Need Based Nitrogen Management in Rice (*Oryza sativa* L.) Using Diagnostic Tools

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(2012 - 11 - 199)

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KERALA, INDIA

2014

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by

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(2012 - 11 - 199)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695 522

KERALA, INDIA

2014

DECLARATION

I, hereby declare that this thesis entitled **"Need Based Nitrogen Management in Rice (*Oryza sativa* L.) Using Diagnostic Tools"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Need Based Nitrogen Management in Rice (*Oryza sativa* L.) Using Diagnostic Tools"** is a record of research work done independently by Mr. Palle Pavan Kumar Reddy under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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ACKNOWLEDGEMENT

First and foremost, I offer my obeisance to the ***'Almighty God'*** *who provided me the strength, courage to fulfill my duty in a satisfactory manner, guiding me through all critical situations. I am deeply indebted for the bountiful blessings he has showered upon me during the course of my study and research work each and every moment I needed it most.*

With respectable regards and immense pleasure, I take it as a privilege to place on record my profound sense of gratitude, indebtedness and thanks to the Chairperson of the Advisory Committee, ***Dr. M. Meerabai,*** *Professor (Agronomy), College of Agriculture, Vellayani for her worthy counsel, constant attention, meticulous supervision, splendid and stimulating guidance, kind treatment, abundant encouragement, valuable suggestions, moral support, wholehearted co-operation, I received at every stage of planning and execution of research work and the preparation of my thesis. I also place my sincere thanks for her patience and constructive criticism, without which this work would not have been possible.*

I deem it my privilege in expressing my fidelity to ***Dr. V.L. Geethakumari,*** *Professor and Head (Agronomy), College of Agriculture, Vellayani and member of my Advisory Committee for her munificent acquiescence and meticulous reasoning to refine this thesis and most explicitly to reckon with set standards. Ineffable in my gratitude and sincere thanks to her for her dexterous help, transcendent suggestions and efforts to embellish the study.*

I wish to take this opportunity to express my profound gratitude and appreciation to the member of my advisory committee to ***Dr. Shalini Pillai. P,*** *Associate Professor (Agronomy), College of Agriculture, Vellayani, for her keen interest, explicit instructions, affectionate advices and unaccountable help rendered throughout the course of work, field experiment and thesis preparation.*

I cordially offer my sincere and heartfelt gratitude to ***Dr. K.C. Manorama Thampatty,*** *Professor (Soil Science and Agricultural Chemistry), College of Agriculture, Vellayani, member of advisory committee for her erudite suggestions, astute remarks and wondrous guidance in conducting the research work and thesis preparation.*

I fervently express my immense and gargantuan respect and thanks to all my beloved teachers of the Department of Agronomy for keeping abreast of me and providing their valuable help whenever needed, during the course of my study and research work.

I owe my special thanks to the teaching staff of all the departments in the College of Agriculture, Vellayani for extending their co-operation and support in my course and research work.

I place on record my immense gratitude to Sri. C.E. Ajith Kumar, Programmer, Department of Agricultural Statistics, for rendering his help in the analysis of data and interpretation of results.

I express my immense and whole hearted gratitude to Shibu chetan, Remani chechi, Viji chechi for their sincere and whole hearted co-operation and help during the entire period of my research work.

I express my special thanks to Sri. Bhuvana Chandran, owner of the rice field for his whole hearted help during the field work.

Its my privilege to extend heartfelt thanks to Raju chetan and Ally chechi for being with me whenever I was in trouble.

It is a great pleasure to acknowledge the affection and inspiration rendered by PG and Ph.D students of the Department of Agronomy for their help occasionally.

I wish to express my warmest thanks to my dear colleagues Pintu, Sasna, Reshma, Anju, Athira for their love, affection, special care and all time pragmatic help and cooperation which helped for my goal setting and spiritual up liftment during my studies and worries.

My keen sense of gratitude to my friends, seniors and juniors for their timely cooperation during my course of study.

I sincerely acknowledge the Kerala Agricultural University for the financial support in the form of KAU Junior Research Scholarship during my study period.

With boundless affection, I would hearty acknowledge the constant encouragement and inspiration given to me by beloved brothers Sudharsan Reddy, Mallikarjuna Reddy, Raveendra Reddy, Bharat Kumar Reddy and sisters Sireesha, Sreekala, Sivani, Bhavani, Bhanu, Sujatha, Swapna, Jyoshna. Ineffable is my sense of gratitude for the love, prayers and blessings of all my relatives.

