The total iron in shoot varied from 520 ppm in Chittor to 1300 ppm in Palakkad central plains. While in root the Fe content ranged from 18 ppm in Palakkad eastern plains to 210 ppm in Onattukara. The lowest iron in shoot from Palakkad eastern plains was the direct reflection of lowest available Fe content in these soils.

The total Mn content in shoot ranged from 100 ppm in north central laterites to 240 ppm in Palakkad central plains. While in the root the lowest value of 12 ppm was found in Kuttanad and highest of 87 ppm in Kole lands. The total Cu content in shoot ranged from 9 in Chittor to 18 ppm in Palakkad plains. While in root it varied from 1.3 in Pattambi to 6.6 ppm in Kuttanad region. The total Zn in shoot was highest (36 ppm) in Pokkali and lowest (9 ppm) in north central laterites (AEU 10). While in root the lowest value (3.1 ppm) was observed in Pattambi and the highest value of 7.4 ppm in Palakkad central plains. The shoot boron ranged from 4.9 ppm in Chittor to 11.6 ppm in Palakkad central plains. While in root the lowest value of 2.27 ppm was observed in Pokkali and highest of 17.28 ppm in north central laterites (AEU 10).

The Mn, Cu, Zn and B content in shoot at active tillering was not in proportion to their available status in soils. This may require further investigations on the factors governing absorptions of these ions and their interactions in soils.

5.8.2. Visual panicle initiation

The nutrient content in rice during visual panicle initiation stages are given in table Nos.30, 31 and 32. The total nitrogen content neither in shoot nor in root showed any relations with total and available nitrogen content in soil at visual panicle initiation stage. This needs further investigations. The total P content recorded the highest value in Onattukara. In soils of Pokkali where the available P content at different stages recorded the highest values in contrast to this the shoot P content recorded the lowest value for Pokkali soils. Eventhough the highest K content was recorded in Pokkali soils the shoot K content from these soils was the lowest among the samples collected. The inverse relation of shoot content of P and K with the corresponding available content in soils might be due to competitive and/or inhibitory effects of other factors in Pokkali soils. The kinetics of absorption by plants in these soils in relation to available status needs further detailed investigations. The Ca content in shoots recorded lowest values in Pokkali soils where the available Ca was also lowest. While in black cotton soils, where the Ca was the highest resulted in highest Ca content in shoot. The same trend was observed in panicle also. The magnesium content in shoot and root did not show any relation with available Mg status. However, lowest Mg content was recorded in panicles from Onattukara region where available Mg status was also low. The S content in panicle was lowest from those in Palakkad central plains where the available S status was also lowest. The content of Fe, Mn, Cu and Zn did not show any relation to their respective available status in soil. As in case of P and K, the boron content in shoot and panicle showed an inverse relation with the available B status of the soil.

Thus soils from Pokkali having highest available B recorded lowest B content in shoot whereas Onattukara soils having lowest available B content recorded highest shoot content of boron (9.6 ppm).

5.9. **Correlations between different soil parameters and nutrient contents in soils of 7 AEU's**

The correlations between different soil parameters and nutrient contents in soils of 7 AEU's are given in table Nos. 33 and 34.

In case of dry analysis, the significant negative correlation of pH with organic carbon and available S would mean the decrease in pH with increase in organic carbon and available sulphur. Increase in organic carbon naturally should have resulted in reduction of organic acids leading to a decrease in pH. Similarly, an increase in available S indicate accumulation of SO_4^{2-} ions which in turn lead to decrease in pH. The negative correlation of EC with pH could be resulted from increase of acidity. The positive correlation of EC with available N, K, Mg, Fe, S and B is the outcome of increased salinity levels due to increased concentration of the ions or salts of the above elements. Significant negative correlation of available P with Ca is due to formation of insoluble Ca phosphates resulting in decreased availability of P. Significant negative correlation of Ca with available B is due to decrease in solubility of B due to excess of Ca.

In case of wet analysis, the significant positive correlation of pH with available Ca is due to the liming effect of Ca. While significant negative correlation of pH with available S is due to dominance of SO_4^{2-} ions. The significant positive correlation of organic carbon with available N, Ca, Mg, Fe and B clearly indicate the role of organic matter as a source of nutrient elements.

5.10. Correlations between computed C: N ratios and total N and available N in soil

Correlations between computed C: N ratios and total N and available N in soil are given in table Nos. 36-41. The significant correlation of computed C: N ratios with total nitrogen as well as available N indicated the already established fact that above 95 % of nitrogen in soil exist in organic form. Thus either total carbon or organic carbon estimation in these soils will definitely give an index of N status in soil.

5.11. Correlation between nutrient status in soil and plant content

The lack of correlation may be an indication of highly variable parameters in soils from different agroecological units. This was further estsblished when spearman correlation was done after cross tabulation based on weightage given to values based on their ranges (Table No. 42).

5.12. Changes in pH, Eh, total carbon, total nitrogen, and available nitrogen and computed C: N ratios with respect to days of submergence

Irrespective of type of soil and irrespective of the organic manure addition pH of the soil did not show any appreciable variation with days of submergence for the first 15 days. However, in all the soils pH slightly increased 7 days after submergence and further it decreased and stabilized. The redox potential was recorded in only 2 soils i.e. Onattukara and Kuttanad incubated with and without organic matter. In Onattukara soils with addition of organic matter redox was decreasing to negative values within 15 days showing reduced atmosphere. (Fig. 2).While in the same soils without addition of organic matter redox potential was decreasing but not attained negative value on 15^{th} day. The same trend was observed in Kuttanad soils also with or without addition of organic matter. (C: N) 1 ratio was found to stabilize at 7 to 9 after 3 months of incubation in Onattukara soil with the addition of organic matter whereas it stabilized at 7 in the treatment without the addition of organic matter. The (C: N) 1 ratio observed in Kuttanad soils with and without the addition of organic matter was 18.32 and 17.26 respectively, whereas it stabilized in and around 10 in Chittor black soils. Addition of organic matter slightly increased the ratio in Onattukara and Kuttanad soils whereas such a difference was not noticed in lateritic and Chittor soils. In case of (C: N) 3 trend was almost similar but was found to stabilize around 7 to 8 in Onattukara, 8 to 9 in Kuttanad, 12 to 13 in Pattambi soils and around 8 in black soils from Chittor. It is clear from the data i.e. (C: N) 1 and (C: N) 3 that the ratio increased and stabilized in all the soils except in Kuttanad where a gradual decrease and stabilization was noticed (Figures 21 to 41).

