Diagnosis & Recommendation Integrated System (DRIS) to identify yield limiting nutrients of an intensively rice grown soil (*Inceptisol)*

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By

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CERTIFICATE-I

This is to certify that the thesis entitled "**Diagnosis & Recommendation Integrated System (DRIS) to identify yield limiting nutrients of an intensively rice grown soil (*Inceptisol)*"** submitted in partial fulfillment of requirements for the award of the degree of **MASTER OF SCIENCES IN AGRICULTURE(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)**to the **ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,**Bhubaneswar, is a faithful record of bonafide and original research work carried out by **TIRTHA PATTNAYAK**, **Adm.No. 09AC/15** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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This is to certify that the thesis entitled "**Diagnosis &Recommendation Integrated System (DRIS) to identify yield limiting nutrients of an intensively rice grown soil (*Inceptisol)***" submitted by **TIRTHA PATTNAYAK Adm. No. 09AC/15**to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)** has been approved by the students' advisory committee and the external examiner.

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Place: Bhubaneswar …………………

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Rice-rice is an important production system for eastern India. Over years of continuous cropping the system has lost its potential to sustain the productivity. For restoration of the degraded soil there is an urgent need to understand the changes in the soil properties that have occurred over years, and correctly identify the nutrients limiting that crop yield. By soil test method actual nutrient that limits crop yield is not always correctly identified and therefore precise and effective fertilizer recommendation could not be done.The Present investigation was therefore made to identify nutrients limiting crop yield under rice rice system in the order of limiting importance by using DRIS, which is an integrated Plant Nutritional diagnostic technique developed by Beaufils (1973)

In order to fulfill the objective a 10 year old long term fertilizer experiment conducted on a light textured sandy loam a acidic soil of Bhubaneswar with 12 numbers of manurial treatments was used. Leaf samples were collected at flowering stage of crop grown in two seasons, *kharif* 2015 and *rabi* 2015 -16 for Plant analysis of different nutrients. Various nutrient ratios were computed for determining DRIS Index ofindividual nutrient following standard computational method DRIS Index values obtained were arranged in ascending order from most negative to most positive value. From index value nutrient balance index (NBI) was calculated by the summation of the absolute values. Higher the NBI value, greater is the nutrient imbalance. Based on this concept, in *kharif*100%N treatment had highest NBI of 155.13 was found to be nutritionally most imbalanced and 100%NPK +FYM with smallest NBI of 20.07 was nutritionally most balanced treatment. In *rabi* season the unmanured control with highest NBI (237.14)was most imbalanced followed by 100%NPK+Zn (174.32),100%N(133.28),100%PK(117.18) and 100% NPK +FYM was the most balanced treatment followed by 100%NPK+FYM and Lime(39.75) .

Based on the DRIS indices and average NBI (NBIa) it is observed that continuous application of RDF(100%NPK),nitrogen is the most limiting followed by phosphorous and potassium in both *kharif* and *rabi* season and . By increasing the dose by 50% phosphorous was found be the most limiting nutrient after 10 years followed by sulphur and nitrogen. Addition of 5t FYM to RDF however improved the situation with more balanced nutrition. However, after 10 years calcium with DRIS index of -12.38 appeared to be limiting followed by K and Mg. In *kharif* potassium was the limiting nutrient in most treatments. Where as in *rabi*, nitrogen was most deficient.

Thus depending on the treatment, the nutrients limiting crop yield varied and the limiting nutrients also varied in terms of their extent of deficiency. Besides the nutrients which are sufficient to excess could also be determined .There is seasonal difference with respect to nutrients limiting crop yield. Nutrients limiting crop yield as identified through plant analysis DRIS method are not always same to those found deficient by soil test method. DRIS technique can be applied to different crops and different agroclimatic situations to identify the nutrients limiting crop yield under a particular situation.

CHAPTER-1

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.*)* is one of the widely cultivated and consumer oriented crop in India occupying an area of 43.77 million hectare with a production of 69.43 million tonnes (Ravi *et al.,* 2015). It is an important cereal crop grown in Odisha with production of 70 Lakh tonnes (Assocham, 2017). It is the staple food of Odisha. Because of growing population, the demand for rice is expected to increase in the coming decades. However, to meet this demand the crop should perform to its full potential. Rice production in India is plateaud over the years. The yield stagnation is due to poor nutrient supply capacity of soil.

Soil testing is one of the most commonly used diagnostic techniques of soil fertility evaluation. The soil analysis method is based on assumption that chemical extractant simulate the root system. However it does not take into account the factors such as soil temperature and aeration and even higher and lower absorption rate due to the plant own nutritional demands. Another soil analysis limitation is soil sampling, which is supposed to actually represent the soil portion explored by root(Reuther and Smith 1954)it also sometimes fails to correctly diagnose the problem for correcting the deficiency.

On other hand Plant analysis is another method to know the sufficiency and deficiency of nutrient in soil .Plant analysis has been considered a very practical approach for diagnosing nutritional disorders (Kelling *et al.,* 2000.) But this method also fails to issue correct recommendation for fertilizer application. Plant analysis in conjunction with soil testing becomes a highly useful tool not only in diagnosing the nutritional status but also an aid in management decisions for improving the crop nutrition.

Plant analysis is a quantitative analysis of total nutrient content in the leaf tissue based on principle that amount of nutrient in diagnostic plant parts indicate soil's ability to supply that nutrient and its directly related to the available nutrient status in the soil (Halvin *et al.,* 2004, Rashid 2005) .In plant analysis interpretation is done comparing the level of nutrient(s) in the in tissue of the index leaf with critical or optimum range of the concerned nutrient. In case of rice, third leaf from terminal position of plant has been identified as the index leaf for sampling

Tissue analysis is considered as the more direct method of plant nutritional evaluation than soil analysis but that method must necessarily involve a precise analysis of plant parts (Hallmark and Beverly 1991). Among the several tissues top considered for nutrition diagnosis purposes, leaves constitute the main sampling material (Hallmark and Beverly 1991). The leaf tissue is considered the most important part of the plant where the physiological activity happens and this tissue shows easily the nutritional changes. Furthermore, to assess the nutritional status there is a need to have leaf standard to sample, and this leaf standard depend on the crop.

The leaf analysis data can be a useful tool to assess the nutritional status of plant, but, the procedure to analyse the data must be appropriate. The interpretation of nutrients contents in leaf analyses can be made by several methods to assess plant nutritional status. To interpret results of traditional chemical analyses of plant tissue for the assessment of the nutritional status of plants, the methods of critical level and sufficiency range are used more frequently (Beaufils, 1973; Walworth & Sumner, 1987;MourãoFilho, 2004).

The sufficiency range is the most used method of diagnosis, and this method consists on optimum ranges of nutrients concentration to establish the nutritional state of crops, otherwise to use the sufficiency range it is necessary to develop regional calibration that is very expensive and also does not give nutritional balance index of plant. The interpretation of the limiting nutrients based on this critical nutrient concentration (CNC) of one nutrient does not take in to consideration the level of other nutrients. Moreover, this CNC varies with local climate and soil, as well as with type of cultivars, age and the type of the plant tissue being sampled (Escano *et al.,* 1981).

The work of Beaufils (1971, 1973) has clearly indicated that the adequacy of given nutrient or otherwise could be better diagnosed in relation to the level of other nutrients. He developed a technique called as “Diagnosis and Recommendation Integrated System” (DRIS), in which not only the nutrient(s) deficient is/are identified but also the order of their severity is prioritized, which indicate the nutrient that needs to be corrected first before attempting to correct the next deficient nutrient through its application.

DRIS is a perfect combination of soil test and Plant analysis .It identifies all nutritional factors that retard the optimum crop production. Nutrient concentration changes with the physiological growth stage of plant and varies in different plant parts. Here the results of plant analysis are compared with critical nutrient concentration .The first step to implement DRIS or any other foliar diagnostic system is the establishment of standard values or norms (Walworth and Sumner 1987, Bailey *et al* 1997). In Oder to establish DRIS norms, it is obligatory to use representative value of leaf nutrient concentrations and respective yields to obtain accurate estimates of means and variances of certain nutrient ratios.

DRIS relates the nutrient contents in dual ratios (N/P, P/N, N/K, K/N...), because of the relation between two nutrients, the problem with the biomass accumulation and reduction of the nutrients concentration in plants with its age is solved (Beaufils, 1973; Walworth & Sumner, 1987; Singh *et al.*, 2000). The use of DRIS on concept of nutritional balance of a plant is becoming an efficient method to assess the nutritional status of plants, this method puts the limitation of nutrients in order of plant demand, enabling the nutritional balance between the nutrient in leaf sample.

For each nutrient under diagnosis, the DRIS method provides one DRIS index, this index can be positive or negative, which represents the effect of each nutrient into the nutritional balance of the plant. The closer the proximity of the DRIS index to zero, closer to the nutritional balance this nutrient will be this nutrient.

The origin of these indices is from the comparative analysis with the norms previously established being necessary to relate the nutrients in dual ratios (N/P, P/N, N/K, K/N, etc.) in the sample, and in this way, it is possible to assess the sample through the DRIS system.

It is necessary to interpret the DRIS index for each nutrient and this interpretation depends on the value and the sign of the index. The order of nutrient requirement by plant is the most used method to interpret the DRIS indices.

In this method, the DRIS indices are arranged from the most negative to the most positive value. When the DRIS index is close to zero, it means that the nutrient is adequate for the plant.

The major advantage lies in its ability to minimize the effect of tissue age on diagnosis. Allow nutrient of classification (from the most deficient to most excessive) can detect cases of yield limiting due to nutrient imbalance.

With the variations in local conditions, this approach of DRIS has produced more accurate nutritional diagnosis than the conventional critical nutrient concentration (CNC) approach in several crops (Beaufils 1973).

Very few studies have been conducted to use DRIS approach for rice-rice system present in India. Conventional soil to rice-rice has also not been successful in sustaining in rice production. Therefore it is proposed to correctly diagnosis the most limiting nutrients in rice-rice system through Diagnosis & Recommendation Integrated System (DRIS) applied to a 10 year old Long term Fertilizer experiment that started in 2005-2006 by ICAR in Central Research Station OUAT at Bhubaneswar with 12 different manurial practices to identify yield limiting nutrients in order of limiting importance for each manorial treatment in each season with following objectives:

1. To determine the nutrient content of indicator leaves of rice at flowering stage of both *kharif* and *rabi* season
2. To determine the DRIS index for different nutrients in each treatment
3. To identify nutrients limiting crop yield and evaluate soil fertility

CHAPTER-2

REVIEW OF LITERATURES

REVIEW OF LITERATURE

The present study on "Diagnosis &Recommendation Integrated System (DRIS) to identify yield limiting nutrients of an intensively rice grown soil (*Inceptisol)*". The related review of work on this problem is presented in this chapter.

1. Soil fertility evaluation

2. Diagnosis &Recommendation Integrated System (DRIS)

3. Effect of manurial treatment on nutrient of plant

4. Effect of long-term fertilization on soil nutrient status

2.1 Soil Fertility Evaluation

There are many diagnostic techniques used for soil fertility evaluation

2.1.1 Nutrient deficiency symptoms

Visual nutrient deficiency symptoms can be a very powerful diagnostic tool for evaluating the nutrient status of plants. Wade (2010) argued that many of the classic deficiency symptoms such as tip burn, chlorosis and necrosis are characteristically associated with more than one mineral nutrient deficiency and also with other stresses that by themselves are not diagnostic for any specific nutrient stress. The symptom may arise present of disease and insect attack which very often confuse the diagnosis.

2.1.2 Plant analysis

Plant tissue analysis is a laboratory determination of the total elemental content of plants or of certain plant parts (Steinhilber and Salak, 2010; Reuter and Robinson, 1997). It is used for a variety of purposes including monitoring the nutrient status of crops and troubleshooting problem areas. It also serves as the basis for nutrient recommendations for perennial fruit crops (Steinhilber and Salak, 2010). It is the only way to know whether or not a crop is adequately nourished during the growing season (Flynn *et al.,* 2004). Plant tissue analysis is performed on dried plant tissue that has been processed in a laboratory (Steinhilber and Salak, 2010). Plant tissue analysis can detect unseen deficiencies (Flynn *et al.,* 2004; Cleveland *et al.,* 2008; Steinhilber and Salak, 2010), confirm visual symptoms of deficiencies and detect toxic levels of nutrients

2.1.3 Soil Chemical analysis

Soil testing is used to determine both the amount of each nutrient that is immediately available and the amount that can become available during the life of a crop. Various methods have been developed and the key to success is that the methods must be correctly calibrated. Soil test calibration implies establishing relationship between soil test values and relative crop response (Agboola and Ayodele, 1987). It is most useful to predict or fertilizer needs (Reisenauer *et al.,* 1983) before planting of crop. Also, it measures levels of specific nutrients in a soil. However, it always indicate whether plants growing in that soil are able to take up the nutrients as determined by soil analysis. Because of this sometimes the recommendation based soil test fails to meet the requirement.

2.2 Approaches for plant analysis

The interpretation of nutrients contents in leaf analyses can be made by several methods to assess plant nutritional status.

2.2.1 Critical nutrient concentration or Range

To interpret results of traditional chemical analyses of plant tissue for the assessment of the nutritional status of plants, the methods of critical level and sufficiency range are used more frequently (Beaufils, 1973; Walworth & Sumner, 1987; MourãoFilho, 2004; Serra *et al.*, 2012).

The sufficiency range is the most used method of diagnose, and this method consists on optimum ranges of nutrients concentration to establish the nutritional state of crops, otherwise to use the sufficiency range it is necessary to develop regional calibration that is very expensive and does not give nutritional balance

2.2.2 Diagnosis and Recommendation Integrated System (DRIS)

The Diagnosis and Recommendation Integrated System (DRIS) was developed by Beaufils in 1973, this method consists in dual relation between a pair of nutrients (N/P, P/N, N/K, K/N...)instead of the use of sufficiency range or critical level that are called univariate methods, because only the individual concentration of the nutrients in leaf tissue is taken into consideration. Critical nutrient concentration not provide any information about the nutritional balance on other hand DRIS consider the evaluation of the nutritional balance of a plant, ranking nutrient levels in relative order, from the most deficient to the most excessive.

With the use of dual relation on DRIS, the problem with the effect of concentration or dilution on the nutrients in plants is solved, Because, with the growth of leaf tissue, on one hand the concentration of nitrogen, phosphorus, potassium and sulphur decrease in older plants and the concentration of calcium and magnesium increase in older plants (Beaufils, 1973; Walworth and Sumner 1987). In DRIS method, where the dual ratio is used, the values remain constant, minimizing the effect of biomass accumulation,

2.2.2.1 Methodology of DRIS

2.2.2.1.1 Sampling for DRIS

Among the several tissues considered for nutritional diagnosis purposes, leaves constitute the main sampling material (Hallmark and Beverly 1991)

Bell and konvar (2004) reported that at mid tillering stage leaf samples should be taken from the youngest, fully developed leaves. About twenty leaves should be collected and at Panicle initiation leaf samples should be taken from the youngest, fully developed leaves. These are the Y-leaves. In case of rice the indicated tissue to be sampled has been identified as third leaves from the terminal position of the plant

(Ravi and Raj 2015). Sahrawat (2006) reported that newest fully developed leaf should be collected for DRIS.

2.2.2.1.2 Nutrient composition of the rice leaf

Bell and Konvar (2004) reported that sufficiency range of leaf sample for rice at mid-tillering stage were between 2.8%-3.6%,0.14%-0.27%,1.5%-2.7%,0.16%-0.39%,0.12%-0.21%,0.17% of N, P, K, Ca, Mg, and 90-190,40-740,20-160,6-25, and 5-25 ppm of Fe, Mn ,Zn, Cu, and B respectively .They also reported that sufficiency range of leaf sample for rice at panicle initiation stage were between 3.0%-3.4%,0.18%-0.29%,1.5%-2.7%,0.19%-0.39%,0.15%-0.39%,0.15% of N, P, K, Ca, Mg, and 70-190, 40-800,20-160,6-25, and 5-15 ppm of Fe, Mn ,Zn, Cu, and B respectively.

DRIS-derived sufficiency ranges obtained from the nutrient indexing survey of rice crops cultivated on lowland areas near the periphery of Sutlej River were N, P, K, Ca, Mg and S for rice crop were 1.49-2.50, 0.140.23, 0.57-1.11, 0.30-0.58, 0.13-0.30 and 0.14-0.26 %, respectively. These limits for Fe, Mn, Zn and Cu were 64-217, 72-184, 15-24 and 3-6 ppm, respectively. (Hundal *et al.*,2008)

Ravi *et al.*, (2013) conducted an experiment on nutrient status and establishment of critical and adequate ranges for different nutrient for rice (*oryza sativa* L.) through DRIS in karimnagar district of Andra Pradesh and found that sufficiency range were between 2.20-3.62, 0.30-.038, 2.02-2.89, 0.18-0.34% for N,P,K and S and 14.93-26.30, 91.69-167.74 ppm for Zn, and Fe respectively.

Ravi and Raj (2015) conducted and experiment in rice and reported that the mean N, P, K, S, Zn and Fe contents in the low and high yielding population were 2.83, 0.62, 2.63, 0.25, 20.2 and 129.0 per cent; and 3.26, 0.32, 2.50, 0.28, 21.7 and 131.8 per cent, respectively. In case of high yielding population, the mean leaf contents of N, S, Zn and Fe were more (3.26%, 0.28%, 21 and 131.8 mg / kg respectively than the low yielding population (2.83%, 0.25%, 20.2 and 129.0ppmrespectively, whereas in the case of low yielding population, the mean leaf content of P and K were more (0.62% and 2.63%) than the high yielding population (0.32% and 2.50%). Sahrawat (2006) reported on the same on the same crop of rice that sufficiency range of rice at maximum tillering were between 2.80-3.60, 0.10-0.18, 1.20-2.40 percent for N,P, and K respectively.

Another experiment conducted by Rheemkh *et al.,* (2016) in rice grown in saline soil through DRIS found that that the sufficient ranges for N, P and K were 2.9 to 3.23, 0.175 to 0.503 and 1.776 to 1.988 %, respectively as well as the sufficient ranges for Fe, Zn and Mn were 149.1 to 162.3, 44.36 to 60.52 and 65.40 to 90.22 ppm, respectively.