Words are inadequate to express my whole hearted and affectionate gratitude to my beloved parents **Sri. P. Rama Subba Reddy** and **Smt. P. Venkata Subbamma** and sister **P. Sravani** for their inspiration, sacrifices, blessings, unbounding love, unparallel affection and unstinted encouragement throughout my career and without whose invaluable moral support, the thesis would not have seen the light of the day.

Finally, I wish to thank to one and all who have directly or indirectly contributed to the conduct of the study.

PALLE PAVAN KUMAR REDDY

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LIST OF ABBREVIATIONS

%	-	per cent
°C	-	degree celsius
AE	-	Agronomic efficiency
AEN	-	Agronomic efficiency of nitrogen
a.i	-	active ingredient
BCR	-	Benefit Cost Ratio
CD (0.05)	-	critical difference at 5 % level
cm	-	centimetre
DAS	-	days after sowing
DAT	-	days after transplanting
DMP	-	dry matter production
DMSO	-	di methyl sulphoxide
DMY	-	dry matter yield
et al.	-	and co-workers/co-authors
Fig.	-	Figure
FTNM	-	fixed time nitrogen management
FYM	-	farm yard manure
g	-	gram

g/ha	-	gram per hectare
g/L	-	gram per litre
ha	-	hectare
HI	-	Harvest index
IE	-	Internal utilization efficiency
i.e.	-	that is
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
kg/ha	-	kilogram per hectare
kg/m^2	-	kilogram per square metre
kg N/ha	-	kilogram nitrogen per hectare
LAI	-	Leaf Area Index
LCC	-	Leaf colour chart
m	-	metre
mg	-	milligram
mg/g	-	milligram per gram
mm	-	millimetre
m^2	-	square metre
MOP	-	Muriate of potash
MSL	-	mean sea level

N	-	Nitrogen
Nc	-	nitrogen concentration
nm	-	nanometre
NS	-	Non significant
NUE	-	Nutrient use efficiency
P	-	Phosphorus
PE	-	Physiological efficiency
PFP	-	Partial factor productivity
PFP-N	-	Partial factor productivity of applied nitrogen
pH	-	Negative logarithm of hydrogen ion concentration
PI	-	panicle initiation
POP	-	package of practices
q/ha	-	quintal per hectare
RBD	-	Randomized block design
RDN	-	Recommended dose of nitrogen
RE	-	Recovery efficiency
Rs/ha	-	Rupees per hectare
RTNM	-	real time nitrogen management
SE	-	Standard error

SPAD	-	Soil plant analysis development
t/ha	-	tonnes per hectare
viz.	-	namely

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most vital food crop and a major food grain for more than a third of the world's population (Zhao *et al.,* 2011). India is occupying 44.6 million ha of land and producing 91.04 million tonnes of grain with a productivity of 2.04 t/ha (Subbaiah, 2006). However, the average per hectare yield of paddy in India is less than that of many other countries in the world. The alarming population growth in India which is expected to touch 1.5 billion mark by 2025 AD and more than 2 billion by the end of the century warrants further increments in per hectare yield of rice on a sustained basis. The area expansion under rice being ruled out, the only option left with is the optimum resource utilization.

Among various reasons for low productivity, inefficient utilization of nitrogen is considered to be the most critical one (Shukla *et al.,* 2004). Nitrogen is the most important and essential plant nutrient that will increase the rice crop yield positively (Dastan *et al.,* 2012). It is also the most important nutritional element for the productivity of cereal crops and a major factor that limits agricultural yields (Balasubramanian *et al*., 2000 and Islam *et al*., 2009). Also nitrogen is essential part of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Azarpour *et al*., 2011). Chlorophyll pigments play an important role in the photosynthetic process as well as biomass production. Genotypes maintaining higher leaf chlorophyll-a and chlorophyll-b during growth period may be considered potential donor for higher biomass and photosynthetic capacity, higher photosynthesis rate being supported by leaf chlorophyll content in leaf blades (Hassan *et al.,* 2009).

Application of higher level of N-fertilizer is very common among Indian farmers, which attribute rice crop greenness and growth response to N application. Furthermore, large field-to-field variability of soil N supply restricts efficient use of N fertilizer when broad-based blanket fertilizer N recommendations are used (Cassman *et al*., 1996). On the recent world-wide evaluation of fertilizer, nitrogen recovery efficiency has been found to be around 30 per cent in rice (Krupnik *et 2al.,* 2004). It has been observed that more than 60 per cent of applied nitrogen is lost due to lack of synchronization between the nitrogen demand and nitrogen supply (Yadav *et al.,* 2004). Since the rice growing conditions are congenial for loss of N from the soil, split applications of N have been suggested to enhance its use efficiency. Farmers generally apply nitrogen fertilizer in fixed time at the recommended N split schedule in 1:2:1 or 2:1:1 ratio at basal, maximum tillering and panicle initiation stages respectively, without taking into account whether the plant really requires N at that time, which may lead to loss or may not be found adequate enough to synchronize nitrogen supply with actual crop nitrogen demand (Pillai and Kundu, 1993; Ladha *et al.,* 2000). Appropriate diagnosis of N in leaves to decide about top dressing the fertilizer N is one of the strategy to increase N use efficiency.