Figure 21. Changes in pH in Onattukara sandy soil with respect to days of submergence

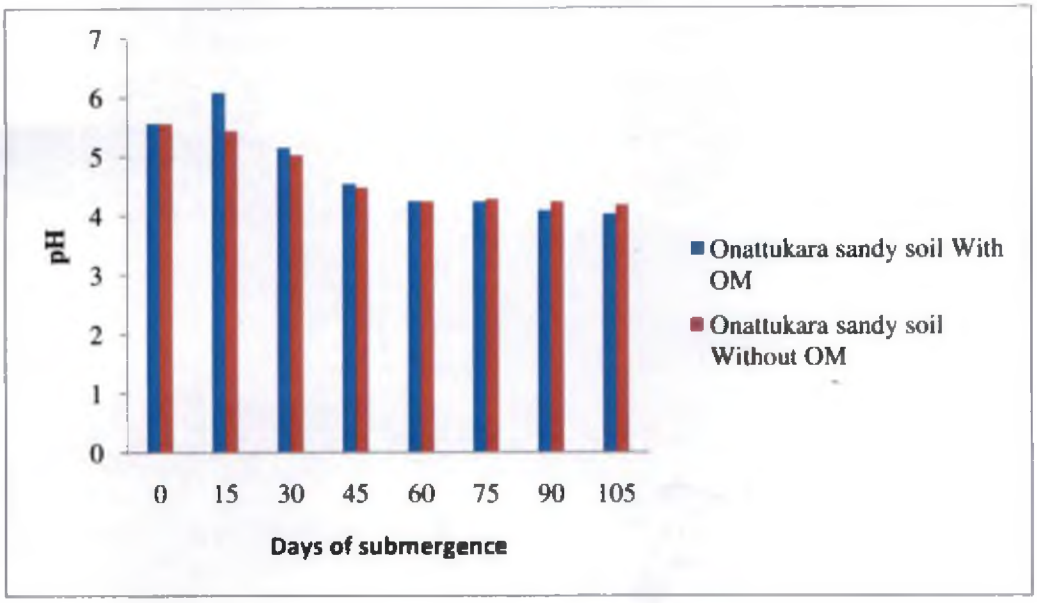


Figure 22. Changes in pH in Kuttanad soil with respect to days of submergence

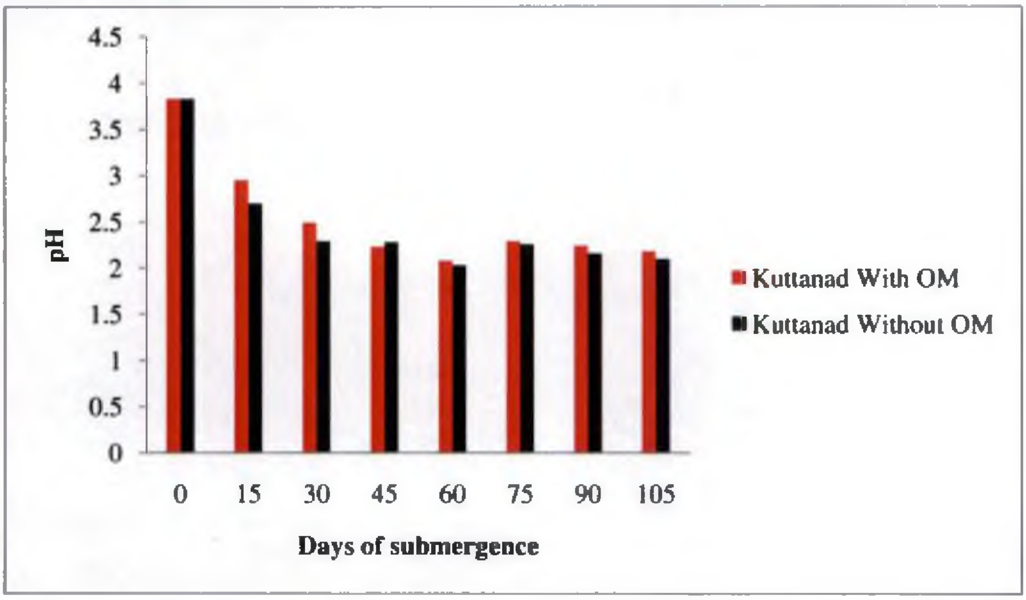


Figure 23. Changes in pH in north central laterites with respect to days of submergence

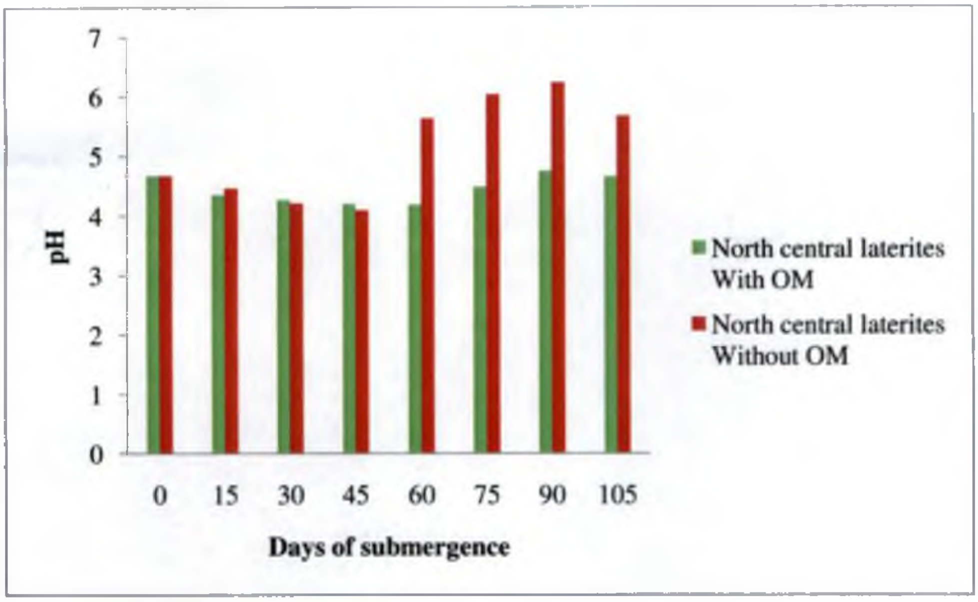


Figure 24. Changes in pH in Palakkad eastern plains with respect to days of submergence

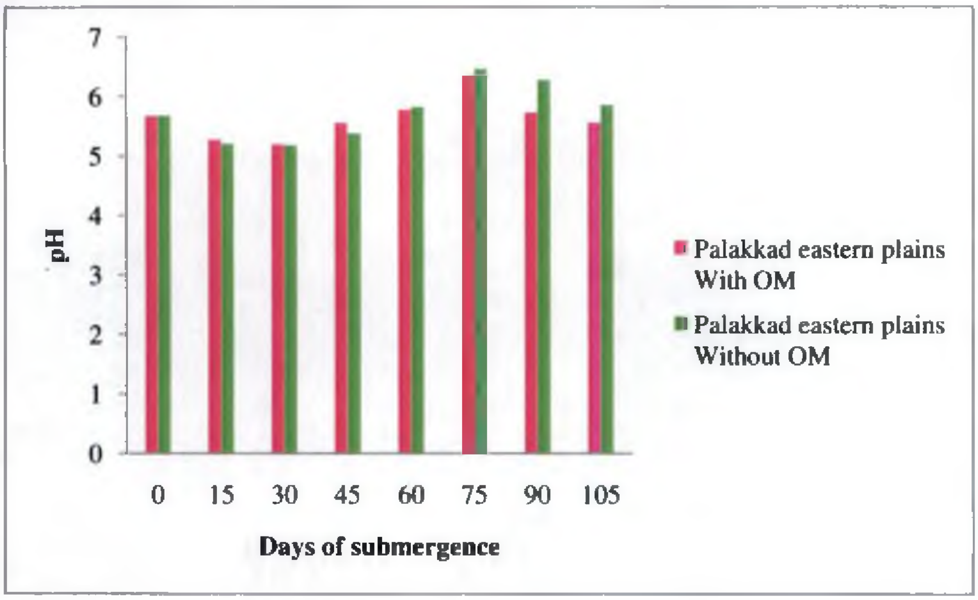


Figure 25. Changes in redox potential, Eh in Onattukara sandy soil with respect to time of submergence