In addition to sufficiency ranges, nutrient and other ion toxicities also have been reported. Aluminium (Al) toxicity is likely if whole plant Al is >300 ppm (Tanaka and Yoshida 1970). In some cases, ferrous iron (Fe II) may also pose a toxicity problem. Toxicity is possible in rice if chloride (Cl) reaches >10,000 ppm and nitrate >1600 ppm (Helms 1994). Leaf concentrations of manganese (Mn) in the range 4000–8000 ppm are toxic to rice (Adriano, 1986). Molybdenum (Mo) toxicity is very rare, but an approximate value would be >100 ppm for leaves from grass species such as rice (Jones, 1991). Zinc (Zn) toxicity was reported by Chino (1981), when rice shoots contained 100–300 ppm and rice roots contained 500–1000 ppm. With respect to deficiencies, rice and other cereal grasses are not sensitive to low Mo. For whole plants at boot stage, 0.09–0.18 ppm are considered sufficient. Deficiency of silicon (Si) may occur when Si is <5% in straw sampled at maturity (Tanaka and Yoshida, 1970).

2.2.2.1.3 DRIS norms development

To assess the nutritional status of plants, the first step is to establish the DRIS norms or standard. The DRIS norms consist of an average and standard deviation of dual ratio between nutrients (N/P, P/N, N/K, K/N, etc.) obtained from a crop reference population, but, it is necessary that the crop reference shows high yield (Beaufils, 1973). This method has been followed along the years (Jones, 1981; Maccray *et al.*, 2010; *Serra et al.,* 2012). The data bank to compose the DRIS norms is formed by the crop yield and chemical analysis of leaf tissue and this information can be obtained from commercial crop or experimental units. For each pair of nutrients there are three forms of expression that may be considered. For example N and P can be related as ratio N/P, its inverse P/N or product N × P.

In DRIS calculation only one expression is used to relate each nutrient pair. The selection of this is done by, comparing the variation of low yielding group to that of high yielding segment of the population. The form of expression (N/P, P/N or N×P) selected for use in DRIS computation is that with the largest variance ratio (Beaufils, 1973 and Walworth and Sumner, 1987).

The size of the data bank is not a factor that is directly related to the quality of the DRIS norms (Walworth *et al.,* 1988; Sumner, 1977). Walworth *et al.,* (1988) observed that, when they used 10 data to establish the DRIS norms, the results obtained were more accurate then the use of a large number of data. What is more important to improve efficiency on DRIS norms is the quality of the data, because it is not accepting the use of sick plants to compose the data bank to establish the DRIS norms. To make part of the DRIS norms, the rations between nutrients can be selected by the direct form (N/P) or reverse (P/N), but, there is more than one way to change the ratio that is going to compose the DRIS norms. Following the premises of DRIS proposed by Beaufils (1973), it is feasible to change the dual ratio (A/B or B/A) that is more important to compose the DRIS norms. This way it is expected that the dual ratio from crop with high-yielding (reference population), composed with healthy plants, shows less variation than the population of plants with low-yielding (non-reference population), thus, the relation between variance ratio method, the F value, was defined as the variance ratio of low-yielding (non-reference) and high-yielding population (reference), and the order of the ratio with the highest value was chosen among the variance ratios (Jones, 1981; Letzsch, 1985; Walworth & Sumner, 1987).

Hundal *et al.,* 2008 has developed DRIS norms for rice with number of observation. Mean values of selected nutrients ratio for rice plants and their percent coefficient variation (CV) are presented in appendix 2.

Counce and Well (1986) has developed DRIS norm in Eastern Arkanas rice tissue with number of observation Mean value of selected nutrients for rice plant at Eastern Arkanas and their percent coefficient variation (CV) are presented in appendix 3 and Ravi (2010) had developed DRIS norms for rice. Mean value of selected nutrients ratios for rice plant are presented in Appendix 4.

2.2.2.1.4 DRIS index

Several changes in the methodology of DRIS indices calculation were proposed in order to increase the accuracy in the nutritional diagnosis for several crops. The calculation of the functions or standard deviation units can be defined by the methodology originally developed by Beaufils (1973), Jones (1981) or Elwali & Gascho (1984), there are some conflicting results in the literature regarding the effectiveness of each method of calculation. According to Mourão Filho (2004), there is still no clear definition of what would be the best recommendation to calculate the functions or standard deviation units for the DRIS.

According to Serra *et al.*,(2012), the use of the methodology proposed by Jones (1981) when compared with Beaufils (1973) and Elwali & Gascho (1984) showed better efficiency on DRIS index for cotton crop (*Gossypium hirsutum* r latifolium). The measure of the efficiency used by Serra *et al.*, (2012) was the relation between yield and nutritional balance index (NBI)

2.2.2.1.5 Interpretation of DRIS

The DRIS also provides a mathematical means of arranging a large number of nutrient ratios into nutrient indices that can be easily interpreted. A nutrient index is a mean of functions of all ratios containing a given nutrient (Beaufils, 1973 and Sumner, 1981). The details of computation of DRIS indices are given under material and methods.

Because the value of each ratio function is added to one index sub total and subtracted from another prior to averaging, all indices of a particular sample are balanced around zero (Beaufils, 1973). Walworth and Sumner (1987) stated that the more negative an index, the more lacking is nutrient it represents relative to other nutrients used in the diagnosis. Alternatively a large positive nutrient index indicates that the corresponding nutrient is present in relatively excessive quantity.

In a plant sample with optimal nutrient balance, all nutrient indices would equal to zero. However, it is important to recognize that an individual nutrient is not necessarily present in optimum concentration even if its index equals zero (Walworth and Sumner, 1987). If for instance, results of a diagnosis were as follows:

Nutrient	N	P	K	Ca	Mg
Index	-21	0	+7	+7	+7

One could accurately say that, among all the nutrients tested, N had the most negative index and was likely to be yield limiting if nutrition were governing growth. Although the P index equal zero, it was relatively less abundant than K and Ca or Mg and was the second most needed nutrient in this diagnosis. K, Ca and Mg levels were excessive relative to N and P.

In this example K, Ca and Mg may have actually been more yields limiting than P for instance. However, because nutrients can in practical terms be added and not taken away, the recommendation from this diagnosis index supplementing the deficient N and to a lesser extent P, even though the P index is zero (Walworth and Sumner, 1987). When the sums of the DRIS indices are large, one or more of the measured factors limits yield. Higher yields can result only when sum of indices is small, although low yields may still occur if other factors are limiting (Beaufils, 1973; Walworth and Sumner, 1987).

2.2.2.1.6 Nutritional Balance Index

DRIS index values of different nutrients is useful determine deficiency or sufficiency of nutrients in the order of their limiting importance. Beside DRIS index NBI has been suggested by (Badlock and Schulte, 1996) to obtained the status of nutrient balance.

NBI is the sum of the modulus of DRIS index from sample. The higher the NBI the greater is the nutritional imbalance (Beaufils 1973) and vice versa

NBI has been used to provide the effective of DRIS in diagnosing nutritional status of plant the greater the relation between NBI and Yield great in diagnostic system response to point out Nutritional status of plant. Silveria *et al.*,(2005).

2.2.2.1.7 Comparison of DRIS and other diagnostic systems

The diagnostic methods like critical value approach and sufficiency range approach were compared with DRIS (Sumner, 1983; Walworth and Sumner, 1987). The critical value and sufficiency range systems are general approaches with no specific guidelines for standard value generations, although accuracy of both these systems is to some extent dependent upon this process.

In most comparisons of diagnostic capabilities of critical value or sufficiency range systems and DRIS, tissue sampling has been done at a specific stage of growth. Even under these conditions DRIS usually maintain slightly higher diagnostic precision. According to Sumner (1979), the DRIS based treatment resulted in 39 successes and 12 failures whereas treatment based on critical values resulted in 22 successes and 11 failures in the case of potato. The corresponding figures for sugarcane were 38 successes and 13 failures with DRIS, 20 successes and 9 failures when using critical value. For corn 166 successes and 24 failures were recorded with DRIS, where as 133 successes and 34 failures with critical value systems (Walworth and Sumner, 1987).

The critical level approach is one of the first methods proposed by Ulrich and Hills (1967) for assessing the nutrient status of a plant by foliar analysis. It is the most widely used diagnostic method. Before use of this approach, single concentration values or critical or standard concentrations were used (Smith, 1962). But in order to interpret plant analysis results for diagnostic purposes, the full concentration range from deficiency to excess is needed (Benton, 1993).

Consequently, it is more reliable to use a critical nutrient range that is defined as that range of nutrient concentration at a specified growth stage above which the crop is apply supplied with nutrients and below which the crop is deficient in specific nutrients (Kelling *et al*., 2000; Havlin *et al*., 2004; and Rashid, 2005).

Sumner (1979) critically evaluated the precision and flexibility of different foliar techniques in making a valid diagnosis of nutrient imbalances. Comparison of diagnostic precision between critical level and DRIS approach was made using data from various field experiments with corn, soybean sugarcane, and potatoes and opined that DRIS is superior to critical value approach.

Johnson and Sumner (1980) developed foliar diagnostic norms for potato from 745 sets of leaf N, P and K compositions and corresponding yield. The advantage of DRIS approach over critical level approach was illustrated. Mackay *et al.,* (1987) and Sharma (1991) also developed foliar diagnosis norms for potato. Sharma (1991) reported that DRIS assesses elements, but also the order in which other elements would become limiting.

Elwali and Gascho (1984) reported that sums of DRIS indices irrespective of sign for sugarcane were significantly lower when fertilization was based on DRIS rather than on critical values. Yields of both cane and sugar were significantly improved when DRIS recommendations were followed.

Beverly *et al.,* (1986) derived DRIS norms using data bank of about 3500 tissue samples for evaluating the status of soybean and the DRIS diagnosis generally agreed with those obtained by sufficiency range method. Authors also reported geographic differences in DRIS norms and indicated that regional deviations of diagnostic values may be necessary.

2.2.2.1.8 DRIS in different crop plants

DRIS norms have been developed for corn, soybean and wheat and the interpretation of tissue analysis by DRIS approach offered several distinct advantages over the critical nutrient level approach (Sumner, 1977a, b and c).

Amundson and Kochler (1987) observed significant sampling date/time dependence for the DRIS norms derived for winter wheat grown in eastern Washington and opined that DRIS procedure may not be independent of the age of the plant. Paul and Wells (1986) developed DRIS norms for rice and tested its accuracy by applying the DRIS predicted nutrient recommendations.

Soltanpour *et al.,* (1995) reported that DR1S is a potential method for interpreting plant nutrient composition and compared DRIS with the nutrient sufficiency range (NSR) for corn *(Zea mays* L.). They identified the following flaws in DRIS: (i) very high levels of one nutrient can cause false relative deficiency diagnosis of other nutrients, and (ii) an optimal ratio between two nutrients produces maximum yields only when both nutrients are in their respective sufficiency ranges. They recommend using the NSR technique in combination with a soil test to avoid the misdiagnosis of Zn and Cu deficiencies in corn when N is extremely deficient

Singh and Agarwal (2007) studied on leaf nutrient contents recorded in rice at tillering and booting stages were used to develop DRIS norms. The content of all the nutrients decreased with advancement in age. The DRIS indices developed for N, P, K and S indicated that N was most limiting nutrient at tillering whereas S was the most limiting nutrient at the booting stages. The critical nutrient concentration (CNC) and DRIS norms were not found compatible. The DRIS approach appeared to be better than CNC for predicting nutrient requirements for higher yields.

Ravi *et al.*, (2015) conducted an experiment on DRIS in 150 locations of Karimnagar district of Telangana and also to identify the yield limiting nutrients in rice. The population was divided into low (113 observations) and high yielding groups (37 observations) based on the third quartile method for developing the DRIS foliar diagnostic norms. Index leaf samples were collected from all the selected rice fields at tillering stage and analyzed for N, P, K, S, Zn and Fe contents. Based on the highest variance ratio between low and high yielding populations, forms of expression for different nutrients and their norms were selected. The DRIS norms were established for various nutrient ratios obtained from high yielding population of rice crop and were further used to compute the DRIS indices assessed the yield limiting nutrients and their requirement in order of priority were addressed. He concluded that number of nutrients diagnosed as yield limiting by DRIS was more than those identified by the CNC method.

Hundal *et al.*, (2008) reported that in lowland areas in the vicinity of Satluj River in district Ludhiana. Standard reference DRIS norms were established for various nutrient ratios obtained from high yield population of rice crop and were further used to compute DRIS indices, which assessed nutrient balance and order of limitation to yield. Validation experiments were carried out in the following year at some selected sites for rice crop on the basis of most required nutrient element by DRIS approach. Soil application of the most required macronutrient elements (N, P, K and S) through their respective fertilizer and micronutrients (Zn, Cu and Mn) through foliar spray of their salts changed their respective order from the most required to their lesser or the least one among the ten nutrient elements and eventually contributed to increase in grain yield of rice except Mn. Thus, he concluded that DRIS approach, besides diagnosing the deficiency or identification of inadequacy of a certain nutrient element(even if all the ten nutrients are within the sufficiency range), helped in increasing rice yield by application of most required nutrient through fertilizer

Hanson (1981) conducted an experiment on DRIS evaluation of the N, P, and K status for soybeans in Brazil. He evaluated the DRIS method utilizing 3 datasets of foliar analyses for N, P, and K. The results of their experiments show that the DRIS method proved useful as an analytical tool to diagnose the soybean response to P.

Hundal *et al.,* (2002) reported that DRIS indices indicated that 54.8, 0.40, 11.5 and 35.0 per cent of the total sunflower area surveyed in Punjab were suffering from the inadequacy of N, P, K and Mg respectively. The system was used irrespective of variety, position of leaf sampled and time of sampling. Again in 2003 they monitored the status of N, P, K and S of cauliflower in Punjab. The DRIS indices inferred that 24, 23, 31 and 22 per cent of total samples were showing inadequacy of N, P, K and S respectively. Thus these results conclusively elucidate that DRIS is capable of making meaningful diagnosis, which when followed by appropriate treatment could lead to higher yield of cauliflower.

Akhter (2011) conducted a study on wheat of Farmers' fields (181) were selected on the basis of a survey of wheat-growing areas .for comparison of DRIS and critical level approach for evaluating nutrition status of wheat he selected DRIS norms were: N/P, N/K, N/Cu, N/Fe, N/Mn, N/Zn, N/B, P/K, P/Cu, P/Fe, P/Mn, P/Zn, P/B, K/Cu, K/Fe, K/Mn, K/Zn, K/B, Cu/Fe, Cu/Mn, Cu/Zn, Cu/B, Fe/Mn, Fe/Zn, Fe/B, Mn/Zn, Mn/B and Zn/B. The result of his experiment the critical level approach, the average concentration of N in the leaf tissue at GS-39 is deficient (which is in contrast to the DRIS evaluation), whereas all other nutrients are adequate. The average nutrient concentration in the shoot material at GS-29is similar to that in the leaf at GS 39.He further concluded that to the DRIS evaluation, if the N supply is improved during early development, other nutrients may become yield limiting, e.g., P and K. The DRIS norms can provide guidelines for the policy makers in the region regarding recommendations for appropriate fertilizer application.

Silveira *et al.,* (2005) conducted a study to evaluate three procedures (methods of Beaufils (1973), Jones (1981), and Elwali & Gascho (1984)) for the calculation of DRIS indices, and to verify the efficiency of DRIS as interpretation method. They selected *Brachiaria decumbens* (signal grass) for the study and the concentrations of N, P, K, Ca, Mg, S, Cu, Fe, Mn, and Zn were taken from the expanded leaf laminae of the grass. Subsequently, they calculated the nutritional balance index according to the generated norms, presented negative and significant correlation coefficients with the productivity in the combinations of methods tested. DRIS as proposed by Beaufils (1973), Jones (1981) and Elwali & Gascho (1984) which were efficient in detecting concentrations that show nutrient deficiency or excess.

2.3 Effect of manurial treatments on nutrients content in plant

Vageesh *et al.*, (1990) observed that uptake of N, P, K by rice was highest with application of 150% of the recommended fertilizer rate to both *kharif* and summer crops. Uptake of N and K were high with 50% recommended NPK +50 % N as glyricidia applied during monsoon and 100% of recommended NPK applied during summer. Uptake K was high with 75 % of recommended NPK +glyricidia applied in monsoon and 75% of recommended NPK applied in the summer.

Sisworo *et al.*,(1992) in their studies on effect of legume residues pertaining to N uptake and N concentration observed increased N uptake by application of legume residues. Further increased grain N concentration was observed due to addition of legume residues at higher levels. The higher rate of K uptake by the crops under NPK treatments was believed to restrict level of K accumulation in the soil (Agarwal *et al.,* 1993)

Maximum uptake of nutrients (N, P, K and S) in rice was recommended with 75 % of recommended dose of N, P and K along with FYM @ 10t/ha compared to 100percent NPK fertilizer alone (Mondal *et al.*,1994)

Azam and Yousaf (1991) reported that N content in grain and straw and N content was greater in treatments which has a given compost +green manure than application of green manure alone.

Nitrogen content of rice straw was significantly higher in treatments that received that received N than in treatments without N. Similar was the case with P and K in rice grain and straw. Up take Of N, P and K was significantly higher in treatment that received manures besides N, P and K than no manure and NPK treatments.

Sinha *et al.,* (1981) studied the effect of continuous use of fertilizers and manures on crops and indicated a highly beneficial role of phosphorus in 26 nutrient composition and uptake by all the crops (wheat-soybean and potato) in rotation. In general NPK fertilizer in combination with FYM recorded the maximum removal of nutrients by the crops.

Pande (1987) observed that application of phosphorus positively affected nitrogen and phosphorus availability to plants. Total and available nitrogen increased significantly with application of phosphorus along with FYM .

Subramanian and Kumaraswamy (1989) reported that the response of finger millets to phosphorus at different fertilizer gradients. Highest yield of dry matter at active tillering and flowering stages and grains and straw at harvest were recorded under 100% NPK plus organic manure treatment. The yield increased with increasing level of phosphorus upto 100 kg P_20_5/ ha. Phosphorus uptake by the crop was generally highest under 100 per cent NPK plus organic manure treatment and lowest under unmanured treatment at all stages of crop growth.

Prasad *et al.*, (1982) found the highest K content (1.7%) when NPK fertilizers were applied with FYM. They also found that removal of K increased with higher doses of NPK. The lowest uptake of K was in N alone treatment with N and P applications. The uptake was only 70.2 kg/ha as compared to 160.6 kg/ ha in 50% NPK treatment.

The availability of zinc was increased with the addition of FYM (Mann *et al*., 1978). Bharadwaj *et al.*, (1984) in a long term experiment found that the uptake of Zn generally increased with the increase in crop yields.

Minas and Mehta (1984) reported that the highest uptake of zinc was under 100% NPK treatment and the lowest in control. The increasing fertilizer doses enhanced nutrient uptake.