There is a need to synchronize N-fertilizer application with plant need to optimize nutrient use and minimize environmental pollution. Effective management of fertilizer, particularly N is a major challenge for researchers and producers. To answer the questions of when, where and how much, we require a monitoring technique to evaluate the N status of crops. Ideally the technique needs to be fast and inexpensive and should allow for on the spot decision making. Tissue tests and chlorophyll meter could be used to take decision. Innovative tools such as chlorophyll meter are faster than tissue testing for N and can help to find when plant needs N more (Ladha *et al*., 2000). Nitrogen is a key element in chlorophyll molecules. Chlorophyll meter provides instantaneous on-site information on crop N status as SPAD reading in a non-destructive manner (Swain and Sandip, 2010). It has been successfully used for rice, maize, wheat and cotton crops.

The concept of using spectral reflectance ratio to quantify colour of intact crop leaves was reported in early 60's in Japan (Inada, 1963). It was only in the late 80's and early 90's that researchers (Furuya, 1987; Jund and Turner, 1990 and Peng *et al*., 1993) focused on using gadgets such as leaf colour chart (LCC) (based on spectral properties of leaves) and chlorophyll meter [SPAD meter (Soil Plant Analysis Development meter)] (based on light transmittance through leaves) for guiding real-time N top dressings in rice. These gadgets helped efficient N management in rice under situations encountering diversity in field, season and variety by ensuring high yield and providing economic benefits to the farmers.

Chlorophyll meter is too expensive (US $1200-1800/unit) to be owned by farmers in developing countries, which restricts its widespread use by farmers. Farmers generally use leaf colour as a visual and subjective indicator of the crop's nitrogen status and thus the need for N fertilizer application. Therefore, International Rice Research Institute (IRRI) has developed a simple and inexpensive leaf colour chart (LCC) that can be used as a complementary decision making tool to determine the need for N application. The chart contains six shades of green from yellowish green (No. 1) to dark green (No. 6) and is calibrated with the SPAD meter. It is small and handy and can be easily carried to the field. LCC can promote need based variable rate of N application to crops based on soil N supply and crop demand. It is an ideal and eco-friendly tool to optimize N use, irrespective of the source of N (Balasubramanian *et al.,* 2000a). Under practical on farm situations, LCC proved to be as good as the chlorophyll meter method in terms of higher yield and improved nitrogen use efficiency. The SPAD meter and LCC are used currently in Asia for N management in rice and wheat (Singh *et al*., 2002). Soil testing kit, a farmer friendly tool for assessment of nutrient status of soil, can easily be utilized for scheduling topdressing of nitrogen in rice.

There is a need to investigate on N management with tools like LCC, SPAD meter and soil testing kit for site specific nutrient management in rice. In rice, need based N management can be an important thing which can answer the questions of when, where and how much to apply nitrogenous fertilizers and its combination with other nutrients, synchronizing it with crop demand, so as to acquire maximum threshold level of yield, reducing environmental harms.

Hence, there is a tremendous scope for use of LCC, Chlorophyll meter and soil testing kit for N management in rice crop.

Keeping these facts in view, the present investigation entitled "Need based nitrogen management in rice (*Oryza sativa* L.) using diagnostic tools" was carried during the *Virippu* season (first crop season), 2013 at farmer's field, Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state with the following objectives:

1. To study the technical and economic feasibility of chlorophyll meter, leaf color chart and soil testing kit for assessing the crop nitrogen status

2. To schedule N application in rice, based on crop need and

3. To work out the economics.

Review of Literature

2. REVIEW OF LITERATURE

Investigations were carried out on "Need based nitrogen management in rice (*Oryza sativa* L.) using diagnostic tools" during the *Virippu* season (first crop season), 2013 at farmer's field, Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state. Literature from previous research endeavours helps to establish a basic frame work in formatting thrust areas. Published literature pertaining to LCC (Leaf Colour Chart), SPAD (Soil Plant Analysis Development) meter or chlorophyll meter and soil testing kit based N management effect on the performance of rice has been reviewed in this chapter.