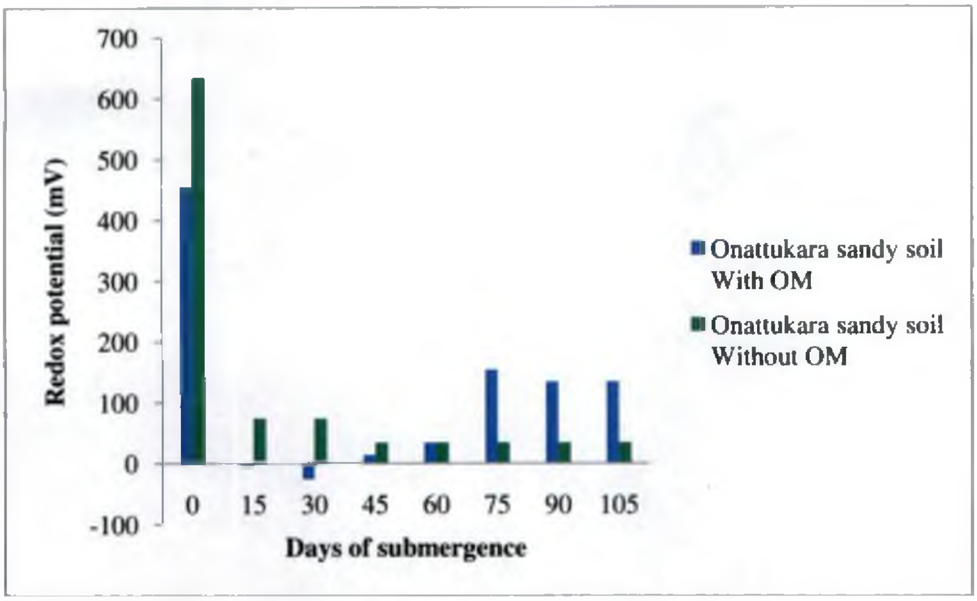


Figure 26. Changes in redox potential, Eh in Kuttanad soil with respect to time of submergence

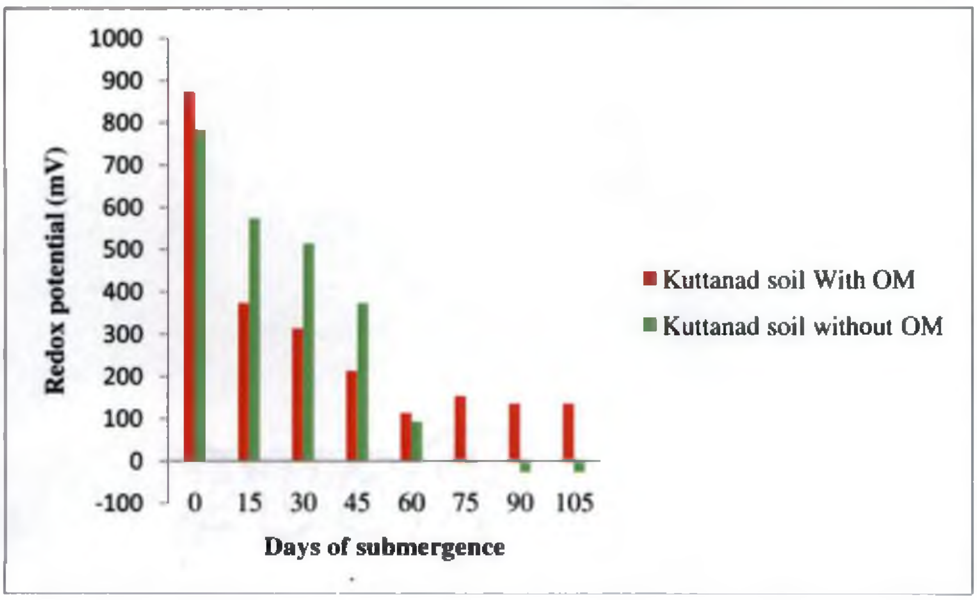


Figure 27. Changes in total carbon: total nitrogen (C:N)1 ratio in Onattukara sandy soil with respect to time of submergence

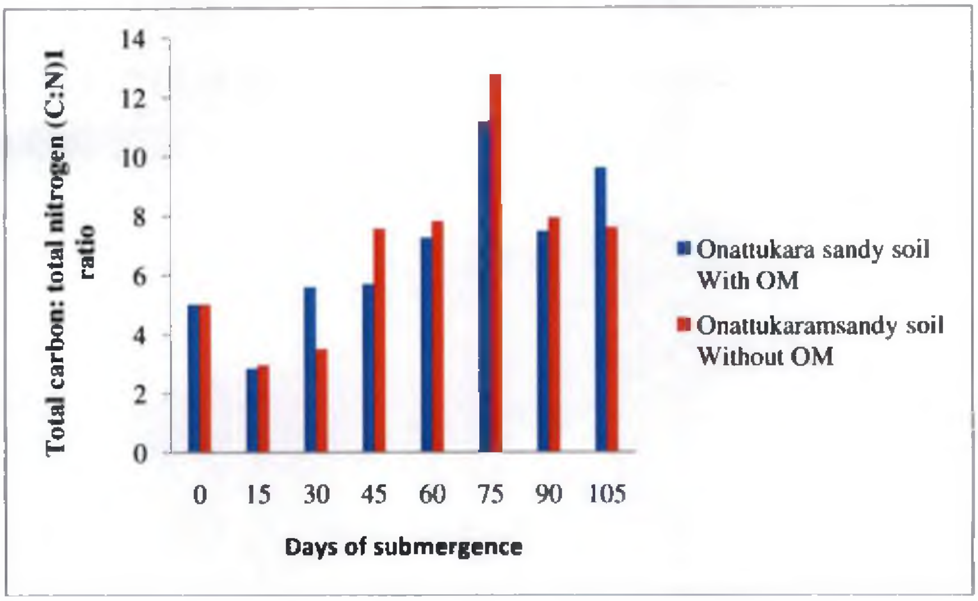


Figure 28. Changes in total carbon: total nitrogen (C:N)1 ratio in Kuttanad soil with respect to time of submergence

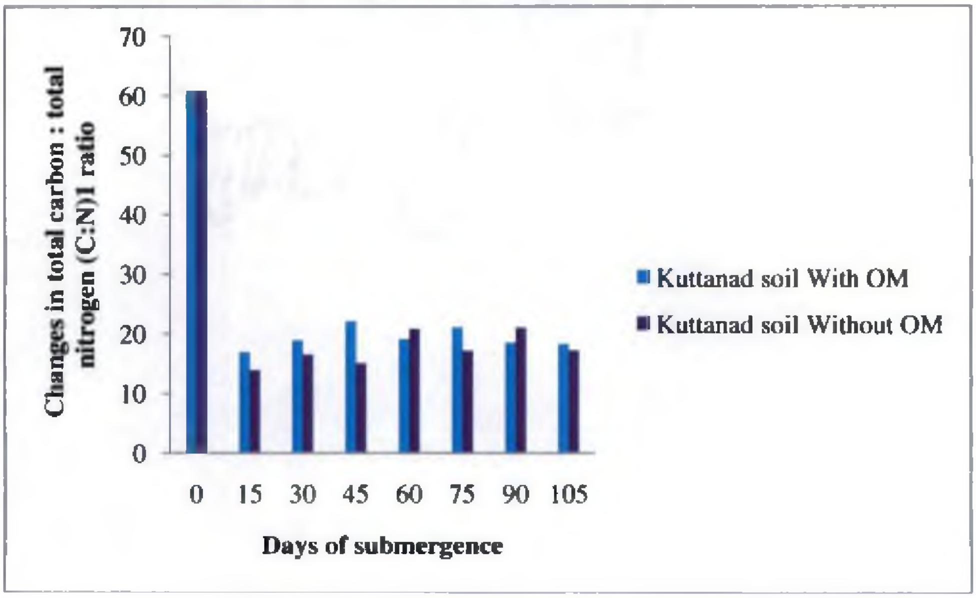


Figure 29. Changes in total carbon: total nitrogen (C: N) 1 ratio in north central laterites with respect to time of submergence