Pogula and Rout (2018) suggested that the effect of different manures on nitrogen availability at different growth stages showed that the nitrogen availability was highest in the treatment six treated with STBR+FYM 5t /ha + Green Manuring + Biofertilizer and found highest in the active tillering stages and gradually decreases up to maturity this due to the increase in the uptake of nitrogen. The effect of different manures on phosphorous availability at different growth stages showed that the nitrogen availability was highest in the treatment six treated with STBR+FYM 5t /ha + Green Manuring + Biofertilizer and found highest in the active tillering stages and gradually decreases up to maturity this due to the increase in the uptake of phosphorous. The effect of different manures on potassium availability at different growth stages showed that the nitrogen availability was highest in the treatment six treated with STBR+FYM 5t /ha + Green Manuring + Biofertilizer and found highest in the active tillering stages and gradually decreases up to maturity this due to the increase in the uptake of phosphorous

2.4 Effect of long-term fertilization on soil nutrient status

2.4.1 Available nitrogen

Application of major nutrients especially N plays a key role in determining the yields of crops (Duraisami and Mani 2000). Tool *et al.*, (2001) reported that among the major nutrients, nitrogen is universally deficient and most vulnerable to losses especially under tropical climate. Its regular supply during crop growth period is possible through release of nitrogen from organic manures.

Nitrogen accumulation was higher when manure or straw was added along with NP fertilizers. This might have been partially due to a slow release of N from manure and straw, resulting in reduced losses of N (Fan *et al.,2005*). Similar result was also reported by (Bhandari *et al* .,2002).

In the red loam soils of the old and new permanent manurial experiments at Coimbatore, the available nitrogen content was found to be enhanced due to continuous incorporation of organic manures (Muthuvel *et al.,* 1990). Continuous addition of potassium had decreased the available N status of the soil due to the blocking up of adsorbed NH4 by added potassium preventing its release (Govindarajan and Rao 1978). The results of the long-term fertilizer experiments were reviewed by Nambiar (1985) and reported that there was a decline in the available N status of the soil in plots where N had not been applied for many years. Subramanian and Kumaraswamy (1989), stated that the soil available N status in the long - term fertilizer experiment conducted on Inceptisol was the highest under100 per cent optimum NPK + FYM treatment while under cropped but unmanured treatment it was the lowest as against the initial status.

A comparison of available N status of the fallow plots with control clearly revealed that cultivation without any addition of fertilizers or manures drastically reduced the soil N availability. Increasing the NPK dose from 50 to 150 per cent increased the available N content of the soils and the highest available N was noticed under FYM treated plots (Bharadwaj and omankar 1994). The results of Long –term Manurial Experiment showed that the N availability was not altered by the levels of phosphorus or potassium application, but their application without FYM caused depletion of available (Rao and Dakhore 1994). (Mandal *et al*., 1991) reported that any increase in the rate of FYM applied would increase the available N status of the soil. The available N content of the soil increased over the initial value under 100 per cent NPK + FYM treatment and was due to higher organic carbon content. (Santhy *et al*., 2001). Continued cropping without fertilization depleted the available N status from the initial value in plots receiving only FYM. However, it increased significantly with regular dressing of N fertilizers. The increase in available N status due to organic manure application would be due to the multiplication of soil microbes leading to enhanced conversion of organically bound N into inorganic forms.(Parmar and Sharma 2002).

2.4.2 Available phosphorus

A build up in the available P status of the soil over the initial value recorded in 1972, occurred in 100 per cent NPK + FYM and also in 150 per cent NPK treatments. The results of LTFEs all over the country have revealed that the use of N alone leads to accelerated depletion of soil P (Nambiar and Ghosh. 1984). Reviewing the results of long-term fertilizer experiments, Nambiar reported a considerable build-up in the available P status of alluvial, red loam and submontane soils of Punjab, Ranchi and Palampur due to the application of increasing rates of P. Similar trends were also reported in the medium black soils of Coimbatore by Subramanian and Kumaraswamy (1989) and Muthusamy *et al*.,(1990) a marked rise in the available P status of the soil with the application of lime and FYM might be due to the inactivation of iron, aluminium and hydroxyl Al ions thereby reducing the P fixation in soil. Bahl and Avtar Singh (1997), stated that an increase in the available P status with the application of organics and the increased availability was a consequence of decrease in P adsorption and phosphate potential of soil. A balance sheet of P under different fertilizer treatments was worked out in LTFE of soil type Typic Ustrochrept .

Graded levels of P application were accompanied by a corresponding increase in the amount of available P owing to higher rates of P application in the amount exceeding crop uptake (Santhy *et al*., 1998). The available P status of soil after 10 years of rice - wheat cropping was minimum in control whereas the maximum available P was found in NPK + FYM + Zn treatment. The NPK + FYM + Zn and NPK + FYM treatments nearly maintained P availability as that of the initial value whereas in other treatments noticeable depletion in available P was seen (Singh *et al.,* 1999).

Jayasree Sankar *et al.,* (2000) stated that the continued application of phosphatic fertilizer to a rice-wheat crop rotation over the years resulted in an increased available soil P status .The combined application of organic manure and inorganic fertilizer increased the available P status of the soil. The increased release of P may be due to the fact that organic anions compete with the phosphate ions for binding sites on soil particles thereby reducing the P fixation (Panneerselvam *et al*., 2000).

A build-up of P in P- receiving plots and depletion in N and K treated plots was observed fym (Ghosh 2000). In calcareous soil, CO_2 produced during the decomposition of organic matter plays an important role in increasing the phosphate availability. Organic matter enhanced the labile P in soil through complexation of cations like Ca and Mg when it is applied in combination with inorganic fertilizers (Tolanur and Badanur2003). Among the treatments, 100 per cent NPK + FYM recorded the highest level of P availability in the surface layer of soil in LTFE (Inceptisol). Also the addition of 150 per cent of NPK had shown a beneficial effect. Phosphorus availability was found to increase with increase in the amounts of applied NPK in the 0-15 and 15-30 cm layers (Santhy *et al.*,2001). The availability of P was significantly increased in the treatments where 50 per cent or 100 per cent of N was applied through organic source or where 150 per cent NPK was applied (Mairan *et al.*, 2005).

Slope of the trend lines for soil available P indicated declines of about 0.20 mg /kg /y for the unfertilized and N only treatments, but increases of 0.19, 0.25, 0.38 and 0.67 mg kg-1 y-1 for the manure, NP, SNP and MNP treatments respectively (Fan *et al.,* 2005).

2.4.3 Available potassium

Decline in available K status was observed in the plot receiving only fertilizer N but the significant increase in available K content has been noted in the plot receiving either FYM or GM along with fertilizer N. This suggests that FYM and GM helped to maintain the supply of K by releasing the K from reserve source (Muneshwar *et al.,* 2001). Intensive cropping with high yielding crop varieties led to depletion of K from soil which was evident from a number of long term field experiments conducted across the country under AICRP programme of ICAR (Ananda 2002).

The application of zinc and sulphur fertilizers along with 100 per cent optimal NPK increased the available K status, compared to the application of 100 per cent NPK alone (Ravankar and Sarap 2002). The effects of the long- term intensive cropping and fertilizers on available potassium status in a Haplustert soil was that the available soil K declined over the 29 years of intensive cropping and fertilizer application even at 150 per cent NPKS (Temphare 2002).

The status of available K in soil was found to decrease in all the treatments but the decrease was of lower magnitude in 100% NPK + FYM and 150% NPK treatments indicating the need to raise the level of K fertilizer application to meet the demand of the crops. The long- term effect of application of micronutrients on the available K status of the soil was studied and it revealed that the application of micronutrients alone decreased the available K status of the soil whereas the application of these nutrients along with FYM increased its availability (Vyas *et al*.,2003).

The beneficial effects of FYM on the availability of K may be ascribed to the reduction in K fixation and release of K due to the interaction of organic matter with clay (Tolanur and Badanur2003)

Declined rate of 2.06, 2.44 and 2.45 mg kg-1 y-1 for the control, N and NP treatments, respectively was found. In contrast, available K levels increased with time at rates ranging from 0.98 to 1.18 mg/ kg/ y for plots receiving manure or straw. Inputs of K with organic materials resulted in a build-up of soil available K because manure or straw generally contains high amount of K (Fan *et al.,* 2005). Available potassium contents were higher when higher rate of FYM was added to the soil.

2.4.3 Available micronutrients

Lowest amounts of available micronutrients were observed in the unmanured control which was due to the continued exhaustion of micronutrients. The availability of micronutrients in the soil was suppressed due to lime application in acid soils, which might be due to the change in pH and physical adsorption on the finer particles of $CaCO_3$ rendering them unavailable to plants (Kumar *et al.,* 1993). A study was conducted on the effect of the continued manuring on the extractable micronutrients in an Alfisol. DTPA-extractable Zn content was found to be higher in 100 per cent NPK + Zn treatment and 100 per cent NPK + FYM treatment. The increase in Zn content due to the application of FYM was due to the mineralization of organically bound forms of Zn in the FYM and possible addition of Zn through super phosphate (Deepak 1993).

A study on alluvial soil recorded the decrease in available Zn content of the soil due to the application of higher levels of N and P and also the available Cu content was found to be higher in N alone treatment compared to N applied in combination with P and K indicating that the P and K have adverse effects on available copper content. The available Mn status increased with the addition of FYM. This may be due to the release of Mn^{2+} bound to organic ligands in the organic matter and acceleration of the reduction of Mn^{4+} to Mn^{2+} (Sinha *et al*.,1997).

The depletion rate of DTPA- extractable micronutrients was higher in soils treated with chemical fertilizers alone as compared to the plots that received both fertilizers and organic manures after completion of 12 cycles of rice- wheat sequence in an Inceptisol (Yadav and Alok 1998). The DTPA - Mn content in soil showed statistically significant positive effect of all balanced fertilizer treatments (Singh *et al.,* 1997). The DTPA - Zn content of N, NK and NPK treatments were observed to be higher than that of control. The DTPA - Zn level in NPK + Zn treatment was higher (2.75 mg/ kg) due to continuous application of Zn in the soil. The balanced or imbalanced fertilizer treatment increased the DTPA - Cu over control. The DTPA - Cu level was high in NPK + FYM and NPK + FYM + Zn treatments.

CHAPTER-3

MATERIALS & METHODS

MATERIALS AND METHODS

In order to achieve the objective of the present investigation ,the long term fertilizer experiment (LTFE) of All India Coordinated research Project (AICRP) of ICAR conducted at Odisha University of Agriculture and Technology (OUAT), Bhubaneswar with effect from 1994 and with modified set of treatment from 2005 -06 was used

3.1 Field experiment

The long term fertilizer experiment of ICAR at Bhubaneswar that started during 2005-2006 with rice rice cropping system was used. The present investigation was carried out on *kharif* rice grown during 2015 and *rabi* rice grown during 2015-2016.

3.1.1 Materials

3.1.1.1 Location of the experiment

The experiment plot was located in E block of the Central Research Station Bhubaneswar which lies between longitude of $85^{0}48$ and 85^{0} 49 E and latitude at 20^{0} 16 N and 20^{0} 17 N

3.1.1.2Climate

The climate of Bhubaneswar is humid tropical with dry season from Octobers to June and wet season from July to September. The climate parameters prevailing during the *kharif* 2015 and *rab*i 2015-2016is presented at Appendix 1.

3.1.1.3 Soil

The soil of experimental field belongs to lateritic *Inceptisols.* The initial physio-chemical properties of the soil as measured during 2005 is given in table 1

Table 1: Physio chemical properties of initial surface soil

Serial no	Properties	Value
1	Mechanical composition	
	Sand%	71
	Silt%	12
	Clay%	17
2	Textural class	Sandy loam
3	Bulk density (Mg/m$^{3)}$	1.55
5	pH(1:2)	5.8
6	EC(dS/m)	0.12
7	OC (g/kg)	4.3
8	CEC(cmolp(+)/kg)	3.75
9	Available nutrient(kg/ha)	
	Available N(alkaline $KMnO_4$)	187(low)
	Available P(Olsen's)	19.7(medium)
	Available K (NH_4OAc Extractable)	43.4(low)
	Available S(0.01M $Cacl_2$)	22.2(medium)
10	**Extractable micronutrients (DTPA)in ppm**	
	DTPA Zn	1.80
	DTPA Fe	33.0
	DTPA Mn	7.53
	DTPA Cu	3.15
	Hot water B	0.46

3.1.1.4 Test Crop

Two popular rice varieties cultivar Swarna and Lalat were used as test crop for *kharif* and *rabi* season respectively.

3.1.1.5 Source of nutrient

3.1.1.5.1Organic source

Only one organic source i.e. Farm Yard Manure (FYM) was used @ 5 t/ ha the study. The nutrient contents and C:N ratio of FYM used in proposed study are presented below in table

Table 2: Chemical composition and C:N ratio of FYM used during *kharif* and *rabi*

Serial no	Properties	Value
1	Carbon (%)	20.3
2	Nitrogen (%)	0.79
3	Phosphorous (%)	0.50
4	Potassium (%)	0.80
5	C:N Value	25.70

3.1.1.5.2 Inorganic sources

Common fertilizer such as Urea, DAP and MOP were used to supply the nitrogen, phosphorus and potassium at 100% Recommended Dose (RD) of 80-40-60 kg/ha. Gypsum was applied to supply sulphur @ 30kg /ha and A solution of 0.4% ZnO was used for seedling root dipping. Borax was sprayed as a source of boron @0.25%. AND $CaCO_3$ @ 1t/ha was applied as a liming material.

3.1.2 Methods

3.1.2.1 Treatment and design

Total 12 treatments as given in table 3 below were used for the study. The experiment was laid out in randomised block design (RBD) with treatments replicated 4 times in plots of size 15m x 10m with rice-rice cropping sequence out.

Figure 1. Layout of experimental site

R-IV			R-III			R-II			R-I	
T_7	T_1		T_4	T_1		T_{11}	T_7		T_8	T_5
T_{11}	T_6		T_2	T_3		T_1	T_{12}		T_3	T_9
T_{12}	T_9		T_{10}	T_8		T_5	T_6		T_7	T_{11}
T_4	T_8		T_6	T_{11}		T_9	T_4		T_{10}	T_6
T_5	T_{10}		T_9	T_7		T_{10}	T_8		T_2	T_1
T_3	T_2		T_{12}	T_5		T_2	T_3		T_4	T_{12}

Table 3: Manurial Schedule of the treatments for *kharif* rice-2015 and *rabi* rice 2015-2016

Treatment	**Details**
$\mathbf{T_1}$	100%PK
$\mathbf{T_2}$	100%NPK
$\mathbf{T_3}$	150%NPK
$\mathbf{T_4}$	100%NPK+Zn
$\mathbf{T_5}$	100%NPK+FYM
$\mathbf{T_6}$	100%NPK+Lime+FYM
$\mathbf{T_7}$	100%NPK+B+Zn
$\mathbf{T_8}$	100%NPK+S+Zn
$\mathbf{T_9}$	100%N
$\mathbf{T_{10}}$	100%NP
$\mathbf{T_{11}}$	100%NPK+Lime
$\mathbf{T_{12}}$	Control

3.1.2.2 Methods and time of application of manures and fertilizer

Nitrogen was applied in 3 splits i.e. 25% as basal, 50% at 15 days after transplanting and 25% at panicle initiation stage. Total phosphorus was applied as basal. Potash was applied as 50% basal and 50% at panicle initiation stage, gypsum was applied at the time of transplanting and Zn was applied by root dipping @0.4% solution. Borax was sprayed twice at panicle initiation stage (PI) and 15 days after panicle initiation

3.1.2.3 Field preparation and planting

Wet season (July-November) rice was grown under rainfed condition. FYM@5t/ha was applied during the last week of May. The field was ploughed thoroughly and flooded 2-3 days before transplanting for puddling and levelling. Rice plants (21 days old seedlings of cv.MTU-7029, Swarna) were transplanted @ 2-3 plants /hill at a spacing of 15×10 cm^2 in third week of July. All the field plots remained continuously flooded to a water depth of 3cm during the entire period of crop growth and were drained 10 days before harvest. The crops were grown with recommended agronomic practices.

3.2 Analysis of sample

3.2.1 Collection of soil samples

Soil samples were collected from the surface soil (0-15 cm depth) in pre *kharif* (2015) and pre *rabi* (2015-2016).The soil samples were dried in shade at ambient temperature, passed through 2 mm sieve and stored for further analysis.

3.2.2 Analysis of soil sample

3.2.2.1 pH.

It was determined by pH meter at soil: water = 1:2 (Jackson, 1973).

3.2.2.2 Available Nitrogen

It was determined by alkaline KMnO4 method as outlined by Subbiah and Asija (1956).

3.2.2.3 Available Phosphorus

The soil available phosphorus was extracted with 0.5M $NAHCO_3$ (pH adjusted to 8.5) and estimated by spectrophotometer as described by Olsen, 1954.

3.2.2.4 Available Potassium

It was determined by extracting the soil with neutral normal ammonium acetate (NH_4OAC)) solution and estimated by flame photometer as described by Jackson, 1973.

3.2.2.5 Available Sulphur

Available S of soil samples was determined by turbidimetric procedure by using 0.15% $CaCl_2$ by the help of spectrophotometer (Chesin and Yien 1951)

3.2.2.6 Available micronutrient

Iron, Manganese, Copper and Zinc was determined by using DTPA extract with the help of Atomic Absorption Spectrophotometer (AAS) (Lindsay and Norvell 1978)

3.2.3 Collection of plant sample

For leaf analysis 3^{rd} and 4^{th} leaves of 20 selected plants were sampled at flowering stage. The plants were selected randomly from 4^{th} and 5^{th} row from the border in both the season. The sampled leaves were cleaned air dried and then oven dried at 60-70^{0}C.The dried sample was then chopped and grinded into fine powder for further analysis

3.2.4 Plant Analysis

The chemical analysis of the plant sample was carried out by digestion of 0.5 g of powdered sample. Kjeldahl digestion was used for N and digestion with HNO_3: $HClO_4$ (2:1) diacid mixture as per the procedure outlined by Jackson (1973) was prepared and diluted to 50ml with water and stored in plastic bottle This diacid extracts of straw were used to analyze P, K, Ca, Mg, S, Zn, Fe, Mn, Zn and Cu content by following the standard analytical procedures.

3.2.4.1 Nitrogen

Analysis of leaf sample was done by taking 0.5g powdered sample in digestion tube. 1 gm salt mixture (K_2SO_4 and $CuSO_4$. $5H_2O$ in the ratio of 10:1) was added in the tube. The 10ml of concentrated H_2SO_4 acid was added and material was digested at 350^0C in digestion block .Nitrogen in digested material was distilled by automatic KEL plus distillation apparatuses and N content was determined by titration of the distillate.