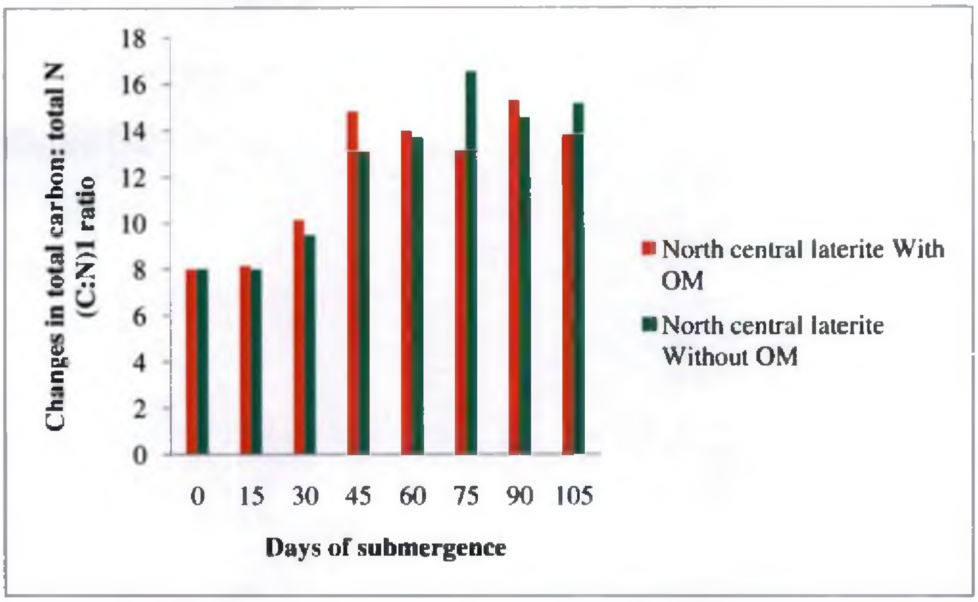


Figure 30. Changes in total carbon: total nitrogen (C: N) 1 ratio in Palakkad eastern plains with respect to time of submergence

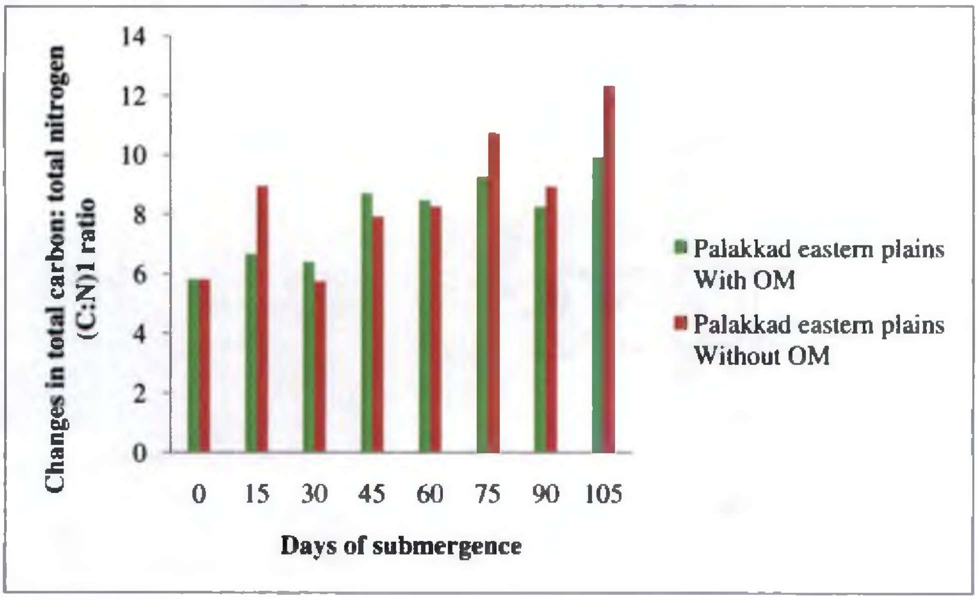


Figure 31. Changes in total carbon: available nitrogen (C:N)2 ratio in Onattukara sandy soil with respect to time of submergence

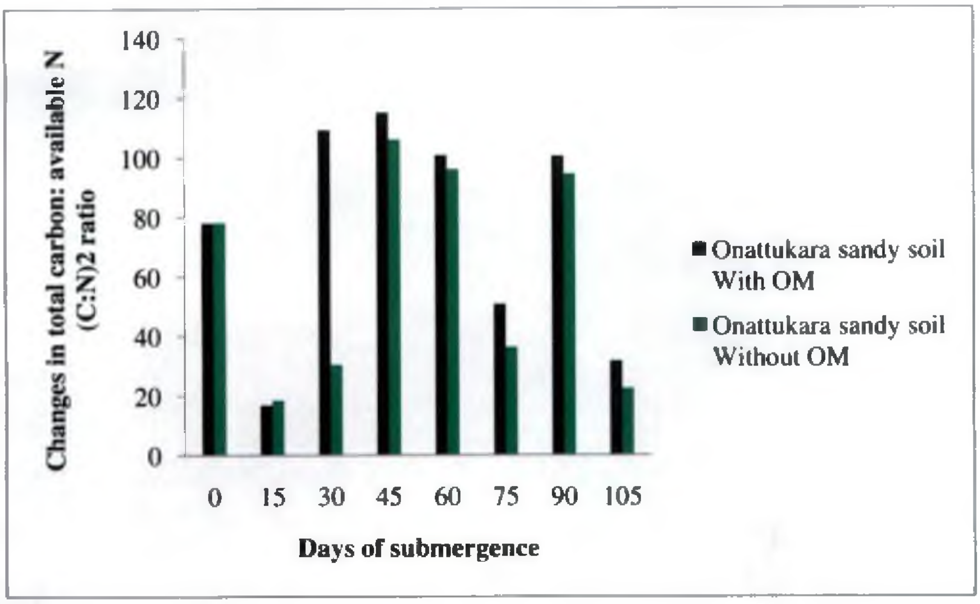


Figure 32. Changes in total carbon: available nitrogen (C:N)2 ratio in Kuttanad soil with respect to time of submergence

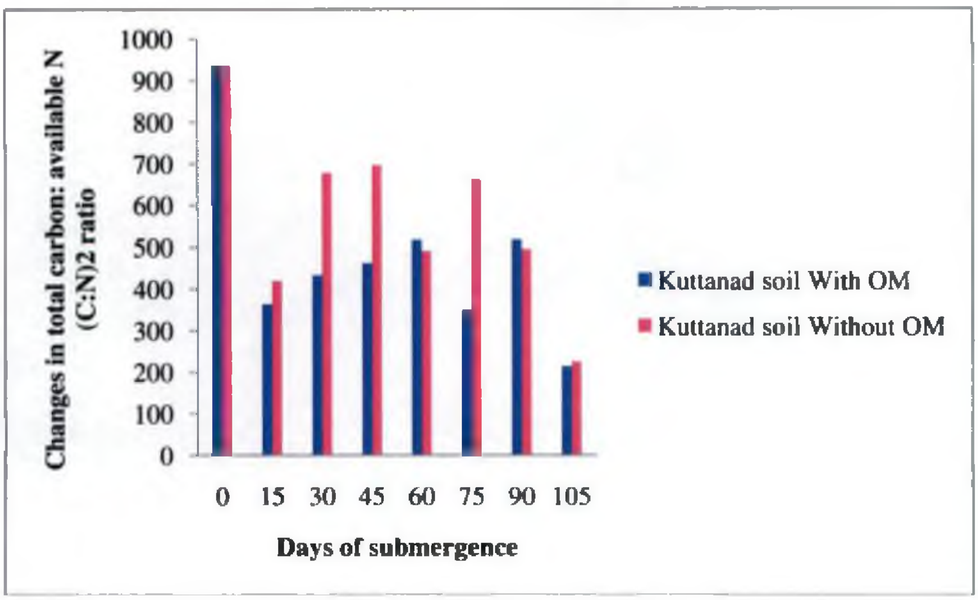


Figure 33. Changes in total carbon: available nitrogen (C:N)2 ratio in north central laterites with respect to time of submergence

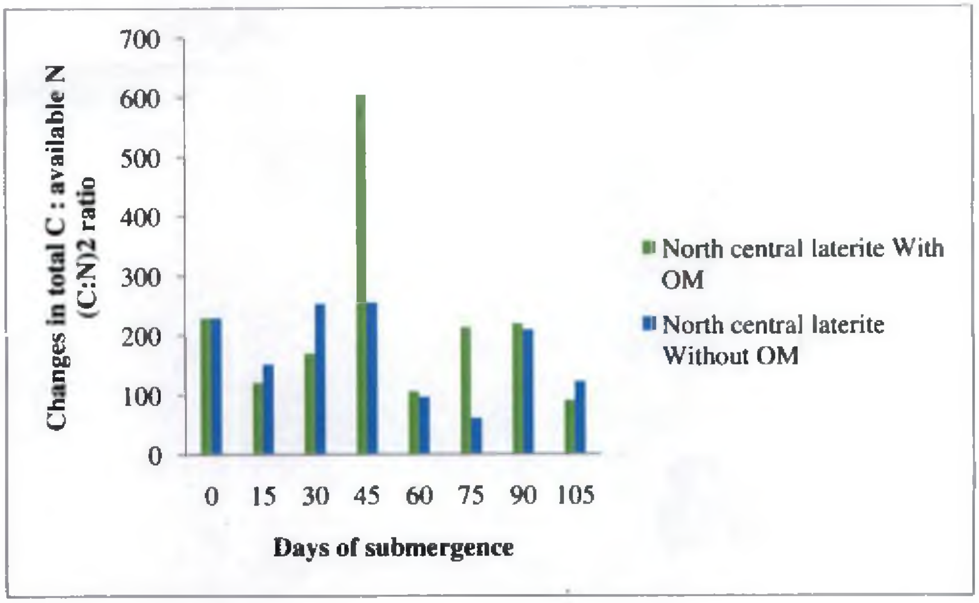


Figure 34. Changes in total carbon: available nitrogen (C:N)2 ratio in Palakkad eastern plains with respect to time of submergence

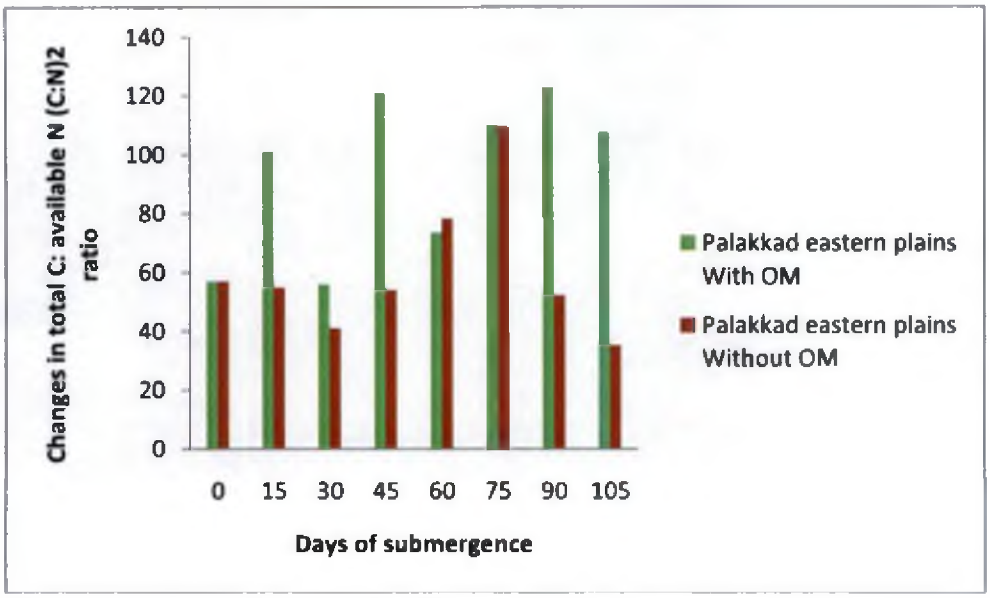


Figure 35. Changes in organic carbon: total nitrogen (C: N) 3 ratio in Onattukara sandy soils with respect to time of submergence

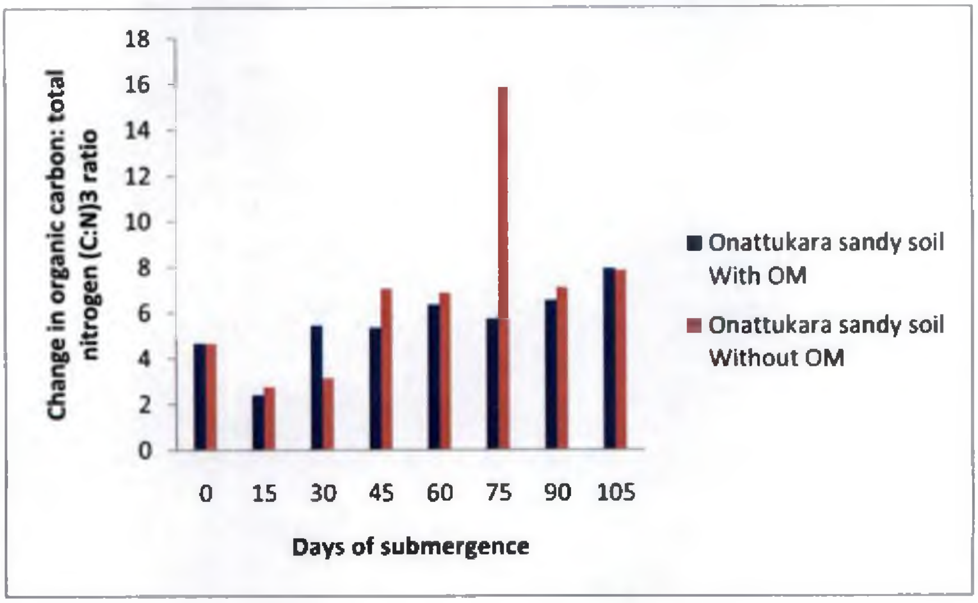


Figure 36. Changes in organic carbon: total nitrogen (C:N)3 ratio in Kuttanad soils with respect to time of submergence