3.2.4.2 Phosphorus

Phosphorus content was determined by vanadomolybdo-phosphoric acid yellow colour complex method as described by Jackson (1973) on the diacid extract. An aliquot of 5 ml was taken, 5 ml of vanado-molebdate yellow reagent was added and volume was made up to 25 ml. After half anhour colour intensity was measured by Spectrophotometer

3.2.4.3 Potassium

Potassium content was determined by flame photometer as described by Chapman and Pratt (1961). An aliquot of 5 ml was taken and made up to volume of 25 ml in volumetric flask and potassium content was determined in flame photometer

3.2.4.4 Sulphur

Sulphur in the digest was estimated by turbid metric method using barium chloride and gum acacia solution.

3.2.4.5 Calcium and Magnesium

Calcium and magnesium contents were determined by Versene titration (Cheng and Bray 1951).

3.2.4.6 Iron, Manganese, Copper and Zinc

These nutrients were determined directly using atomic absorption spectrophotometer.

3.3. Determination of Diagnosis &Recommendation Integrated System (DRIS)

The steps adopted for calculation are mentioned and explained in detail as below

i. Selection of forms of expression

ii. Selection of DRIS norms

iii. Calculation for DRIS index

iv. Interpretation

3.3.1 Selection of forms of expression:

The major nutrient concentration was expressed in percent (%) and micronutrients in ppm. All possible ratios for of nutrient concentration were calculated. Co efficient of variation of each expression was also determined for all 12 ratios the three of the best performing treatment on the basis of past record (T_3,T_5 and $T_{6)}$

3.3.2 Selection of DRIS norms:

Mean values and Coefficient of variation of corresponding ratio was used in calculation for DRIS indices.

3.3.3 Calculation for DRIS indices :

The DRIS indices for primary (NPK), secondary (Ca,Mg,S) and micronutrient (Zn,) were developed from the mean value of selected form expression with help of DRIS norms. The procedure for calculating DRIS indices described by Walworth and Sumner (1987) were adopted in this study is follows

- A index= { f(A/B)+f(A/C)…. +f(A/N)}/Z
- B index ={(-f(A/B)+f(B/C)+f(B/D).....+f(B/N)}/Z
- N index= {(-f (A/N)-f(B/N).....f(M/N)}/Z

when, A/B ≥ a/b, then f(A/B) = (A/B/a/b – 1] × 1000/CV

If A/B < a/b, then f(A/B) = (1– a/b/ A/B) × 1000/CV

In these equations, A/B is the value of the ratio of the two elements in the tissue of the plant to be diagnosed (test data); and a/b is the optimum value (mean value of high yielders) of norm for that given ratio, CV is the coefficient of variation associated with the selected norm and Z is the number of functions in the nutrient index composition. Values for other functions, such as f(A/C) and f(A/D) are calculated in the same way, using appropriate norms and CVs. When calculating the A index, A/B is added to the other functions prior to averaging. However, the same function is used with a reverse sign in calculation of the index B. If an inverse ratio has to be used, (e.g. B/A), then it is added to the other functions

3.4 Interpretation

Negative DRIS index values indicate that the nutrient level is below optimum, consequently the more negative index, the more deficient the nutrient. Similarly, a positive DRIS index indicates that the nutrient level is above the optimum, and the more positive the index, the more excessive the nutrient is relative to normal, and DRIS index equal to zero indicates that the nutrient is at the optimum level (Baldock & Schulte, 1996). The result can be interpreted through various concept.

3.4.1 Interpretation of DRIS index value by order of the value indices

The nutrient indices are arranged in ascending order from most negative to most positive. Most negative index value means most limiting to plant and most positive index indicate more than optimum.

3.4.2 Nutritional balance index (NBI)

NBI is calculated by the summation of modulus of nutrient indices of all the nutrient from the sample

NBI = |I DRIS A| +|I DRIS B|+ |I DRIS C|....|I DRIS Z|

If the NBI is inversely proportional to yield of crop

Higher the NBI greater is the nutrient imbalance and vice versa

3.4.3 Nutritional Balance Index average (NBIa)

It is calculated by dividing NBI by number of DRIS index involved in analysis NBIa=NBI/n

Interpretation of DRIS index by nutrient application potential response (NAPR).The interpretation of DRIS index for(NAPR) originated by wad (1996) This method of interpretation considered method of grouping NAPR by comparing the rate of each nutrient DRIS with the NBIa as given in the table

Table 4 : Average Nutritional Balance Index

Nutritional	Criteria	Type of nutrient application potential response
Deficiency	I DRIS A<0, |I DRIS A|>NBI $_a$ and I_A is the index of lower value	Positive with higher probability
Deficiency prone	I DRIS A<0, |I DRIS A|>NBI $_a$	Positive with low probability
Sufficient	|I DRIS A|=NBI $_a$	Null
Excess prone	I DRIS A>0, |I DRIS A|>NBI $_a$	Negative with low probability
Excess	I DRIS A>0, |I DRIS A|>NBI $_a$ and I_A is the index of higher value	Negative with higher probability

NAPR was calculated according to Wadt (1996)

NBIa = Nutritional Balanced Index

3.5 Effectiveness of DRIS system : by response Curve .

A curve is constructed by taking NBI value in X axis and relative Dry matter percentage in Y axis .Greater the relation between NBI and Dry matter more efficient diagnostic system approach in identifying Nutritional status of the plant.

3.6 Statistical analysis

The data generated will be subjected to statistical analysis. The statistical analysis of the experimental data are to be carried out as per the methods suggested by Gomez and Gomez (1983).

CHAPTER-4

RESULT & DISCUSSION

RESULTS

The present study on “Diagnosis &Recommendation Integrated System (DRIS) to identify yield limiting nutrients of an intensively rice grown soil (*Inceptisol)*” was carried out in the rice at Long Term Fertiliser Experiment (LTFE) E-Block Central Research Farm OUAT, Bhubaneswar. The nutrient status of the plant samples for macro and micronutrients were determined from all the treatments.

The DRIS indices were worked out for all the nutrients and were arranged in the order of importance that is limiting the yield. In addition, soil samples were collected and analyzed from these areas to study the general fertility of the soils of the rice. The results of the experiment at are presented in this chapter under different heads.

4.1 Effect of long term manuring on concentration of nutrients of rice at flowering stage during *kharif* season

4.1.1 Primary Nutrient

4.1.1.1 Nitrogen

Result on nitrogen content in the index leaf presented in the table 5 reveal that nitrogen content varied from lowest of 0.64% observed in control plot to a highest of 1.27% observed in 100%NPK+FYM+lime. Treatments 100%NPK+FYM, 100% NP and 150% NPK were at par with 100% NPK +FYM + lime. In 100% NPK nitrogen content (0.82%) is much lower than that of 100%NP (1.23%). Application of Zn, B and S did not have any effect on nitrogen content in leaf However, in 100%NPK +LIME there is increase of nitrogen content (0.89%).

4.1.1.2 Phosphorous

The phosphorous content varied from lowest of 0.05% measured in control plot to highest of 0.20% with measured with 100% NPK +FYM treatment. Omission of phosphorous from the manuring schedule resulted much lower content phosphorous in leaf. In treatment which received phosphorous without FYM maintained higher level of phosphorous than control and 100 % nitrogen treatment. Consecutive use of FYM 5t/ha caused higher content of phosphorous. Application of potassium, boron, zinc and sulphur did not have any effect on phosphorous content. Omission of nitrogen however caused a fall in phosphorous content.

4.1.1.3 Potassium

Data pertaining to potassium, content in index leaf showed that superoptimal dose of potassium caused accumulation of more potassium than all other treatments. With omission potassium fertilizer the content was much lower (0.63 to 0 .96%). Continuous application FYM with 100% NPK caused significant increase in potassium content as compared to 100% NPK treatment

Application of micro and secondary nutrients did not have any significant effect potassium contents of leaves.

4.1.2. Secondary nutrients

4.1.2.1 Calcium

Calcium content varied between 0.16% to 0.35%. Application of FYM or Lime or superoptimal dose of NPK caused higher content of calcium. Exclusion of phosphatic fertilizer caused lower content of calcium. Application of zinc, boron and sulphur did not have any effect on calcium

4.1.2.2 Magnesium

Magnesium content of index leaf varied from lowest of 0.10% measured in control plot to highest 0.26% measured in 150% NPK treatment. 100% NPK+FYM, 100% NPK+Lime+FYM, 100% NPK +S+Zn,100%NPK+Lime, 100% NPK were at par in there magnesium content in the leaf. 100%N and 100% NP maintained a lower content.

4.1.2.3 Sulphur

Sulphur in the index leaf varied from lowest of 0.01% measured in control 0.15% measured in 100%NPK. +FYM +Lime ,Higher content were also measured in 100%NPK+B+Zn, 100%NPK+S+Zn, 100%NPKplot and 100% NPK+FYM plot

4.1.3 Micronutrients

Among the micronutrient cationic micronutrient highest content was measured with in iron (152 to 535 mg/kg) followed by manganese (189 to 443 mg/kg) zinc 13.70 to 328.67 mg/kg and copper (4.55 to 6.45 mg/kg).

Treatment that received the micronutrient zinc or FYM accumulated more zinc in the index leaf than other treatments .Both iron and manganese content were higher than the reported range of 64-217mg/kg &72-184 mg/kg respectively. Control plot recorded lowest content of iron and manganese. Most of treatments recorded higher values of both and were at par without any significant treatment effect .Copper content was highest in 150% NPK treatment (6.55 mg/kg)followed by the 100% NPK +FYM treatment and 100% NPK +S +Zn(6.17 mg/kg).

Table 5: Effect of long term manuring on concentration of nutrients of rice at flowering stage during *kharif* season 2015.

Content (%)							Content (mg/kg)			
Treatment	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**Cu**	**Mn**	**Fe**
100% PK	0.87	0.10	1.43	0.23	0.20	0.117	21.6	5.3	242	316
100% NPK	0.82	0.13	1.52	0.30	0.23	0.139	21.4	6.4	290	399
150% NPK	1.17	0.14	2.40	0.35	0.26	0.132	23.7	5.7	364	349
100%NPK + Zn	0.88	0.15	1.47	0.28	0.21	0.122	25.2	5.1	249	415
100% NPK + FYM	1.18	0.21	1.87	0.32	0.25	0.145	24.1	6.4	444	403
100% NPK+ Lime+ FYM	1.27	0.20	1.83	0.35	0.24	0.155	24.5	5.3	398	560
NPK +B +Zn	1.04	0.14	1.46	0.34	0.26	0.141	28.6	5.5	384	240
100% NPK+ S+ Zn	1.03	0.14	1.37	0.32	0.24	0.140	25.0	6.1	364	483
100% N	0.89	0.09	0.77	0.21	0.16	0.141	22.6	5.8	394	439
100 %NP	1.23	0.13	0.96	0.32	0.19	0.135	22.6	5.9	170	536
100% NPK+ lime	0.89	0.14	1.26	0.35	0.25	0.135	23.5	5.1	210	354
Control	0.64	0.06	0.63	0.16	0.10	0.061	13.7	4.5	189	152
CD(0.05)	0.12	0.10	0.22	0.23	0.03	0.02	3.88	1.62	118.4	255.87
CV%	8.8	0.13	10.57	0.30	8.17	8.3	11.6	1.7	26.7	45.93

4.2 Effect of long term manuring on concentration of nutrients of rice at flowering stage during *rabi* season 2015-16.

Data pertaining to nutrient content in the index leaf at flowering in rabi rice (crop variety lalat) is presented in table- 6.

4.2.1 Primary nutrient

4.2.1.1 Nitrogen

Nitrogen content varied of lowest of 0.56% measured in control plot to a highest of 2.03% measured in 100% NPK+FYM treatment. Higher content of nitrogen (2.01) was also measured in 150% NPK treatment. Exclusion of nitrogen or application of nitrogen alone maintained a good status (0.56% to 0.92%). of nitrogen. Similar to *kharif* season application of FYM also caused an increase in the nitrogen content.

4.2.1.2 Phosphorous

Phosphorous content varied from a lowest of 0.05% to highest of 0.28% measured in 100% NPK+LIME +FYM treatment. FYM amended plot recorded higher content of phosphorous (0.268%).Application of boron did not have any significant effect on phosphorous content.

4.2.1.3 Potassium

In *rabi* season potassium content varied from a lowest 0.91%measured 100%N treatment to highest of 1.75% measured in 150% NPK treatment. In contrast to *kharif* season in *rabi* season application of FYM did not contribute significantly

4.2.2 Secondary nutrients

The calcium content varied between 0.078%measured control to a highest of 0.38 measured in 100% NPK+FYM+Lime treatment and magnesium varied from 0.10 measured in control plot to 0.27% measured in 100% NPK+Zn. Application of FYM maintained at high status of both calcium and magnesium content.

Sulphur content varied from 0.08% in control plot to highest of 0.23% found in treatment in sulphur applied treatment .Application FYM or superoptimal dose of

NPK caused higher accumulation of sulphur in leaf tissue. Other treatments excluding 100% N or 100% NP were at par

4.2.3 Micronutrients

Similar to *kharif* season, among the cationic micronutrients iron (Fe) content was highest followed by manganese, zinc and copper .Iron content ranged from 208 to 350 mg/kg, manganese ranged from 230 to 381 mg/kg with highest measured in 100% NPK+FYM treatment. Application of lime in presence of FYM caused a decline in manganese content

Zinc content varied from 16.75 to 43.75 mg/kg. Treatment that received either high zinc or FYM recorded higher accumulation of zinc register in high content than other treatments

Copper varied from 5.4 to 7.87 mg /kg also show similar trend. Continuous use of FYM with 100%NPK caused Higher accumulation of all micronutrients.

Table 6: Effect of long term manuring on concentration of nutrients of rice at flowering stage during *rabi* season

	Content in %						Content in mg/kg			
Treatment	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**Cu**	**Mn**	**Fe**
100% PK	0.92	0.20	1.59	0.24	0.14	0.159	23	6.8	303	368
100% NPK	1.05	0.12	1.40	0.31	0.24	0.167	23	6.1	293	249
150% NPK	2.02	0.14	1.75	0.36	0.23	0.182	27	6.7	361	239
100%NPK + Zn	1.12	0.16	1.51	0.23	0.27	0.169	44	7.2	374	259
100% NPK + FYM	2.03	0.27	1.63	0.28	0.25	0.200	35	7.9	381	291
100% NPK+ Lime+ FYM	1.99	0.29	1.56	0.37	0.25	0.208	33	6.3	346	350
100% NPK +B +Zn	1.28	0.15	1.53	0.26	0.21	0.139	25	6.3	328	305
100% NPK+ S+ Zn	1.35	0.14	1.48	0.34	0.21	0.230	25	6.4	230	278
100% N	0.83	0.15	0.91	0.33	0.21	0.135	24	6.2	239	308
100 %NP	1.04	0.14	0.95	0.35	0.20	0.120	24	6.5	300	212
100% NPK+ Lime	1.08	0.14	1.54	0.38	0.18	0.126	25	6.0	317	301
Control	0.56	0.04	1.59	0.08	0.10	0.088	21	5.4	281	208
CD(0.05)	0.08	0.05	0.32	0.03	0.3	0.04	3.08	1.48	89	163
CV %	4.63	0.1222.7	16.1	8.23	11.8	16.37	8.57	15.91	19	40.52

4.3 Nutrient Ratios in Index leaves of rice grown in *kharif* -2015

N/P Data pertaining to treatment wise ratio of various nutrient are presented in table 7 for *kharif* 2015 and *rabi* 2015-2016 respectively.

4.3.1 Kharif 2015

The results reveal that the ratio of nitrogen with P (N/P) varied from lowest of 5.89 measured in 100%NPK+FYM to the highest of 11.59 measured in control plot followed by the treatment which received only N (10.20).

N/K varied from lowest of 0.494 to in measured in 150% NPK to highest of 1.33 measured in 100% NP treatment. Treatment such control and 100% N were close to 100% NP treatment. In other treatment the ratio ranged between 0.494 to 0.755.

The value of N/Ca ratio varied from lowest 2.56% measured in 100%NPK+Lime to a highest of 4.03 measured in control plot.

The value of N/Mg varied from a lowest value of 3.8 observed in 100%NPK to a highest value of 6.49 observed in 100% NP. Treatment like 100%NPK +FYM +Lime and Control were also close to the highest value

The ratio of N/S varied from lowest of 6.02 observed in 100%NPK treatment to a highest of 11.48 observed in control N/Zn varied from a lowest of 351 measured in 100% NPK+Zn to a highest of 578 measured in 100% N treatment. Higher values were also measured in 100% NPK+FYM, 100%NPK+FYM+Lime and 150% NPK treatment.

P/Ca varied from a lowest of 0.37 measured 100% NPK+Lime treatment to highest of 1.00 measured higher values were also observed in 100% PK and 100% NPK+Lime+FYM treatment P/Mg varied from a lowest of 0.45 measured in control plot to highest of 100%PK treatment P/S varied from lowest of 0.49 measured in control plot to highest of 1.38 measured in 100% NPK +FYM+ Lime treatment. The ratio P/Zn varied from 25.9 to 86.5, K/Ca varied from 2.75 to 6.75.K/Mg varied from 4.3 to 9.28, K/S varied from 6.49 to 13.94, K/Zn varied from 345 to 645, Ca / Mg ratio varied from 1.22 to 1.66, Ca/S varied from 1.54 to 2.70 and Ca/Zn from 105 t0 151 to 151.1 Mg/S ratio was less than ranged between 1.15 to 2.03. The ratio of Mg/Zn varied from 75 and 113. S/Zn ratio varied from 45 to 65.