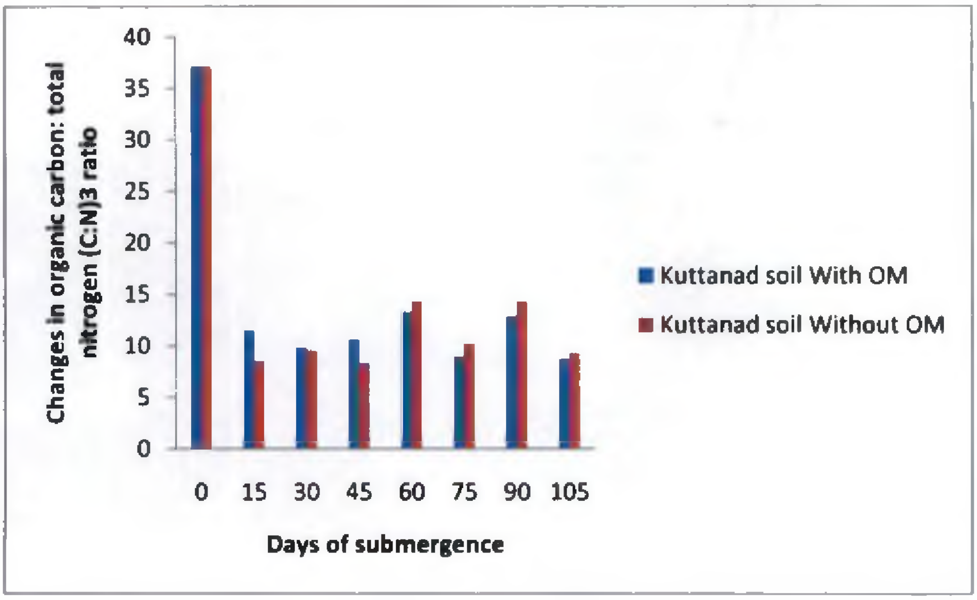


Figure 37. Changes in organic carbon: total nitrogen (C:N)3 ratio in north central laterites with respect to time of submergence

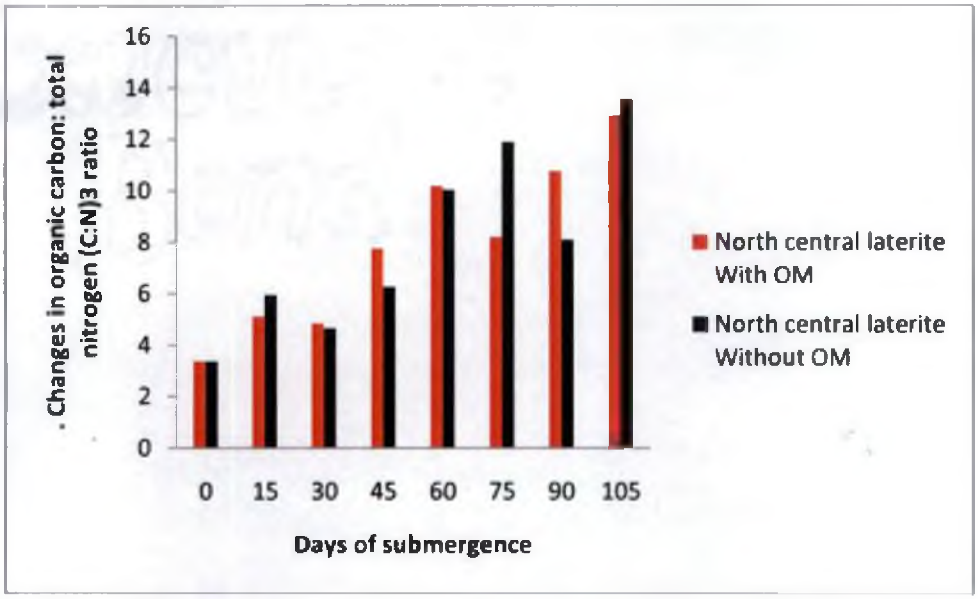


Figure 38. Changes in organic carbon: total nitrogen (C: N) 3 ratio in Palakkad eastern plains with respect to time of submergence

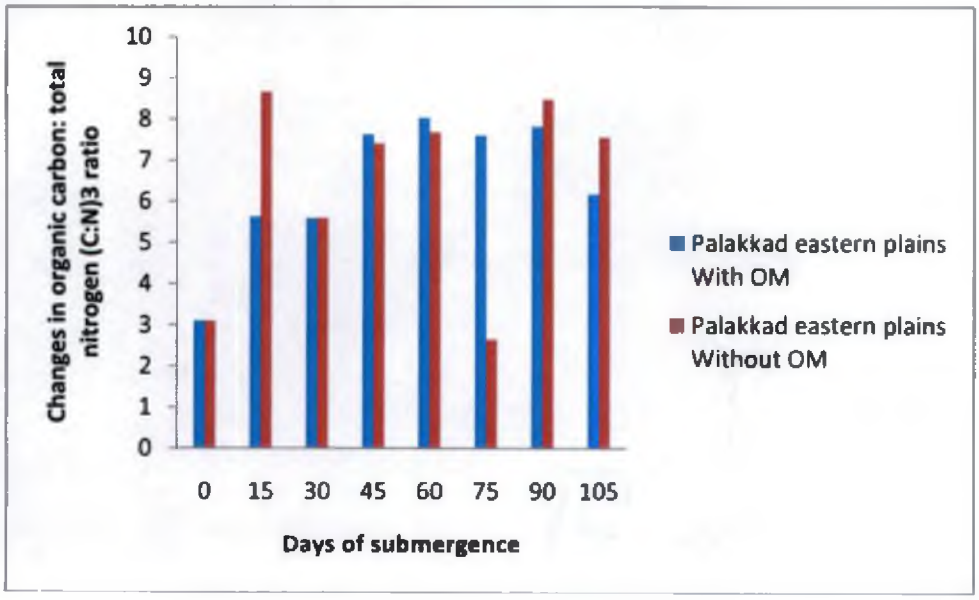


Figure 39. Changes in organic carbon: available nitrogen (C:N)4 ratio in Onattukara sandy soils with respect to time of submergence

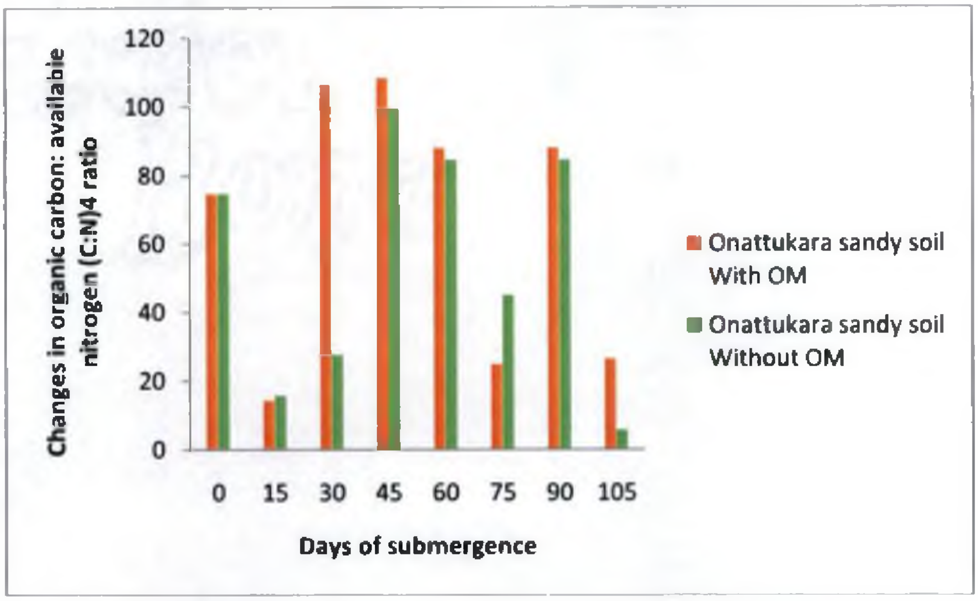


Figure 40. Changes in organic carbon: available nitrogen (C:N)4 ratio in Kuttanad soils with respect to time of submergence

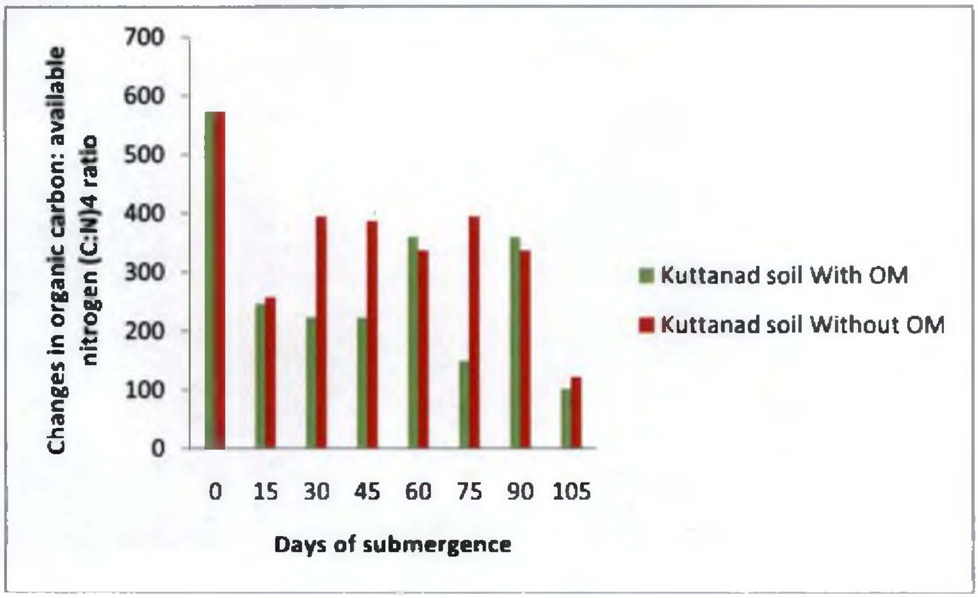


Figure 41. Changes in organic carbon: available nitrogen (C:N)4 ratio in north central laterites with respect to time of submergence

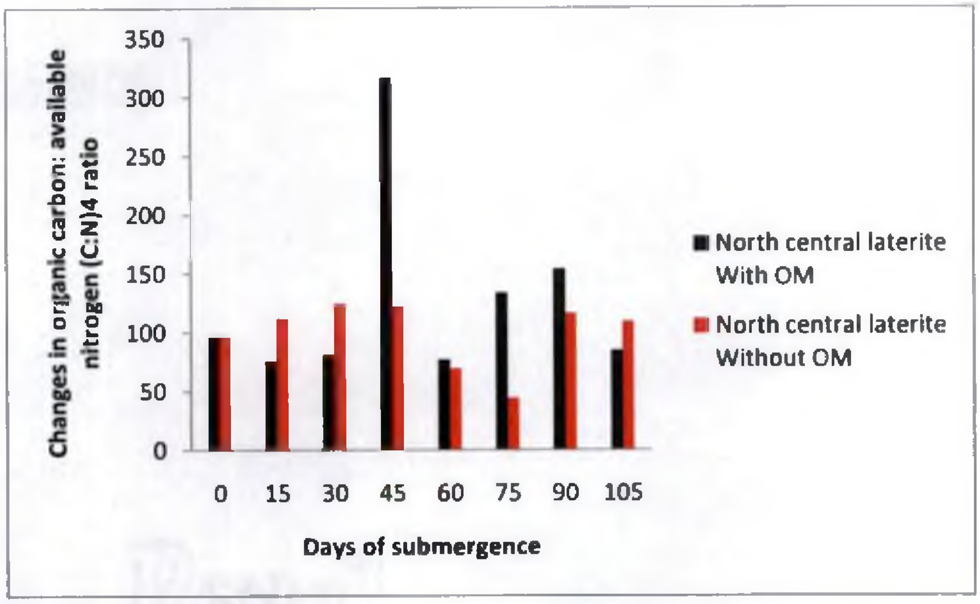
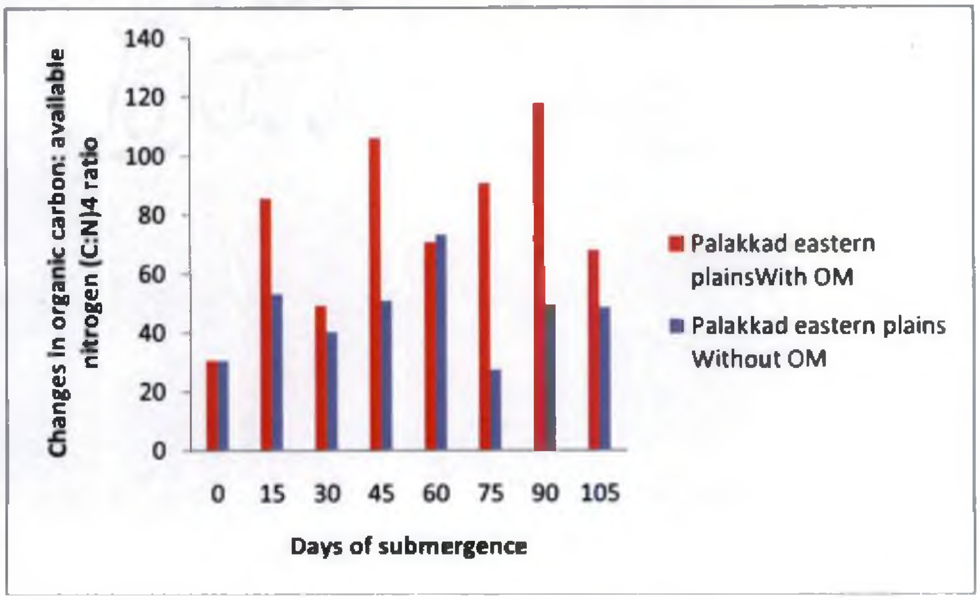


Figure 42. Changes in organic carbon: available nitrogen (C:N)4 ratio in Palakkad eastern plains with respect to time of submergence



Summary

Summary

Representative soil samples from major rice growing tracts in state coming under 7 agro-ecological units(AEU's) were selected namely, *Onattukkara* sandy soil (AEU 3), *Kuttanad* (AEU 4), *Pokkali* (AEU 5), *Kole* (AEU 6), midland wetland laterite (AEU 10), rice soils of Palakkad (AEU 22) and black soil from Chittor Taluk of Palakkad (AEU 23) have been collected and characterized for the study on "Wet soil analysis for nutrient prescription in paddy soils". Soil samples were collected at 3 stages viz. the first before starting rice cultivation and the second and third at active tillering and visual panicle initiation stages of rice crop. Plant samples were also collected during the above stages of the crop. Soil samples were characterized with respect to pH, EC, OC, total carbon and nitrogen, available nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B). Plant samples were also characterized for total C, N, , P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. Four soil types namely, (i) *Onattukara* sandy soils (Entisol AEU 3), (ii) *Kari* soils from *Kuttanad* (Entisol AEU 4), (iii) Wet land lateritic soil (Ultisol AEU 10) and (iv) Black soil from Chittoor Taluk of Palakkad (Vertisol AEU 23) were used for an incubation study on the pattern of decomposition of added organic matter and to identify the corresponding variations and stabilization of C: N ratio at equilibrium. The salient results of the study are summarized and listed below.