Table 7 :Nutrient Ratios in Index leaves of rice grown in *kharif* -2015

Treatment	N/P	N/K	N/Ca	N/Mg	N/S	N/Zn	P/K	P/Ca	P/Mg	P/S	P/Zn	K/Ca	K/Mg	K/S	K/Zn	Ca/Mg	Ca/S	Ca/Zn	Mg/S	Mg/Zn	S/Zn
100% PK	8.55	0.616	3.90	4.339	7.53	408	0.12	0.80	1.46	1.31	84.9	6.58	6.51	9.79	627	1.12	1.94	105.1	1.74	94	55
100% NPK	6.45	0.547	2.73	3.635	6.02	386	0.09	0.40	0.54	0.75	54.0	4.55	6.03	8.43	612	1.33	2.21	142.7	1.66	107	65
150% NPK	8.22	0.494	3.36	4.474	9.05	502	0.08	0.39	0.64	0.75	50.6	4.94	8.06	9.62	645	1.33	2.70	151.1	2.03	113	56
100%NPK + Zn	5.80	0.603	3.13	4.172	7.27	351	0.10	0.69	0.58	0.94	35.3	6.75	5.64	9.29	345	1.33	2.32	112.1	1.74	84	48
100% NPK + FYM	5.89	0.635	3.83	4.729	8.30	512	0.18	1.00	1.07	1.33	76.3	6.07	6.43	8.36	464	1.27	2.24	134.9	1.75	108	64
100% NPK+ Lime+ FYM	6.48	0.702	3.66	5.539	8.34	522	0.19	0.78	1.14	1.38	86.5	4.24	6.23	7.63	471	1.51	2.29	143.8	1.52	96	63
NPK +B +Zn	7.53	0.721	3.08	4.106	7.53	371	0.10	0.61	0.72	1.11	61.0	6.19	7.19	11.24	614	1.33	2.44	120.4	1.83	90	49
100% NPK+ S+ Zn	7.63	0.755	3.29	4.384	7.46	414	0.10	0.42	0.69	0.62	58.7	4.36	7.20	6.49	607	1.33	2.27	126.1	1.71	95	56
100% N	10.20	1.167	4.19	5.593	6.42	403	0.16	0.45	0.71	1.16	63.2	2.75	4.33	7.08	386	1.33	1.54	96.4	1.15	72	64
100 %NP	9.43	1.339	3.90	6.490	9.22	578	0.15	0.41	0.71	1.28	58.4	2.72	4.71	8.85	399	1.66	2.37	148.2	1.44	90	62
100% NPK+ Lime	6.34	0.735	2.56	3.710	6.74	383	0.09	0.37	0.79	1.27	57.0	4.04	8.69	13.99	625	1.45	2.63	150.4	1.82	106	58
Control	11.59	1.037	4.03	6.400	11.48	478	0.05	0.60	0.45	0.49	25.9	12.04	9.28	10.58	433	1.61	2.93	118.8	1.79	75	45
CD(0.05)	3.05	0.2	0.58	0.95	2.23	105.49	0.05	0.23	0.32	0.42	20.1	2.15	1.73	4.2	150	0.23	0.69	29.3	0.37	21.77	16.27
CV%	27.04	17.74	11.71	13.79	19.50	16.57	27.68	27.8	27.69	27.90	23.2	27.52	17.9	31.81	19.77	11.79	20.64	15.47	15.48	16.06	19.79

4.3.2 Nutrient Ratios of *rabi* season 2015-2016

Data pertaining to ratio N with different nutrient are presented in table 8 N/P ratio varied between 4.89 to 14.86 with significant difference among the treatments, N/K ratio varied between 0.58 and 1.38 with significant difference among the treatments. N/Ca varied between 2.50 measured in 100%N treatment to 5.69 measured in 150%NPK.significant difference among the treatment except some treatment which are at par. N/Mg ratio varied from 4.57 to 9.33, N/S ratio varied from 6.25 to 11.09 and N/Zn varied from 256 to 744.

The P/K ratio varied from 0.05 to 0.19, P/Ca from 0.37 to 1.0 P/Mg from 0.322 to 1.46, P/S from 0.49 to 1.38 and P/Zn from 25.9 to 86.

K/Ca varied from 2.72 to 12.04. K/Mg varied from 4.33 measured in measured in 100%N treatment to the highest of 9.28 measured in control plot. K/S varied from 6.49 to 13.99 and K/Zn varied widely from 345 to 645.

The Ca/Mg ratio varied between 0.81 and 2.15, Ca/S varied from 0.61 to 3.04 and Ca/Zn 38.17 to 153.Mg/S ratio ranged from 0.90 to 1.62. Mg/Zn from 72 and 113.30. S/Zn from 39 to 94.

Table 8: Nutrient Ratios in Index leaves of rice growth in *rabi* -2015-16.

Treatment	N/P	N/K	N/Ca	N/Mg	N/S	N/Zn	P/K	P/Ca	P/Mg	P/S	P/Zn	K/Ca	K/Mg	K/S	K/Zn	Ca/Mg	Ca/S	Ca/Zn	Mg/S	Mg/Zn	S/Zn
100% PK	4.89	0.58	3.78	6.82	6.25	400	0.12	0.80	1.46	1.31	84.9	6.58	6.51	9.79	627	1.80	2.04	94.45	0.929	94.14	57
100% NPK	8.47	0.75	3.40	4.57	6.33	458	0.09	0.40	0.54	0.75	54.0	4.55	6.03	8.43	612	1.36	1.86	134.49	1.415	107.03	73
150% NPK	14.86	1.15	5.69	9.33	11.09	744	0.08	0.39	0.64	0.75	50.6	4.94	8.06	9.62	645	1.65	1.95	130.99	1.241	113.30	67
100%NPK + Zn	7.40	0.75	4.99	4.19	6.81	256	0.10	0.69	0.58	0.94	35.3	6.75	5.64	9.29	345	0.84	1.33	51.41	1.626	84.09	39
100%NPK+ FYM	8.15	1.38	7.53	8.04	10.32	581	0.18	1.00	1.07	1.33	76.3	6.07	6.43	8.36	464	1.08	1.38	78.46	1.286	108.01	57
100%NPK+Lime + FYM	7.28	1.28	5.43	7.98	9.75	604	0.19	0.78	1.14	1.38	86.5	4.24	6.23	7.63	471	1.47	1.77	111.51	1.235	95.98	63
100%NPK+B +Zn	8.42	0.86	5.13	6.05	9.32	513	0.10	0.61	0.72	1.11	61.0	6.19	7.19	11.24	614	1.20	1.84	101.73	1.545	90.29	56
100% NPK+ S+ Zn	9.88	0.92	3.99	6.61	5.92	550	0.10	0.42	0.69	0.62	58.7	4.36	7.20	6.49	607	1.66	1.48	139.00	0.902	94.55	94
100% N	5.68	0.91	2.50	3.95	6.36	352	0.16	0.45	0.71	1.16	63.2	2.75	4.33	7.08	386	1.57	2.44	140.34	1.656	72.34	58
100 %NP	7.35	1.09	2.97	5.13	9.64	436	0.15	0.41	0.71	1.28	58.4	2.72	4.71	8.85	399	1.73	2.93	146.43	1.900	90.02	50
100% NPK+ Lime	7.67	0.70	2.82	6.07	9.59	433	0.09	0.37	0.79	1.27	57.0	4.04	8.69	13.99	625	2.15	3.04	153.99	1.580	105.65	49
Control	13.58	0.64	7.66	5.87	6.62	345	0.05	0.60	0.45	0.49	25.9	12.04	9.28	10.58	433	0.81	0.61	38.17	1.142	74.53	43
CD(0.05)	2.46	0.21	1.24	1.34	2.78	66.52	0.05	0.23	0.32	0.42	20.1	2.15	1.73	4.2	150	0.32	0.92	18.99	0.54	21.77	13.8
CV%	19.78	16.19	18.49	14.92	23.64	9.77	27.68	27.8	27.69	27.90	23.2	27.52	17.9	31.81	19.77	15.43	32.50	11.18	27.58	16.06	15.8

4.4 Nutrient index for different nutrients.

4.4.1 DRIS Index for *kharif* 2015

Data on DRIS index pertaining to *kharif* season are presented in table 9 along with order of requirements of different nutrients i.e. for seven nutrients N, P, K, Ca, Mg, S, Zn.

The nutrient indices were calculated following standard norms measured in the material and methods chapter. N index varied from a lowest of -17.32 calculated for 100% NPK to a highest of 20.65 in 100% NP treatment. Higher negative values were also measure in 100% NPK + Lime (-14.2) and 100% NPK + Zn (-11.57) treatments indicating N to be most deficient in these treatment. Higher positive values were measured in control (18.47) and 100% N treatment (10.07). In all other treatment the values were smaller.

Phosphorous (P) index varied from highest negative value -30.50 in control to a highest positive value of 7.92 measured in 100% NPK +FYM treatment. Higher negative values were also observed in 100% N (-20.60), 150% NPK (-19.19), 100 % PK (-15.11), 100% NPK (-14.07), 100% NPK + B +Zn (-12.52) and 100% NPK + S+ Zn (-11.86).

Potassium (K) index varied from highest negative value of (-55.99) measured in 100% N treatment to highest positive value of 14.30 in 100% NPK treatment. Higher negative values are measured in 100% NP (-53.60), 100% NPK + Lime (29.95), 100% NPK + B + Zn (-22.41), 100% NPK + S + Zn (22.51).

Calcium (Ca)index varied from highest negative value of -8.70, measured in 100% PK treatment to highest positive value of 19.58 measured in 100% NPK +Lime treatment.

Magnesium(Mg) index varied from highest negative value of -6.99 observed in 100% NPK + Lime + FYM treatment to highest positive value of 16.3 measured in 100% NPK + Lime treatment.

Table 9: DRIS Index value for different nutrients and order of requirement in *kharif* season 2015.

Treatment	N index	P Index	K index	Ca index	Mg index	S index	Zn index	Order of requirement
100% PK	-2.62	-15.11	-3.52	-8.70	12.54	7.88	9.53	P>Ca>K>N>S> Zn >Mg
100% NPK	-17.32	-14.07	-7.76	9.01	12.42	11.75	5.97	N>P>K>Zn>Ca>S>Mg
150% NPK	-2.98	-19.19	14.30	4.43	8.28	-4.68	-0.15	P>S>N>Zn>Ca>Mg>K
100%NPK + Zn	-11.57	-5.74	-11.48	0.65	3.27	1.51	23.35	N>K>P>Ca>S>Mg>Zn
100% NPK + FYM	-0.35	7.92	-4.57	-5.57	2.10	1.03	-0.54	Ca>K>Zn>N>S>Mg>P
100% NPK+ Lime+ FYM	2.82	6.68	-8.75	6.81	-6.99	4.16	-4.73	K>Mg>Zn>N>S>P>Ca
100% NPK +B +Zn	-7.58	-12.52	-22.41	8.47	13.08	4.41	16.55	K>P>N>S>Ca>Mg>Zn
100% NPK+ S+ Zn	-3.61	-11.86	-22.51	6.60	10.84	8.27	12.26	K>P>N>Ca>S>Mg>Zn
100% N	10.07	-20.60	-55.99	-0.97	3.75	36.93	26.81	K>P>Ca>Mg>N>Zn>S
100 %NP	20.65	-6.14	-53.60	17.25	-0.61	13.54	8.91	K>P>Mg>Zn>S>Ca>N
100% NPK+ Lime	-14.12	-9.02	-29.95	19.58	16.35	7.19	9.97	K>N>P>S>Zn>Mg>Ca
Control	18.47	-30.05	-27.70	13.13	-0.71	-3.35	30.20	P>K>S>Mg>Ca>N>Zn

Sulphur index varied from a lowest of -4.68 observed in 150%NPK to highest positive value 36.93 in 100% N treatment.

Zn index varied from highest negative value -4.73 measured in 100%NPK +Lime +FYM treatment to 30.20 measured in control plot.

4.4.2 DRIS index for *rabi* season 2015-2016

Nitrogen (N) index a measured in *rabi* season varied from highest negative value of -55.25 in 100%N treatment to a highest positive value of 6.69 in 150 % NPK. Higher negative values are also measured in 100% NPK+Zn (-55.23), 100% PK (-44.57), 100%NPK (-37.04), 100%NPK+Lime (-33.97), 100% NP-30.50, control (-27.50), 100% NPK +B+Zn(-18.08)

Phosphorous (P) index varied from highest negative values of -45.98 measured in control plot to a highest positive value of 17.36 measured in 100%PK treatment .Higher negative value are also measured in 150%NPK(-20.45), In 100%NPK (-13.86), 100% NPK +Zn(-10.19), 100%NPK+S+Zn (-13.28).

Potassium (K) index varied from highest negative values of -11.29 measured in 100% N plot to a highest positive value of 32.63 measured in control treatment.

Calcium (Ca) index varied from highest negative values of -49.11 observed in control to a highest positive value 38.93 measured 100%NPK+Lime .Higher negative values were also measured in 100%NPK+Zn(-20.2) and 100%NPK+FYM(-12.39). Higher positive values are measured in many treatments.

Magnesium (Mg) Index varied from lowest negative value of -14.02 observed in 100% PK to a highest positive value (18.05) measured 100%NPK+Zn Other values are lower than the highest value.

Table 10: DRIS Index value for different nutrients and order of requirement in *rabi* season *2015-2016*

Treatment	N index	P-Index	k index	Ca index	Mg index	s index	zn index	Order of requirement
100% PK	-44.57	17.36	16.94	9.19	-14.02	3.09	12.01	N>Mg>S>Ca>Zn>K>P
100% NPK	-37.04	-13.86	10.47	19.56	11.83	6.90	2.16	N>P>Zn>S>K>Mg>Ca
150% NPK	6.55	-20.45	10.38	15.45	-6.28	0.60	-6.24	P>Mg>Zn>S>N>K>Ca
100%NPK + Zn	-53.23	-10.19	5.87	-20.29	18.05	-3.45	63.24	N>Ca>P>S>K>Mg>Zn
100% NPK + FYM	-1.65	11.25	-2.95	-12.39	-0.83	-1.98	8.54	Ca>K>S>N>Ca>Zn>P
100% NPK+ Lime+ FYM	-6.63	12.09	-5.51	6.44	-6.34	-1.40	1.35	N>Mg>K>S>Zn>Ca>P
1000% NPK +B +Zn	-18.08	-2.80	12.46	2.23	3.27	-4.86	7.78	N>S>P>Ca>Mg>Zn>K
100% NPK+ S+ Zn	-20.46	-13.28	6.41	19.35	-5.48	18.83	-5.38	N>P>Mg>Zn>K>S>Ca
100% N	-55.25	3.49	-11.29	33.48	11.58	-0.11	8.54	N>K>S>P>Mg>Zn>Ca
100 %NP	-30.50	-2.85	-8.83	34.53	7.42	18.80	5.17	N>S>K>P>Zn>Mg>Ca
100% NPK+ Lime	-33.97	-6.44	16.92	38.93	9.80	3.39	3.39	N>S>Mg>P>Zn>K>Ca
Control	-27.51	-41.95	32.63	-49.11	5.22	15.97	64.76	Ca>P>N>Mg>S>K>Zn

Sulphur (S) index varied from a highest negative value (-4.86) measured in 100%NPK+B+Zn treatment to highest positive value (18.80) .

Zinc (Zn) index varied from highest negative value -6.24 measured in 150% NPK to highest positive value in control plot (64.76). Higher positive values were also measured in 100% NPK + Zn (63.24) and 100% PK (12.01).

4.3 Nutritional Balance Index (NBI)

4.3.3.1 Interpretation through NBI

Data pertaining to NBI for *kharif* and *rabi presented in table* 11 and 12

Higher the NBI greater is the nutrient Imbalance. In *kharif* season the NBI varied from the lowest of 22.07 measured in 100% NPK+FYM treatment to a highest of 155.13 measured in 100%N treatment.

Higher values are also measured in control (NBI =123.59) followed by 100% NP (NBI =120.69), 100%NPK+Lime (NBI=106.17), 100%NPK +Zn +B (NBI =85.01), 100% NPK+Zn+S (NBI=75.95), 100% NPK (NBI=70.30), 100% NPK+FYM+Lime treatment also measured a lower value of 40.49 followed by 150%NPK (54.0)

In *rabi* season the Nutritional Balance Index which was used as a tool to asses the nutrient balance in plant nutrition varied from a lowest of 39.57 measured in 100%NPK+FYM treatment to highest of 237.14 measured in control plot. Higher value are also measured in 100% NPK+Zn (NBI=174.32), 100%N (NBI=133.28) and 100% NPK+Lime (NBI=118.48), 100%PK (NBI=117.18), 100%NP (103.92), 100% NPK (101.81) and 100% NPK+Zn+S (NBI=89.19), Lower values of 39.75 was measured in 100% NPK+FYM +Lime treatment followed by 150% NPK(NBI=65.93)

4.3.3.2 Interpretation of DRIS Index value based on average nutritional balance index (NBIa).

Interpretation was done based on criteria to interprete DRIS index by Nutritional Application Potential Response (NAPR) outlined by Wadt (1996).

In *Kharif* NBIa varied from lowest of 3.15 measured in 100%NPK +FYM to highest of 22.16 measured in 100%N treatment and in *rabi* it varied from lowest 5.65 measured in 100%NPK+FYM treatment to a highest of 53.88 measured in control plot.

Table 11: Treatment wise ordering of nutrient index, Nutritional Balance Index and average NBI measured in *kharif* season 2015

Treatment	Most deficient →						← Most sufficient	Nutritional Balance Index (NBI)	Average Nutritional Balance Index (NBI a)
Treatment									
T_1	P -15.11	Ca -8.6	K -3.5	N -2.6	S 7.8	Zn 9.53	Mg 12.5	59.88	8.55
T_2	N -17.3	P -14.07	K -7.75	Zn 5.96	Ca 9.01	S 11.75	Mg 12.4	78.30	11.19
T_3	P -19.19	S -4.68	N -2.97	Zn -0.15	Ca 4.42	Mg 8.27	K 14.29	54.00	7.71
T_4	N -11.57	K -11.47	P -5.7	Ca 0.65	S 1.51	Mg 3.27	Zn 23.35	57.58	8.23
T_5	Ca -5.57	K -4.57	N -0.35	Zn -0.54	S 1.02	Mg 2.09	P 7.91	22.07	3.15
T_6	K -8.75	Mg -6.99	Zn -4.73	N 2.82	S 4.16	P 6.68	Ca 6.80	40.94	5.85
T_7	K -22.41	P -12.51	N -7.57	S 4.41	Ca 8.47	Mg 13.07	Zn 16.54	85.01	12.14
T_8	K -22.50	P -11.86	N -3.60	Ca 6.60	S 8.26	Mg 10.83	Zn 12.26	75.95	10.85
T_9	K -55.99	P -20.60	Ca -0.97	Mg 3.75	N 10.07	Zn 26.80	S 36.92	155.13	22.16
T_{10}	K -53.59	P -6.14	Mg -0.60	Zn 8.90	S 13.53	Ca 17.25	N 20.64	120.69	17.24
T_{11}	K -29.94	N -14.11	P -9.02	S 7.19	Zn 9.96	Mg 16.35	Ca 19.57	106.17	15.17
T_{12}	P -30.04	K -27.69	S -3.34	Mg -0.70	Ca 13.12	N 18.47	Zn 30.19	123.59	17.66

Table 12: Treatment wise ordering of nutrient index, Nutritional Balance Index and average NBI measured in *rabi* season 2015-16.

Treatment	Most deficient →					← Most sufficient	Nutritional Balance Index (NBI)	Average Nutritional Balance Index (NBI a)
T_1	N -44.57	Mg -14.02	S 3.09	Ca 9.19	Zn 12.00	K 16.93	P 17.36	117.18	16.74
T_2	N -37.04	P -13.86	Zn 2.16	S 6.89	K 1.046	Mg 11.82	Ca 19.55	101.81	14.54
T_3	P -20.45	Mg -6.27	Zn -6.24	S 0.05	N 6.55	K 10.37	Ca 15.45	65.95	9.42
T_4	N -53.23	Ca -20.28	P -10.19	S -3.45	K 5.87	Mg 18.05	Zn 63.23	174.32	24.90
T_5	Ca -12.38	K -2.94	S -1.97	N -1.65	Ca 6.44	Zn 8.53	P 11.24	39.57	5.65
T_6	N -6.62	Mg -6.33	K -5.51	S -1.40	Zn 1.34	Ca 6.44	P 12.09	39.75	5.68
T_7	N -18.07	S -4.85	P -2.10	Ca 2.22	Mg 3.27	Zn 7.78	K 12.45	51.47	7.35
T_8	N -20.46	P -13.28	Mg -5.47	Zn -5.37	K 6.41	S 18.83	Ca 19.35	89.19	12.74
T_9	N --55.23	K -11.29	S -0.11	P 3.49	Mg 11.58	Zn 18.00	Ca 33.48	133.28	19.04
T_{10}	N -30.50	S -9.80	K -8..83	P -2.81	Zn 3.39	Mg 7.42	Ca 34.53	103.92	14.11
T_{11}	N -33.50	S -11.63	Mg -7.19	P -6.44	Zn 3.39	K 16.92	Ca 38.92	118.48	16.93
T_{12}	Ca -49.62	P -41.95	N -27.51	Mg 5.22	S 15.96	K 32.62	Zn 64.75	237.14	33.88

Figures indicate DRIS index values of respective nutrients

4.4 Relationship between NBI and Relative Dry Matter/Crop Yield

The effectiveness of DRIS system used for identification of limiting nutrient can be evaluated by constructing graph between NBI and biomass yield (Silveria *et al.*, 2005). The relationship of NBI with % Relative dry matter yield for both *kharif* and *rabi are* depicted in figure2a and 2b and the relationship of NBI with grain yield in *kharif* and *rabi* in figure3a and 3b.

From the graph it is clear that for both biomass and grain yield there is positive relationship in both *kharif* and *rabi* season The R^2value for rabi biomass 0.73 and grain yield 0.70 explaining the effectiveness of NBI from DRIS technique to be good especially for *rabi* season.

For *kharif* season the relation is also good with R^2 value is 0.34 for both biomass and crop yield.

From the result it can be inferred that DRIS can be used as an effective diagnostic tool for identifying the yield limiting nutrient(s) under a particular cropping system and climatic situation.

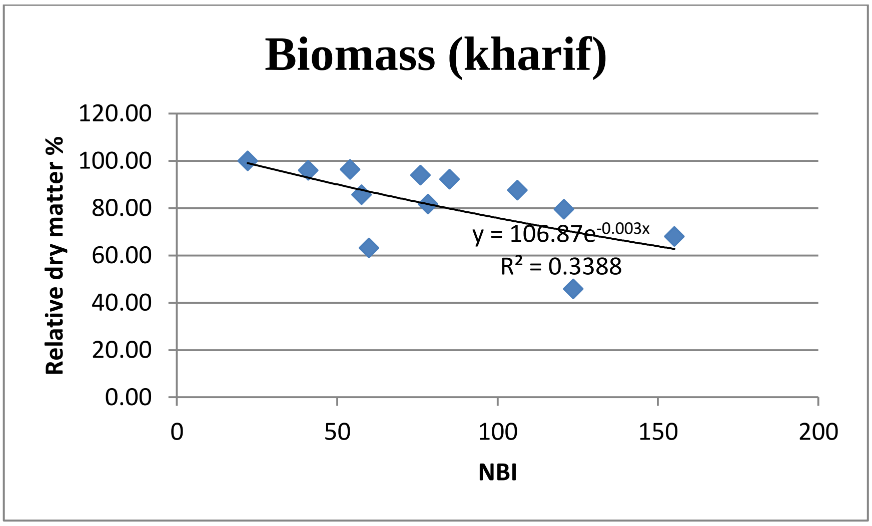

Fig. 2a : Relationship between NBI and relative dry matter yield percentage

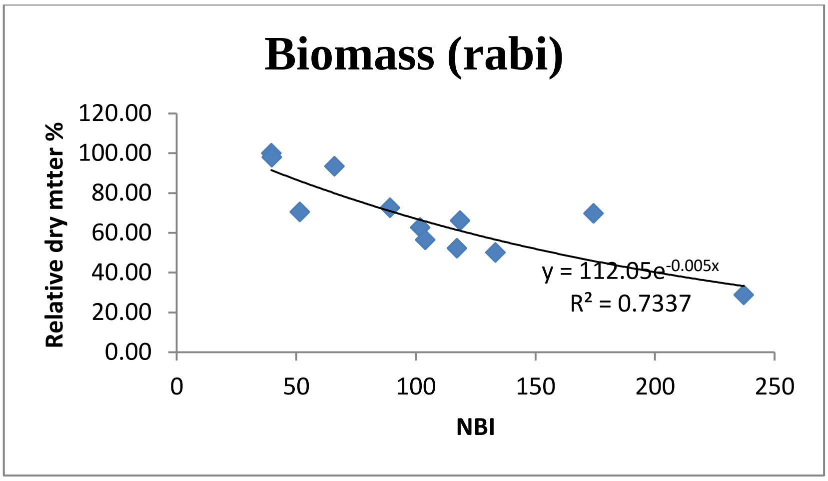

Fig. 2b : Relationship between NBI and relative dry matter yield percentage

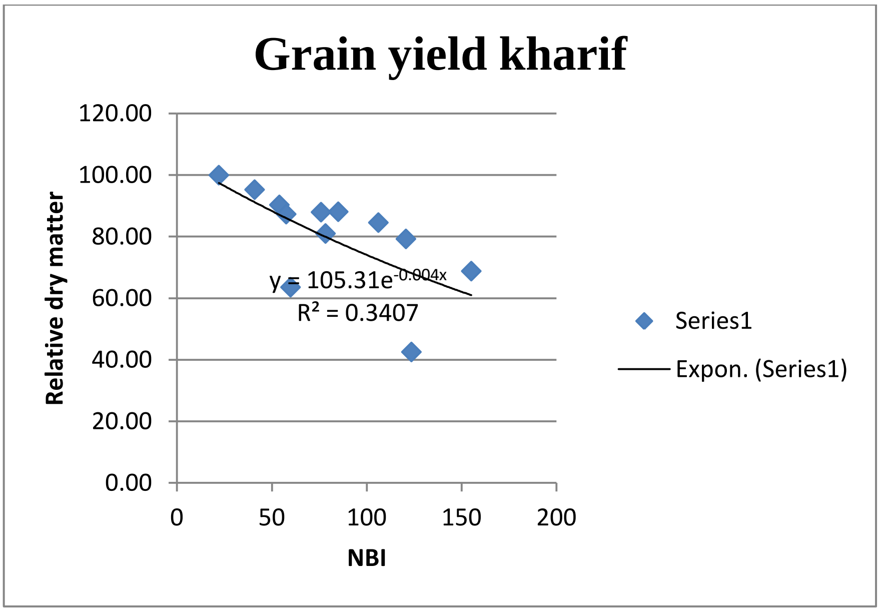

Fig. 3a : Relationship between NBI and relative dry matter yield percentage

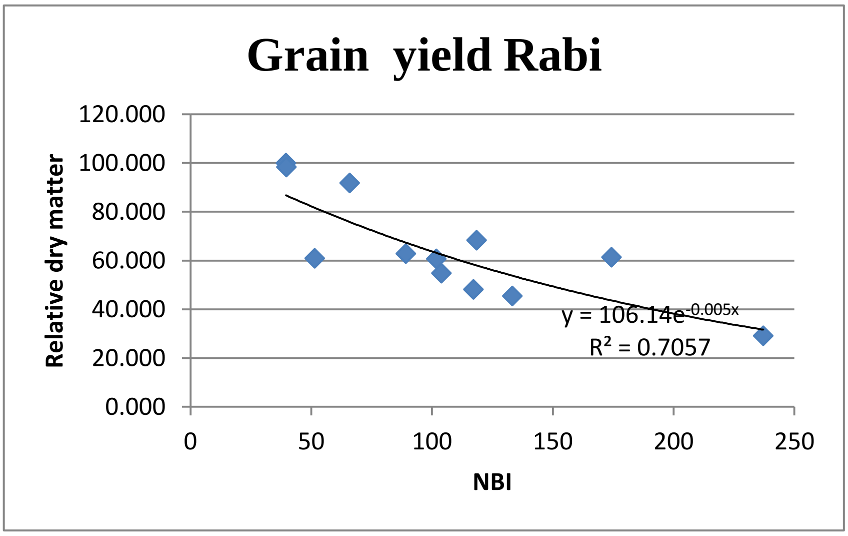

Fig. 3b : Relationship between NBI and relative dry matter yield percentage

4.5 Soil test based soil fertility status

4.5.1 Soil fertility status measured in *pre kharif* in presented in table 13

In pre kharif 2015 soil pH varied from 5.28 to 6.33 There was a general drop in pH from the initial 5.8 ,the FYM amended and lime treated plot resisted this drop and maintained higher pH than all other treatments

Available Nitrogen varied from 129 kg /ha measured in control plot to a highest 246kg/ha measured in 100% NPK+FYM treatment. There was increase in available N content in all fertilizer plot and there was fall in control plot. Soils of all treatments were low in available N.

Available P varied from 7.08kg/ha to highest of 36.50 measured in 100% NP0IK+FYM+Lime treatment. Available P was high in FYM amended treatment and 150%NPK treatment but in other treatment it was medium .In control available P was low and there was general decrease in available P content in almost all treatment except the FYM amended treatment and 150% NPK treatment

Available K varied from 53.46 kg/ha measured control plot to a highest 120.95kg/ha measured in 100% NPK+FYM +Lime treatment. Available K content was much higher than increase over the initial soil status in all other treatments.

Available S it varied from 14.67 to 55.23 kg/ha measured in 100% NPK+ Zn +S. Treatment and 150% NPK maintained high level of available S. The S status was medium in all the treatment except control which was low

The DTPA extractable Zn varied from lowest of 0.7mg/kg to highest of 8.13 mg/kg to a measured in 100% NPK+Zn treatment. The treatment that continuously received Zn showed high content of Zn as compared other treatments.

Table 13: Soil test based soil fertility status of *pre kharif* 2015

Treatment	pH	N(kg/ha)	P(kg/ha)	K(kg/ha)	S(kg/ha)	Zn	Deficient in plant	Excess IN plant
100% PK	5.28	188	13.06	84.55	32.16	1.09	P,Ca	Mg,Zn
100% NPK	5.41	214	18.45	100.44	25.37	0.98	N,P	Mg,S
150% NPK	5.39	240	23.73	120.22	38.78	0.98	P	Mg,K
100%NPK + Zn	5.35	212	17.79	95.60	29.82	10.92	N,K	Zn
100% NPK + FYM	5.98	246	34.24	110.19	38.40	2.32	Ca,K	P
100% NPK+Lime+ FYM	6.20	240	36.50	120.95	39.15	1.99	K,Mg	Ca,P
100% NPK +B +Zn	5.45	216	16.07	96.30	34.78	13.81	K,P	Zn,Mg
100% NPK+ S+ Zn	5.28	218	19.17	85.27	55.23	13.73	K,P	Zn
100% N	5.43	203	9.60	68.94	25.19	0.832	K,	S,Zn
100 %NP	5.47	212	12.22	66.10	26.10	1.48	K	N,Ca
100% NPK+ lime	6.33	213	15.07	103.36	25.73	1.12	K,	Ca,Mg
Control	5.31	129	7.08	53.46	14.67	0.97	P,K	Zn,N
Initial soil	5.8	187	19.7	43.4	22.2	1.80		

4.5.2 Soil fertility status measured in pre rabi are presented in table 14

In rabi season the soil pH varied from minimum of 4.8 to 6.42. There was a general drop of in soil Ph FROM the initial status of 5.88 except some treatment which received FYM or Lime T he treatment which received Lime or FYM resisted the drop in pH. All the treatments turn acid .There was drop in pH from initial value of 5.8 in all treatments which receive lime and FYM resist the drop.

Available nitrogen was low in all the treatment. Available Phosphorous varied widely the control plot very low P of 3.72 kg/ha and only the treatments 100% NPK+FYM and 100% NPK+FYM+Lime had high status of available phosphorous. With respect to available K all the treatment had low status except 100% NPK +FYM +Lime treatments which had medium status.

Available S was medium in most of the treatments except 100%PK, 100% N, and control which was low .With respect to Zn all the treatments were sufficient and above the critical deficiency level of 0.6 mg/kg.

Table 14: Soil test based soil fertility status of *pre rabi* 2015 -16

Treatment	pH	N (kg/ha)	P(kg/ha)	K(kg/ha)	S(kg/ha)	Zn	Deficient in Plant	Excess IN plant
100% PK	4.848	173.28	5.17	95.18	16.15	0.91	N	P,K
100% NPK	5.093	189.23	9.55	100.81	32.33	0.98	N	Ca,
150% NPK	4.83	220.73	19.09	108.70	23.25	0.98	P	Ca,K
100%NPK + Zn	4.868	178.21	8.96	113.60	25.30	10.92	N	Zn
100% NPK + FYM	5.398	245.51	27.25	122.63	27.97	2.32	Ca	P,Zn
100% NPK+Lime+ FYM	5.455	231.55	30.84	126.70	28.88	1.99	N,Mg	P,Ca
100% NPK +B +Zn	5.678	199.62	7.24	109.63	24.62	13.81	N	K, Zn
100% NPK+ S+ Zn	4.975	211.51	7.45	111.23	38.30	13.73	N,P	Ca ,S
100% N	4.843	177	5.32	71.27	11.17	0.832	N	Ca
100 %NP	5.035	181.25	6.75	76.53	18.58	1.48	N	Ca
100% NPK+ lime	6.420	230.98	13.27	108.99	28.45	1.12	N	Ca, K
Control	4.978	145.63	3.72	42.40	9.07	0.97	Ca,P	Zn
Initial soil	5.8	187	19.7	43.4	22.2	1.80		

DISCUSSION

5.1. Effect of long term manuring on concentration of nutrients in Index Leaves of rice at flowering stage

5.1.1 Kharif,2015

5.1.1.1 Nitrogen

The leaves of treatments like 100% NPK+FYM+Lime, 100%NPK+FYM.and 150%NPK contained significantly more N as compared to other treatments .Addition of 5t FYM /ha increased the nitrogen content by 30 %.This can be ascribed to the release of nitrogen from organic manure (Tool et al.,2001) and increase in biological activity that caused more N fixation and mineralisation. Similar results was also found by (Vageesh *et al.,* 1990)

5.1.1.2 Phosphorous

The phosphorous content is more in treatment like 100%NPK+FYM and 100% NPK +FYM+Lime. Addition of 5t of FYM per ha and 1t of Lime increased the phosphorous content by 37% and36% respectively over 100%NPK. Similar result was reported by Subramanian and Kumaraswamy (1989) .A marked rise in the available P status of the soil with the application of lime and FYM might be due to the inactivation of iron, aluminium and hydroxyl Al ions thereby reducing the P fixation in soil and uptake of more phosphorous

5.1.1.3 Potassium

Addition of 5 t /ha of FYM increased the potassium content by 16% over 100%NPK. Prasad *et al.,*(1982) also reported that FYM increased Potassium content. Another scientist reported that the beneficial effects of FYM on the availability of K may be ascribed to the reduction in K fixation and release of K due to the interaction of organic matter with clay (Tolanur and Badanur, 2003)

5.1.1.4 Secondary nutrients

Application of FYM and lime increased calcium and magnesium content by 14% and 11% respectively. The exchangeable Ca and Mg content in continuously fertilized acid soil increased due to the application of lime and FYM as reported by Kumar *et al.,*1993. The FYM has a positive effect on Ca and Mg built up in soil because it is having high adsorptive capacity that might have adsorbed Ca and Mg which would otherwise be leached thus uptake of Ca and Mg increases.

Sulphur percentage is less than calcium and magnesium. Sulphur percentage increased with application of FYM and gypsum. The increase in available S status due to organic manure application would be due to the multiplication of soil microbes leading to enhanced conversion of organically bound S into inorganic forms and in gypsum there is 15% sulphur which leads to increase in sulphur content of soil leading to more uptake. Similar result was also reported by (Mondal *et al.,* 1993)

5.1.1.5 Micronutrients

Iron and manganese content of leaves were found to be higher than copper and zinc as soil contained much higher amount of Fe and Mn. Copper and zinc found to be more in FYM. The cationic micronutrients in the soil showed a build up with the application of FYM. The increased availability with more plant uptake might be due to the chelation process (Sarkar and Singh, 2002).

5.1.2 Rabi, 2015-16

5.1.2.1 Nitrogen

Here nitrogen content of leaf is more in 100% NPK +FYM than in 100% NPK treatment. Addition of 5 t of FYM in *rabi* season increased the nitrogen content by 50%. The reason for this is might release of nitrogen from organic manure (Tool *et al.*,2001).

5.1.2.2 Phosphorous

The phosphorous content is more in treatment like 100%NPK+FYM and 100% NPK +FYM+Lime. Addition of 5t of FYM/ha and 1t of Lime increased the phosphorous content by53 % and 55% and respectively over 100%NPK. Similar result were reported by Subramanian and Kumaraswamy (1989).

5.1.2.3 Potassium

In contrast to a *kharif* season FYM contributed less to the Potassium uptake which is due to low mineralization of FYM in *rabi* season (Ojha *et al.,(*2014).

5.1.2.4 Secondary nutrients

Application of FYM and lime increased calcium and magnesium by 33% and 4% respectively. The exchangeable Ca and Mg status of continuously fertilized acid soil increased due to the application of both lime and FYM as reported by Kumar *et al.,*1993. The FYM has a positive effect on Ca and Mg content in soil because it is having high adsorptive capacity that might have adsorbed Ca and Mg which would otherwise be leached.

Like kharif season, Sulphur content is also less than calcium and magnesium. Sulphur percentage increased with application of FYM and gypsum The increase in available S status due to organic manure application would be due to the multiplication of soil microbes leading to enhanced conversion of organically bound S into inorganic forms and in gypsum there is sulphur which leads to increase in sulphur content. Similar result was reported by (Mondal *et al.,*1993) and uptake of sulphur increased.

5.1.2.5 Micronutrients

Iron and manganese was found to be higher than copper and zinc. The cationic micronutrients in the soil showed a build up with the application of FYM. The increased availability may be due to the chelation process reported by Sarkar and Singh, 2002.