- The initial characterization of soil samples from 7 agro ecological units indicated that based on pH the samples from different agro ecological units came under the classes: ultra acidic (< 3.5) - Kuttanad (AEU 4), extremely acidic (3.5- 4.4) - Onattukara sandy plains (AEU 3), very strongly acidic (4.5-5.0) - Palakkad central plains (AEU 22) and north central laterites (AEU 10), strongly acidic (5.1-5.5)- Kole lands (AEU 6), and slightly acidic (6.1-6.5)- Pokkali lands (AEU 5) and Palakkad eastern plains (AEU 23).
- Electrical conductivity was highest in Pokkali lands (2.25 dS m^{-1}).

- The organic carbon status indicated high levels in Kuttanad alone. Very low levels of organic carbon was recorded in Onattukara sandy plains. Total carbon and total nitrogen also showed the same trend.
- The C: N ratio based on total carbon and total nitrogen i.e. (C: N) 1 was in and around 10-13 in all soils except Kuttanad where it was 21.53.
- Very wide C: N ratio's were obtained when computed with total carbon and available nitrogen i.e. (C: N) 2 (52-175).
- The C: N ratio based on organic carbon and total nitrogen i.e. (C: N) 3 varied from 6.35 in Pokkali to 19.89 in Kuttanad.
- The C: N ratio based on organic carbon and available nitrogen i.e. (C: N) 4 also resulted wide ratio's varying from 16 to 161.
- The available P status was medium to high with highest value recorded in Pokkali soils (79.14 kg ha^{-1}).
- The available K status varied from low to high with Pokkali lands recording very high values (427 kg ha^{-1}).
- Calcium was deficient in all the agroecological units except in Palakkad eastern plains (AEU 23), 384 mg kg^{-1} soil). Magnesium was extremely deficient in all the AEU's. The sulphur content recorded very high values in Kuttanad followed by Palakkad eastern plains and Pokkali soils (AEU 5).
- The Fe status was highest in Kuttanad soils.Deficiency of Fe, Mn and Cu was not observed in any of the agroecological unit recorded sufficiency levels or more in samples from all AEU's. Zn was deficient only in Palakkad central plains. Whereas B deficiency was observed in Onattukara sandy plains (AEU 3) and Palakkad eastern plains (AEU 23).
- The pH increased from the initial values irrespective of the type of analysis both at active tillering and visual panicle initiation stage. Comparison of wet and dry analysis indicated a reduced value for pH when analyzed after drying. Electrical conductivity decreased from the initial value during

flooding. Dry analysis gave higher values in comparison with that obtained on wet analysis.

- At active tillering stage, (C: N) 1 ratio based on total carbon and total nitrogen tend to stabilize around 18:1 when computed on the basis of wet analysis in Kuttanad, around 15 in north central laterites and Kole and 17 in Pokkali lands. In all other cases it varied from 10-12. On analysis after drying, (C: N) 1 ratio was found to increase from 10 in north central laterites to 22 in Kuttanad soils. While in visual panicle initiation stage, this ratio tend to stabilize at 11-15 in all soils except Kuttanad and Onattukara on the basis of wet analysis. The values for Onattukara soils was 9.3 and in Kuttanad it was 17.3. The same (C: N) 1 ratio computed based on dry analysis indicated a ratio of 11 to 12 in all soils except in Kuttanad and Kole lands where it was above 20:1. The (C: N) 2 computed on the basis of total carbon and available nitrogen and (C: N) 4 based on organic carbon and available nitrogen did not give any clear trends and were very much wider. During active tillering stage, the (C: N) 3 based on organic carbon and total nitrogen on wet analysis basis varied between 8 to 13 where the highest ratio was recorded in Kuttanad and lowest in Onattukara. While in visual panicle initiation stage, (C: N) 3 varied between 8 to 15 where the highest ratio was recorded in Kuttanad and lowest in Onattukara. (C: N) 3 ratio computed on dry analysis basis gave narrower ratio's.
- The data at active tillering and visual panicle initiation on available P was consistently high when analyzed as such on wet basis. At active tillering stage potassium recorded lower values when analyzed after drying in comparison with those obtained on wet analysis. Available Ca and Mg also showed similar trends during active tillering and panicle initiation stage. The available S content showed a reverse trend i.e. available S content was higher when analyzed on dry basis. The available Fe content was found to register

lower values when analyzed after drying. However, the values of available Mn were found to be higher in dry analysis so also the case of Zn. The hot water extractable boron recorded higher values both at active tillering and panicle initiation stages in dry analysis.

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WET SOIL ANALYSIS FOR NUTRIENT PRESCRIPTION IN PADDY SOILS

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Abstract

Three locations from 7 agro ecological units dominated by rice crop were identified namely, *Onattukkara* sandy soil(AEU 3), *Kuttanad*(AEU 4), *Pokkali*(AEU 5), *Kole*(AEU 6), north central laterite(AEU 10), Palakkad central plains (AEU 22) and Palakkad eastern plains (Black soils)(AEU 23). Geo-referenced soil samples were collected at 3 stages: before cropping season, at active tillering and visual panicle initiation. Plant samples were also collected during the above stages and analyzed for nutrient contents. Initial characterization was done with air dried samples while samples during crop growth period were collected by maintaining the wet anaerobic conditions and analyzed as such as well as after drying. Submergence resulted increase in pH both under wet and dry analysis. The pH on the basis of wet analysis was higher than that by dry analysis. EC decreased during flooding and dry analysis gave higher values than by wet analysis. The (C: N) 1 ratio (based on total carbon and total nitrogen) varied from 9.32 :1 in *Onattukara*sandy soil to 18:1 in *Kuttanad* on the basis of wet analysis. Analysis after drying recorded a (C: N) 1 ratio ranging from 10.84 in Palakkad central plains to 22 in *Kuttanad.* Comparison of wet and dry analysis of other available nutrients indicated that higher values were recorded for P, K, Ca, Mg and Fe in wet analysis while the values for availableS, Mn, Zn and B were higher in dry analysis. Data on analysis after drying, recorded significant negative correlation of pH with organic carbon (-0.36**) and available S (-0.37**) due to accumulation of organic acids and SO_4^{2-} ions under aerobic condition. Antagonistic interaction of available P with available Ca was attributed to significant negative correlation obtained between them in dry analysis. Wet analysis gave significant positive correlation of pH with available Ca (0.35**) and significant negative correlation with available S (-0.28*). All the C: N ratios computed on the

basis of, total carbon and total nitrogen (C: N) 1, total carbon and available nitrogen (C: N) 2, organic carbon and total nitrogen (C: N) 3 and organic carbon and available nitrogen(C: N) 4 were significantly correlated with total and available nitrogen at different stages both under wet and dry analysis.

Four soil types namely, *Onattukara* sandy, *Kuttanad*, north central laterites and Palakkad eastern plains were used for an incubation study to unravel the pattern of decomposition of added organic matter and to identify the C: N ratio at equilibrium. Changes in pH and redox potential during submergence indicated slight increase in pH after 7 days of submergence and redox potential was constantly decreasing with increasing period of submergence. The (C: N) 1 ratio was found to stabilize at 9.6:1 after 3 months of incubation with organic matter while it was stabilized at 7.6:1 without organic matter in *Onattukara* soil. In *Kuttanad* soils it was 18.3:1 and 17:3 respectively. In Chittor soils it stabilized at 10:1. The (C: N) 3 also showed similar trends.

However, available nutrient did not give any significant correlation with the corresponding plant content of the respective nutrient. This focuses to the importance of future studies with more number of samples from each AEU's as each of the fertility parameters are highly varying in these units.