5.2 Nutrient Ratios in Index leaves of rice

5.2.1 Kharif -2015

Higher N/P value indicates proportionately low content of phosphorous or high content of N in the leaf tissue and vice versa. Hundal *et al.,*(2008) reported mean ratio of 11.03 by and 9.8 by Counce and Well(1986). They have reported higher ratio because of high nitrogen content in their samples. Higher values are measured in treatment which received no potassium and had low K content in leaf. Lower ratio value was measured in cases where potassium content is high in leaf. Higher values are observed in treatment which contained more N and received less Ca. Lower values of ratio are observed in treatment which received more Ca from lime .Reported mean value of N/Ca is 4.688 by Hundal *et al.*,(2008) and 6.77 by Counce and Bell (1986).The reported high value is due to higher nitrogen value. Higher value of ratio reveals more nitrogen present and vice versa. A mean value of 10.07 was reported by Hundal *et al.,*(2008) and 19.72 by Counce and Well (1986).The higher value reported suggest for presence of higher nitrogen content in the leaf tissue than magnesium. Higher values reveal the presence of less sulphur and vice versa. The mean value of 17.28 is reported by Counce and Well (1986) and 10.51 by Hundal *et al.,*(2008).In Kharif season among the treatment T_9 which received only N was most imbalanced with P being most deficient nutrient. The second and third most nutritionally imbalanced treatments are the Control and 100 % NP treatment. In Control, P is the most limiting nutrient and 100%NP treatment K was most deficient. The treatment which received lime that is T_6 and T_{11} are sufficient in Ca but deficient in K. Between T_6 and T_{11} the later was most deficient in K followed by N than T_6 which receive 5 tons FYM along with 100% NPK as FYM contributed to K availability. In Kharif most of the treatments are deficient in K followed by P. In Rabi season the control plot was nutritionally more imbalanced followed by the treatment which received 100% NPK + Zn. Among the treatment T5 and T6 which received 5 Tons of FYM in addition with inorganic fertiliser and Lime were nutritionally most balanced. Lower values received K/Ca observed in treatments that received no potassium (100%N,100%NP ,Control).Application of lime also caused significant drop in K/Ca ratio .Lime application reduces K availability in soil causing less uptake of it and lower value of K/Ca. As Ca content is less the ratio is mostly governed by K uptake. The ratio varied from 5.24 to 6.06.K/S was relatively low in sulphur applied treatments and plots which received no potassium or limed plot without FYM. The treatment which received Ca in form of Lime record high value of all the three ratio. Hundal *et al.*,(2008) reported the mean value of Ca/Mg ,Ca/S, Ca/Zn is 2.14,0.47,45.044 respectively .Higher value indicate either uptake of relatively more magnesium or less sulphur from the soil. Optimum value of Mg/S was around 1.76. The highest ratio was observed in 150% NPK and lowest was observed in 100% N treatment. Hundal *et al.*, (2008) reported the mean value of Mg/S to be 0.9887 and Mg/Zn, 93.169 .Counce and Well (1986) reported the mean value of Mg/ S to be 0.949.

5.2.2 Rabi, 2015-2016

Treatment with 150% NPK and Control plot recorded highest N/P ratio which was higher than the optimum value 10.07. Hundal *et al.*,(2008) reported N/P ratio of 11.03. The treatment that received FYM along with NPK maintained a higher ratio. 100% PK treatment which received no nitrogen registered lowest N/P ratio. Highest P/K ratio is measured in 100%NPK+Lime +FYM and lowest value observed in control as potassium is more than phosphorous. Counce and Well (1986) reported the mean value of P/K 0.12 .Highest P/Ca ratio was observed in 100% NPK +FYM and lowest in control. Treatment 5 and 6 are higher than all other treatments .Integrated use organic manure with inorganic fertilizer also resulted in higher ratio in P/Mg,P/S and P/Zn ratio. Hundal *et al.*,(2008) reported the mean value of P/Ca ,P/Mg ,P/S ,P/Zn is 2.3, 0.9,1.093,103 respectively. Counce and Well reported for P/Ca,P/Mg ,P/S to be 0.71,2.12,1.80respectively.From result it is concluded that the treatment which receives more Ca in form of Lime result in high value of Ca/S than all other treatment and vice versa. In case of Mg/S, highest value was observed in treatment which received lime and lowest value observed in treatment which received S. In case of Mg/Zn highest value observed in treatment which receives 150%NPK and lowest observed in treatment which received Zn.

5.3 DRIS Index value for different nutrients and order of requirement

5.3.1 Interpretation of DRIS index

5.3.1.1 Kharif, 2015

Higher the negative value of DRIS index, more deficient is the nutrient and higher the positive value, more sufficient or excess is the nutrient. Based on the calculated DRIS Index the deficiency or sufficiency or excess of different nutrients in different treatments can be determined.

In kharif season, nitrogen was most deficient in 100% NPK (I_N = -17.32), followed 100% NPK + Lime (I_N = - 14.12) and 100% NPK + Zn (I_N = -11.57).Phosphorous was most deficient in control plot(I_P=-30.05)followed100%N (I_P = -20.60), 100% PK (I_P = -15.11), 100% NPK (I_P = - 14.07), 150% NPK (I_P = -19.19), 100% NPK + B+ZN (I_P = - 12.52)and 100% NPK + S + Zn (I_P = - 11.86).Potassium was most deficient in 100% N (I_K = -55.9) followed by 100% NP (I_K = -53.60), 100%NPK +lime (I_K = 29.95), 100% NPK + B + Zn (I_K = -22.41), 100% NPK +S+ Zn (I_K = -24.51), 100% NPK + Zn (I_K = - 11.48).Calcium was moderately deficient only in 100% PK (Ica = - 8.70) and 100% NPK +FYM (I_{Ca} = - 5.57).Magnesium was moderately deficient in only in 100% NPK + lime (I_{Mg} = - 6.99)Sulphur was moderately deficient in only in 150% NPK (I_S = -4.68).Zinc was moderately deficient in 100% NPK + Lime + FYM (I_{Zn} = - 4.73) and about to be deficient in 100% NPK + FYM (I_{Zn} = - 5.54) and 150% NPK (I_{Zn} = - 0.15). Zinc was sufficient in control (I_{Zn}=

30.20), 100% N (I_{Zn} = 26.81), 100% NPK + Zn (I_{Zn} = 23.35), 100% NPK + B + Zn (I_{Zn} = 16.55), 100% NPK + S + Zn (I_{Zn} = 12.26)

5.3.1.2 Rabi 2015-16

Nitrogen (N)was deficient in many treatments; 100% N (I_N = - 55.25), 100% NPK + Zn (I_N = - 53.23), 100% PK (I_N = - 44.57), 100% NPK (I_N = - 37.04), 100 % NPK + lime (I_N = -33.97), 100% NP (I_N = - 30.50), control (I_N= -27.51), 100% NPK + S + Zn (I_N = - 20.46), 100% NPK + B + Zn (I_N= - 18.08). Treatments which yield more viz, 100% NPK + Lime + FYM with I_N = -6.63, 100% NPK + FYM (I_N = - 1.65) were also slightly deficient in Nitrogen. Phosphorous was found to be most deficient in control (I_P = - 49.95) followed by 150% NPK (I_P = - 20.45), 100% NPK (I_P = - 13.86), 100% NPK + S + Zn (I_P = -13.28), 100% NPK + Zn (I_P = - 10.19). Phosphorus was sufficient in 100% PK (I_P = 17.36), 100 % NPK + FYM + Lime (I_P= 12.09) and 100 % NPK + FYM (I_P = 11.25).

Potassium was deficient in 100% N treatment (I_K = -11.29) and moderately deficient in 100% NP (I_K = - 8.83). The treatment like 100% NP + lime + FYM (I_K= - 5.51) and 100% NPK + FYM (I_K = - 2.95) were also slightly deficient in K. Calcium was the most deficient in control (I_{Ca} = - 49.11) followed by 100% NPK + Zn (I_{Ca} = - 20.29), 100% NPK + FYM (I_{Ca} = - 12.39). Most of the treatments were sufficient in Caviz, 100% NPK + Lime (I_{Ca} = 38.39), 100% NP (I_{Ca}= 34.53), 100% N (I_{Ca} = 33.48), 100% NPK (I_{Ca} =19.39),150% NPK (I_{Ca}= 15.45) and 100%NPK+S+Zn (I_{Ca} = 19.35).Magnesium was most deficient in 100% PK (I_{Mg} = - 14.20) followed by 100% NPK + Lime + FYM (I_{Mg} = - 6.34) and 150% NPK with (I Mg = - 6.28).

With respect to Sulphur no treatment was found to be most deficient in S in rabi season, However some treatment like 100% NPK + B + Zn (I_S = -4.86), 100% NPK + Zn (I_S = - 3.45), 100% NPK +FYM (I_S = - 1.4) having lower negative values were likely to be develop S deficiency . Zinc was found to be slightly deficient in 150% NPK ($I_{Zn\,=}$6.55) and 100% NPK +S+Zn (I_{Zn}=-5.38).

5.3.2 .Interpretation through ordering of DRIS index value

5.3.2.1Kharif, 2015

100%PK

Interpretation through ordering of DRIS index value from most negative to most positive value revealed that in *kharif* season, 100% PK treatment was most deficient in phosphorous followed by calcium, potassium and nitrogen whereas magnesium was excess followed by Zn and S.

100% NPK

100% NPK was most deficient in N (I_N=-37.04) followed by P & K and sufficient in Mg followed by S, Ca and Zn.

150%NPK

The treatment which received 150% NPK was most deficient in P and slightly deficient in N and Zn, but sufficient in K and Mg and Ca.

100% NPK +Zn

100% NPK + Zn treatment is most deficient in N followed by K and slightly deficient in P and sufficient in Zn.

100% NPK+FYM

The high yielding 100% NPK +FYM treatment was slightly deficient in Ca followed by K and N and slightly sufficient in P, Mg and S.

100% NPK+FYM +Lime

100% NPK + FYM +Lime treatment was slightly deficient in K, Zn and slightly sufficient in Ca, P and N.

100% NPK + B + Zn

100% NPK + B + Zn was most deficient in K followed by P and slightly deficient in N. This treatment was sufficient in Zn, Mg.

100% NPK + S + Zn

100% NPK + S + Zn was most deficient in K followed by P .This treatment was sufficient in Zn, Mg, Ca.

100%N

The treatment which received 100% N was most deficient in K followed by N and P and was sufficient in S, Zn.

100%NP

100%NP treatment was most deficient in K and sufficient in N, S and Zn

100% NPK+Lime

100% NPK+Lime was most deficient in K followed by N, P and sufficient in Ca,, Zn

Control

The unmanured control treatment is most deficient in P and K and was sufficient in Zn, and N.

5.3.2.2 Rabi ,2015-2016

100% P K

In *rabi* season the treatment which received 100%/P K was most deficient in N followed by Mg and it was sufficient in P, K, Zn, Ca and S.

100% NPK

100% NPK treatment was most deficient in N followed by P and sufficient in Ca, K and Mg.

150% NPK

150% NPK treatment was most deficient in P and slightly deficient in Mg Zn sufficient in Ca, K.

100% NPK + Zn

100% NPK + Zn treatment was most deficient in N followed by Ca &P and it was sufficient in Zn followed by Mg and K.

100NPK+FYM

High yielding treatment 100% NPK + FYM in *rabi* season was deficient in Ca and slightly deficient in K, N, S and Mg, It was sufficient in P and Zn.

100% NPK + Lime +FYM

100% NPK + Lime +FYM treatment was slightly deficient in N followed by Mg and K,and slightly sufficient in P, Ca and Zn.

100 % NPK + B +Zn

100% NPK + B +Zn treatment was most deficient in N followed by P, Mg and N, it was sufficient in Ca, S and K.

100 % NPK + S +Zn

100% NPK + B +Zn treatment was most deficient in N followed by P, it was sufficient in Ca, S.

100%N

The treatment which continuously receive N was also most deficient in N. This might be due to poor absorption and utilisation of available N because of K deficiency. This treatment is sufficient in Ca, Zn, Mg and P.

100% NP

This treatment was most deficient in N followed by K and slightly deficient in P and was sufficient in Ca, Mg, Zn and S.

100% NPK + Lime

It was most deficient in N and slightly deficient in P and sufficient in Ca and K.

Control

The control plot was most deficient in Ca followed by P and N. It was sufficient in Zn, K, S and Mg.

5.3.3 Interpretation through Nutritional Balance Index (NBI)

5.3.3.1 Kharif, 2015

Based on NBI value, the highest yielding treatment 100% NPK+FYM was most balanced because of lowest NBI value of 22.07 and the treatment which received 100%N was the most imbalanced with NBI of 155.13.

Treatment like 100%NP, Control and 100%/NPK +Lime were also nutritionally more imbalanced. In terms of nutrient balance the treatment can be ordered as : 100%NPK+FYM > 100%NPK+Lime +FYM > 150% NPK > 100%NPK+Zn > 100%PK> 100%NPK+S+Zn > 100%NPK> 100%NPK +Zn +B > 100%NPK+Lime > 100%NP > control> 100% N.

5.3.3.2Rabi, 2015 -16

Based on NBI value the treatment 100%NPK+FYM and 100%NPK+FYM+Lime were nutritionally most balanced and control plot was most imbalanced followed by 100%N, 100%NPK+Zn, 100% NPK+Lime, 100%PK, 100%NP and 100%NPK

In terms of nutrient balance the treatment can be ordered as: 100%NPK+FYM > 100%NPK+FYM+Lime, > 100%NPK+Zn+B, >150%NPK, >100%NP+Zn+S > 100%NPK,>100%NPK +Zn +S > 100%NPK,> 100%NP,> 100%PK> 100%NPK+Lime ,> 100+NPK +Zn control

5.3.4 Interpretation of DRIS Index value through Average Nutritional Balance Index (NBIa)

If the absolute value of DRIS index is greater than NBIa and DRIS Index is negative with higher negative value the nutrient is deficient and there is high probability of positive response to the nutrient. If the absolute value of DRIS index is greater than NBIa and DRIS value is positive with higher value then the nutrient in considered as excess with high probability of getting negative response to that nutrient.

Basing on this criteria the treatment wise interpretation is as follows.

5.3.4.1 Kharif, 2015

100% PK

It is most deficient in phosphorous followed by calcium ,Potassium and excess in magnesium .followed by Mg and Zn. The crop will respond to application of phosphorous and there will be negative response to magnesium

100%NPK

In this treatment both nitrogen and phosphorous are deficient and crop will respond to their application. On the other hand, magnesium is excess and the crop will respond negatively to Mg.

150%NPK

The treatment is most deficient in phosphorous and crop will respond to its application. Potassium is sufficient and crop will not respond to potassium application.

100%NPK+Zn

It is equally deficient in nitrogen and potassium and excess in Zn.

100%NPK +FYM

It is the high yielding treatment deficient in Ca and K.

100%NPK+FYM+Lime

It is deficient in K and Zn and the probability of getting response to this nutrient is also low.

100%NPK+Zn +B

It is most deficient in K followed by P and probability of getting response to K application is high and excess in Zn and Mg whose application will give negative response.

100%NPK+Zn+S

It is most deficient in K and P like previous treatment and probability of getting response from K is high and from P low.

100% N

It is most deficient in K followed by P and excess in S and Zn and the crop will respond positively to application of both K and P .

100%NP

It is deficient in K and its application has high probability of getting response. The treatment has excess Ca and Mg whose application will yield negative response.

Unmanured Control

In *kharif it* is most deficient in P followed by K. Application of P and K will have high response.

5.3.42Rabi, 2015 - 16

100%/PK

It is most deficient in nitrogen and excess in phosphorous and potassium. The crop will definitely respond to nitrogen application as the Index value is much higher than NBIa.

100%NPK

It is deficient in nitrogen and sufficient in Ca and crop will definitely respond to nitrogen application.

150%NPK

It is most deficient in phosphorous which might be due to less availability in root rhizosphere.

100%NPK+Zn

In this treatment nitrogen is most deficient and Zn is excess The crop will definitely respond to N application and there will be negative response to Zn.

100%NPK +FYM

It is the high yielding treatment which is likely to be deficient in Ca and probability of getting response to Ca is therefore low.

100%NPK+FYM+Lime

It is prone to N deficiency but high in P. Thus the probability of getting response to N is low.

100%NPK+Zn +B

It is most deficient in N and excess in K and there is probable deficiency of S.

100%NPK+Zn+S

Nitrogen is most deficient and thus the crop will definitely respond to its application and P is next most deficient element but probability for getting response is low

100% N

It is deficient in nitrogen followed by K but Ca is excess.

100%NP

Nitrogen is deficient with excess of Ca.

100%NPK +Lime

Nitrogen is most deficient and crop will respond to its application where as Ca is excess.

Control

It is deficient in Ca followed by P .Crop will respond to their application and there is excess of Zn.

5.4 Interpretation of Nutrient requirement Status through Soil Test method Vs DRIS method

5.4.1 *Kharif 2015*

As per soil testing in 100% PK treatment N, and K were low but as per DRIS, P was the most deficient element followed by Ca.

100%NPK was low in N and K and medium in P and S where as through DRIS, N is the most deficient followed by P.

As per soil test, 150% NPK has low N and medium K and high P but as per DRIS, P is the most deficient element and K is sufficient followed by Magnesium.

100%NPK+Zn is low in available N and medium in K and S and Zn are high but as per DRIS N is most deficient and K and Zn are excess.

As per soil test in 100% NPK+FYM, N and K are low, P and S are medium but as per DRIS the soil is prone to be deficient in Ca and K.

100% NPK+Lime+FYM treatment as low in N, high in P, medium in K and S, But as per DRIS, K and Zn were likely to be deficient.

100%NPK +B+ Zn is low in N and K, medium in P and S but as per DRIS it is most deficient in potassium and likely to be excess in Mg

100%NPK +S+ Zn treatment is low in N and K and medium in P and as per DRIS, K is the most deficient and P is next element to be deficient.

In 100 % N treatment, soil is low in N and K but as per DRIS, K is most deficient.

In 100%NP treatment the soil is low N and K and medium in P and K but as per DRIS, K is the most deficient and N is excess.

The treatment 100% NPK +Lime is low in N, medium in P and S as per soil test but as per DRIS the plant is most deficient in potassium and likely to be excess in ca and mg.

The control treatment deficient in N,P,K,S but as per DRIS P is most deficient.

5.4.2 Rabi. 2015-16

As per soil testing is 100% PK treatment, NPK, and S are low but as per DRIS N is the most deficient element followed by Mg.

100%NPK is low in N, medium in P and S, low in K but as per DRIS N is most deficient and P is likely to be deficient.

150%/ NPK has low N and medium P, low K and medium S but as per DRIS, P is the most deficient element and Ca is excess.

100%NPK+Zn is low in available NPK and as per DRIS, N is deficient and Zn is excess.

In 100% NPK+FYM nitrogen is low, P is high, K and S are medium. But as per DRIS Ca is deficient followed by potassium and excess in P.

100% NPK+Lime+FYM is low in N, high in P ,medium in K and S, But as per DRIS, N and Mg are likely to be deficient.

100%NPK +B+ Zn is low in N P, K, and medium in S but as per DRIS N is the most deficient element and Zn is excess.

100%NPK +S+ Zn treatment is low in N and medium S and as per DRIS,N is the most deficient and followed by P and Ca and S as excess .

100%N treatment is low in NPK as per DRIS, N is most deficient, Deficiency of N in continuously N applied treatment is due to poor absorption of N from soil which might be due to low absorption of P and K, other nutrients. But Ca is excess,

100%NP NPK and S are low but as per DRIS N is the most deficient excess C a as excess.

100% NPK +Lime is low N, K and Medium in P and S but as per DRIS it is most deficient in nitrogen and there is excess of calcium.

Control plot is low in N, K but as per DRIS, crop is most deficient in Ca followed by P and excess in Zn.

CHAPTER-5

SUMMARY & CONCLUSION

SUMMARY AND CONCLUSION

Rice-rice is an important production system for eastern India. Over years of continuous cropping the system has lost its potential to sustain the productivity. For restoration of the degraded soil there is an urgent need to understand the changes in the soil properties that have occurred over years due to varied crop management practices. For optimizing plant nutrition correct diagnosis of nutrient deficiency or excess that limit the crop yield under a particular agroclimatic situation is very important. By soil test method actual nutrient that limits crop yield is not always correctly identified and therefore alternative methods are always sought for more precise and effective fertilizer recommendation.

The Present investigation was therefore made to identify nutrients limiting crop yield under rice rice system in the order of their limiting importance by using DRIS, an integrated Plant Nutritional diagnostic technique developed by Beaufils (1973) vis a vis soil test method. This is a more direct method than soil testing as it examines the plant status of nutrients with respect to their content and ratios following standard norm. For the study there is requirement of crop lands with varied management practices. Lands with long term fertilizer experiments with varied nutrient management practices is therefore very useful.

In order to fulfill the objective a 10 year old long term fertilizer experiment conducted on a light textured sandy loam a acidic soil of Bhubaneswar was used. The experiment had 12 treatments i.e. 100% PK, 100%NPK, 150%NPK, 100%NPK+Zn, 100% NPK+ FYM, 100%NPK+FYM+LIME, 100%NPK+Zn+ B, 100%NPK+Zn+S, 100% N, 100%NP, 100%NPK+Lime with 4 replications. Leaf samples were collected at flowering stage of crop grown in two seasons , *kharif* 2015 and *rabi* 2015 -16 for plant analysis of different nutrients. Various nutrient ratios were computed and DRIS index was determined for individual nutrient following standard computational method. DRIS Index values obtained were arranged in ascending order from most negative to most positive value. From index value, nutrient balance index (NBI) and average NBI (NBIa) were calculated for interpretation of the results. The results were compared with that of soil test method and efficiency of the DRIS method was verified by establishing relationship between NBI and relative biomass yields.

Season wise Deficiency or Sufficiency of Nutrients

More negative the DRIS value of a nutrient, more deficient is the nutrient and more positive the DRIS index, more sufficient or excess is the nutrient.

Thus depending on the treatment, the nutrients limiting crop yield varied and the limiting nutrients also varied in terms of their extent of deficiency. Besides the nutrients which are sufficient to excess could also be determined.There is also seasonal difference with respect to nutrients limiting crop yield. The season wise and treatment wise deficiency or sufficiency are as given below.

Treatments	**Kharif-2015**	**Rabi-2015-16**
100% PK	➢ Most deficient: P followed by Ca, K and N ➢ Sufficient :Mg and Zn	➢ Most deficient : N followed by Mg ➢ Sufficient : P, K, Zn, Ca and S.
100% NPK	➢ Most deficient :N followed by P and K ➢ Likely to be deficient: Mg, Zn ➢ Sufficient : Mg, S, Ca	➢ Most deficient : N followed by P Sufficient : Ca, Mg and K.
150% NPK	➢ Most deficient :P ➢ Likely to be deficient: N, Zn ➢ Sufficient : K and Mg and Ca	➢ Most deficient :P ➢ Likely to be deficient: Mg, Zn ➢ Sufficient : Ca, K
100%NPK + Zn	➢ Most deficient: N followed by K slightly deficient : P. ➢ Sufficient: Zn.	➢ Most deficient: N followed by Ca & P Sufficient : Zn , Mg and K.
100% NPK + FYM	➢ Slightly deficient: Ca , K and N ➢ Slightly sufficient: P, Mg and S.	➢ Deficient: Ca ➢ Slightly deficient :K, N, S and Mg Sufficient :P and Zn.

100% NPK+ Lime+ FYM	➢ Slightly deficient : K, Zn ➢ Slightly sufficient : Ca, P and N.	➢ Slightly deficient: N , Mg and K slightly sufficient: P, Ca and Zn.
NPK +B +Zn	➢ Most deficient :K followed by P ➢ Sufficient : Zn Mg	➢ Most deficient : N followed by P, Mg and N ➢ Sufficient : Ca, S and K.
100% NPK+ S+ Zn	➢ Most deficient : K followed by P ➢ Sufficient : Ca, S and K.	➢ Most deficient : N followed by P ➢ Sufficient : Ca, S
100% N	➢ Most deficient: K ➢ Slightly deficient : N ➢ Sufficient : S, Zn	➢ Most deficient :N ➢ Slightly deficient: K ➢ sufficient : Ca, Zn, Mg
100 %NP	➢ Most deficient : K ➢ Sufficient: N,S and Zn	➢ Most deficient: N , K ➢ Slightly deficient : P ➢ Sufficient : Ca,Mg, Zn and S.
100% NPK+ lime	➢ Most deficient: K ➢ Slightly deficient: N ➢ Sufficient : Ca and K.	➢ Most deficient: N ➢ Slightly deficient: S ➢ Sufficient: Ca and K
Control	➢ Most deficient: P and K ➢ Sufficient : Zn, N and Ca .	➢ Most deficient: Ca followed by P and N. Sufficient :Zn, K and S

Deficiency/ Sufficiency of nutrients identified by DRIS Approach *vis a vis* Soil Test Method

Nutrients limiting crop yield as identified through plant analysis DRIS method are not always same to those found deficient by soil test method.

By DRIS Technique Nutrients deficient or sufficient or excess can be identified in order of limiting importance which is not possible through soil test method. Season wise and treatment wise difference between these two methods have been summarized below.

Kharif 2015					
Treatments	**DRIS Method**			**Soil Testing**	
	Deficiency	**Extent**	**Sufficiency or Excess**	**Deficient**	**Requirement of Nutrient(DRIS Method)**
1	P	Most deficient	Mg	NK	**P>Ca>K>N>S>Zn>Mg**
2	N, P	N most deficient, P second most deficient	Mg	NK	**N>P>K>Zn>Ca>S>Mg**
3	P	Most deficient	K	N	**P>S>N>Zn>Ca>Mg>K**
4	N, K	N most deficient, K second most deficient	Zn-Excess	NK	**N>K>P>Ca>S>Mg>Zn**
5	Ca, K	Prone to be deficient	P sufficient	NK	**Ca>K>Zn>N>S>Mg>P**
6	K, Mg	Prone to be deficient	Ca, P sufficient	N	**K>Mg>Zn>N>S>P>Ca**
7	K	Most deficient	Zn and Mg sufficient	NK	**K>P>N>S>Ca>Mg>Zn**
8	K,P	K most deficient, P second most deficient	Zn and Mg sufficient	NK	**K>P>N>Ca>S>Mg>Zn**
9	K,P	K most deficient, P second most deficient	S and Zn sufficient	NPK	**K>P>Ca>Mg>N>Zn>S**
10	K	K most deficient	N and Ca sufficient	NK	**K>P>Mg>Zn>S>Ca>N**
11	K	K most deficient	Ca, Mg sufficient	NK	**K>N>P>S>Zn>Mg>Ca**
12	P,K	P most deficient, K second most deficient	Zn excess and N sufficient	NPKS	**P>K>S>Mg>Ca>N>Zn**

Rabi, 2016-17					
Treatments	DRIS Method			Soil Testing	
	Deficiency	Extent	Sufficiency or Excess	Deficient	Requirement of Nutrient(DRIS Method)
1	N,Mg	N-Most deficient Mg- Likely to be deficient	P,K sufficient	ZnPKS	N>Mg>S>Ca>Zn>K>P
2	N, P	N most deficient, P Likely to be deficient	Ca sufficient	NPK	N>P>Zn>S>K>Mg>Ca
3	P	Most deficient	Ca, K- sufficient	NK	P>Mg>Zn>S>N>K>Ca
4	N	N most deficient, Ca Likely to be deficient	Zn-Excess	NPK	N>Ca>P>S>K>Mg>Zn
5	Ca	Prone to be deficient	P sufficient	N	Ca>K>S>N>Ca>Zn>P
6	N, Mg	Prone to be deficient	P sufficient	N	N>Mg>K>S>Zn>Ca>P
7	N	Most deficient	K sufficient	NPK	N>S>P>Ca>Mg>Zn>K
8	N,K	N most deficient, P Prone to be deficient	Ca and S sufficient	NPK	N>P>Mg>Zn>K>S>Ca
9	N,K	N most deficient, K Prone to be deficient	Ca and Zn sufficient	NPKS	N>K>S>P>Mg>Zn>Ca
10	N	most deficient	Ca sufficient	NK	N>S>K>P>Zn>Mg>Ca
11	N,S	N most deficient S Prone to be deficient	Ca, K sufficient	NK	N>S>Mg>P>Zn>K>Ca
12	Ca, P, N	Ca, P most deficient, Prone to be deficient	Zn excess and K sufficient	NK	Ca>P>N>Mg>S>K>Zn

Season wise Balanced/ Imbalanced Nutrition

Higher the nutritional balance Index (NBI), greater is the nutrient imbalance in a particular manorial treatment. Based on this NBI concept the treatments can be arranged in order of their capacity to have imbalanced/balanced nutrition.

For the cropping season *kharif*, 2015, 100%N treatment had highest NBI of 155.13 was found to be nutritionally most imbalanced and 100%NPK +FYM with smallest

NBI of 20.07 was nutritionally most balanced treatment. The order of treatment for the most nutritionally imbalanced to balanced are:

100%N > Control > 100%NP > 100%NPK+Lime > 100%NPK +Zn +B > 100%NPK +Zn +S > 100%NPK+Zn > 100%PK > 100%NPK > 150%NPK > 100%NPK +Lime +FYM > 100%NPK+FYM.

For *rabi* Season, 2015-16 the un manured control with highest NBI (237.14) was most imbalanced and 100% NPK +FYM with lowest NBI (39.57) was the most balanced treatment. The order of treatment for the most nutritionally imbalanced to balanced are :

Control > 100%NPK+Zn > 100%N > 100%NPK+Lime > 100%PK > 100%NP >100%NPK >100%NPK+Zn+S >150%NPK > 100%NPK+Zn+ B > 100% NPK+FYM+Lime > 100%NPK+FYM.

CONCLUSION

Based on the DRIS indices and average NBI (NBIa)

In *kharif*, 2015

1. It is observed that continuous application of RDF (100%NPK) was not adequate to meet the crop demand .After 10 years nitrogen is identified as the most limiting nutrient followed by phosphorous and potassium.
2. By increasing the NPK dose by 50% phosphorous was found be the most limiting nutrient after 10 years followed by sulphur and nitrogen.
3. Addition of 5t FYM to RDF however, improved the situation with more balanced nutrition. However, after 10 years calcium appeared to be limiting followed by K and Mg.
4. In *kharif* potassium was the limiting nutrient in most of treatments.

In *rabi*, 2015-16

5. Continuous application of RDF (100%NPK) was not adequate. After 10 years nitrogen is identified to be most limiting followed by phosphorus.

6. Increasing the dose to 150% Phosphorus was also found to be most deficient after 10 years.
7. Further Mg and Zn could be identified to be deficient in future.
8. Addition of 5t FYM to RDF however improved the situation with more balanced nutrition. However after 10 years calcium appeared to be limiting followed by potassium and sulphur.
9. In *rabi* season, nitrogen was most limiting in many treatments.
10. Thus depending on the treatment the nutrients limiting crop yield varied and the limiting nutrients also varied in terms of their extent of deficiency. Besides the nutrients which are sufficient to excess could also be determined. There is seasonal difference with respect to nutrients limiting crop yield.
11. Nutrients limiting crop yield as identified through plant analysis DRIS method are not always same to those found deficient by soil test method. By DRIS Technique Nutrients deficient or sufficient or excess can be identified in order of limiting importance which is not possible through soil test method.

Future Thrust

1. DRIS technique can be applied to different crops and different agro climatic situations to identify the nutrients limiting crop yield under a particular situation.
2. DRIS can be used for different stages of crop growth to identify the limiting nutrients at different stages and determine the stage wise nutrient requirement of the crop for optimization of nutrition.

CHAPTER

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REFERENCES

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APPENDIX – I : Weather Data

Week No	Temperature (ºC)		Rainfall (mm)	Evapotation (mm)	Humidity (%)		Sunshine Hour (hr)
	Maximum	Minimum			7 hr	14 hr	
23	38.1	27.1	19	42.8	83	46	5.5
24	34.3	25.8	56.6	37.6	88	62	3
25	35.3	26.6	14.5	38.8	86	59	6.2
26	31.1	25.9	83	25.7	94	75	0.4
27	31.3	25.8	46.5	23.9	90	75	0.8
28	32	25.4	145.4	21.9	94	76	1.6
29	31.7	26.1	164.3	18.3	93	85	2.8
30	31.8	26.3	34.3	23.9	92	78	2.7
31	33.8	26.1	56	20.7	91	71	3.7
32	33.1	25.6	85.1	20.2	90	77	6.1
33	32.4	25.8	76.9	19	91	79	3.6
34	33.6	26	63.2	24.1	87	71	7.3
35	32.1	25.3	161.4	16.1	96	78	3.3
36	33.6	26	24.9	24.1	92	74	5.7
37	34.4	25.7	77.9	20.8	90	65	6.6
38	32.6	25.8	45.1	23	92	71	3.1
39	33.7	25.5	33.7	23.5	92	69	3.4
40	30.7	25.1	77.7	21.7	94	79	2.3
41	33.3	25.4	24.6	23.8	94	64	6.1
42	31.5	24.8	102.2	19.9	93	72	5.3
43	33.5	23.2	0	24.5	92	63	8.8
44	31.1	20.6	0	24.3	90	62	8.2
45	31.4	19.5	0	24.4	86	52	9.3
46	27.3	20.7	55.2	21.2	87	66	3.5
47	29.6	18.7	0	22.8	91	56	6.5
48	29.4	13.9	0	24.3	92	40	8.4
49	27.1	14	36.3	23	88	49	5.6
50	29.5	18.3	0	24.2	94	59	6.3
51	28	13.6	0	24.7	92	43	7.8
52	28	12.5	0	28.2	93	43	7.8
1	26.5	12.6	0	24.9	91	38	6.6
2	28	11.2	0	25.6	91	34	7
3	27.6	11	0	25.2	95	35	7.8
4	29.1	13.4	0	26.4	93	35	7.2
5	31.1	12	0	27.8	91	24	8.9
6	33.5	17.1	0	29	93	31	7.7
7	31.6	15	0	28.9	90	33	7.8
8	35.2	16.5	0	30.7	94	29	8.8
9	37.4	19.6	0	32.5	93	27	8.5
10	36.4	20.4	0	35.7	89	31	7.2
11	36.3	21.3	0	36.7	91	27	5.3
12	37.6	23.2	0	38.5	94	34	6.9
13	37	25.7	0	37.7	91	47	6.2

Appendix 2 Mean values of selected nutrients expressions for rice plants and their percent coefficient variation (CV)

NUTRIENT RATIO	MEAN	CV%
N/P	11.03	28.74
N/K	0.437	33.42
N/Ca	4.868	37.54
N/mg	10.079	40.05
N/S	10.515	34.90
N/Fe	0.0159	38.53
N/Mn	0.01756	44.43
N/Zn	0.1077	30.20
N/Cu	.4728	31.96
P/K	4.575	25.30
P/Ca	2.362	19.66
P/Mg	.915	24.34
P/S	1.093	20.92
P/Fe	0.00146	27.88
P/Mn	0.00159	33.76
P/Zn	103.0	9.77
P/Cu	0.0440	28.02
K/Ca	2.030	36.23
K/Mg	4.133	33.20
K/S	4.322	30.48
K/Fe	0.00662	36.17
K/Mn	0.00743	46.97
K/Zn	0.445	26.52
K/Cu	0.1945	28.38
Ca/Mg	2.1401	28.44
Ca/S	o.4716	21.57
Ca/Fe	0.00341	31.13
Ca/Mn	0.00367	30.69
Ca/Zn	45.044	19.53
Ca/Cu	0.1039	34.01
Mg/S	0.9887	27.34
Mg/Fe	0.00166	35.00
Mg/Mn	0.00186	43.01
Mg/Zn	93.169	20.93
Mg/Cu	0.04986	32.13
S/Fe	0.00156	28.30
S/Mn	0.001741	42.37
S/Zn	97.466	18.99
S/cu	0.04666	25.06
Fe/Mn	1.2333	61.57
Fe/Zn	0.1496	28.07
Fe/Cu	31.604	30.05
Mn/zn	0.1647	35.00
Mn/cu	0.03982	51.54
Zn/cu	4.4851	25.91

Appendix 3 : DRIS Norms

NUTRIENT RATIO	MEAN	CV%
N/P	9.8174	13.2%
N/K	1.19847	32.5%
N/Ca	6.7736	33.5%
N/S	17.2864	53.3%/
N/Mg	19.7246	18.8%
10/Cu	6.3309	15.0%
P/K	0.12042	23.2
p/Ca	0.71713	28.2
P/Mg	2.12043	17.8
P/S	1.80124	56.4
10/Cu	6.811	13.8
P/Fe	0.6195	80.7
K/Mg	20.0648	21.7
K/S	16.0629	66.5
K/Cu	6.4452	18.7
K/Fe	0.6012	91.7
Ca/S	3.00039	82.8
Ca/Fe	0.873	59.3
Mg/s	0.94908	60.5
Mg/Cu	0.3302	20.7
Mg/Fe	0.298	85.6
Fe/Mn	0.15069	35.1

Appendix 4

N*P	1.04
K/N	0.79
N/S	11.90
Zn/N	6.87
Fe/N	41.17
P/K	0.13
P*S	0.09
P/Zn	0.02
P*Fe	42.0
K*S	0.71
Zn/K	8.81
K/Fe	0.02
Zn/S	80.64
Fe/S	482.05
Zn*Fe	2858.96