2.1 NITROGEN MANAGEMENT THROUGH SYNCHRONY BETWEEN DEMAND AND SUPPLY

Nitrogen is the most critical nutrient element in crop production. It is vital for maintaining and improving crop growth and yield. Nitrogen demand of crop is met from native soil nitrogen supply and mineral fertilizer nitrogen application, where fertilizer N fills the gap between crop demand and native soil N supplies (Koyama, 1981). Plants quickly and efficiently absorb nitrogen when their root systems are exposed to the required forms (NO3- and NH4+), even in the micro molar concentrations in the soil solution (Lawlor *et al.,* 2001).

Further, the efficiency of N use decreases with increasing amounts of N applied (Bock and Hergert, 1991). Multiple split applications of mineral nitrogenous fertilizers can reduce N losses (De Datta and Buresh, 1989) and increase nitrogen use efficiency (Cassman *et al.,* 1996). Greater soil N accumulation in fertilized plants than in unfertilized plants is often due to stimulation of mineralization of soil organic matter by fertilizer or greater root exploration in fertilized plants (Bronson *et al.,* 2000).

Nitrogen (N) applied in excess or at the wrong time is subject to losses through volatilization, denitrification and leaching or percolation (Singh and

Buresh, 1994). Nitrogen losses from the soil plant system are large, leading to low fertilizer N use efficiency when N application is not synchronized with crop demand (Singh *et al.,* 2002). It has been documented that synchrony between crop demand and the N supply from all sources throughout the growing season is needed for improving N use efficiency in crop production systems (Robertson, 1997). Efficiency could be improved if the timing and dosage of fertilizer *were* adjusted according to N supplying capacity of the soil and morphological development of the plant (Vlek and Fillery, 1984). Due to large variability for N supplying capacity of the native soil from farm to farm and plot to plot, the strategies of N fertilizer management should be responsive to the large variation of crop N requirements and soil N supply in order to achieve the synchrony of supply and demand and to improve N use efficiency (Peng *et al.*, 1996). Blanket fertilizer recommendations over large areas are not efficient as indigenous nutrient supply varies widely among different fields in Asia (Dobermann and White, 1999).

Rice crop, therefore, requires different amounts of nutrients in different fields, depending on native nutrient supply and demand. Farmers would benefit significantly if they can adjust N inputs to actual crop conditions and nutrient requirements. The chlorophyll meter (SPAD meter) and leaf colour chart (LCC) are simple, portable, diagnostic tools used to measure the greenness or relative chlorophyll content of leaves and in turn assess the crop N status *in situ* in rice fields to determine the timing of N top dressing (Balasubramanian *et al.,* 2000). Chlorophyll meter can provide a quick estimate of the leaf N status, but it is relatively expensive (Peng *et al.*, 1996).

The leaf color chart (LCC), on the other hand, is an inexpensive and simple tool for monitoring the relative greenness of a rice leaf as an indicator of the leaf N status (Balasubramanian *et al.*, 1999 and Witt *et al.*, 2005). Soil testing kits are used to assess the available nutrient status of soil for scheduling topdressing of nitrogen in rice.

2.2 CROP NEED BASED NITROGEN MANAGEMENT

Efficient use of N fertilizer is, therefore, important for economical crop production and also for ground and surface water quality. Insufficient N levels reduce profit and yield, while excessive N can pollute surface and ground water. Furthermore, large field-to-field variability of soil N supply restricts efficient use of N fertilizer when broad-based blanket fertilizer N recommendations are used (Cassman *et al.*, 1996). When N application is not synchronized with crop demand, N losses from the soil-plant system are large leading to low N fertilizer use efficiency. Effective management of fertilizer, particularly N is a major challenge for researchers and producers.

To answer the questions of when, where and how much, we require a monitoring technique to evaluate the N status of crops, tissue tests and chlorophyll meters could be used to take decision. Innovative tools such as chlorophyll meters are faster than tissue testing for N and can help to find when plant needs N most (Ladha *et al.*, 2000). It has been successfully used for rice, maize, wheat, sugarcane and cotton crops. Chlorophyll meter is a simple, quick and non-destructive *in situ* tool for measuring relative content of chlorophyll in leaf that is directly proportional to leaf N content. Hence, the SPAD meter is useful in diagnosing the N status of crops and determination of the right time of N dressings (Peng *et al.*, 1996).

Chlorophyll meter is too expensive (US$1200-1800/unit) to be owned by farmers in developing countries which restricts its wide spread use by farmers. Farmers generally use leaf colour as a visual and subjective indicator of the crop's nitrogen status and thus the need for N fertilizer application. Therefore, IRRI has developed a simple and inexpensive leaf colour chart (LCC) that can be used as a complementary decision making tool to determine the need for N application. The chart contains six shades of green from yellowish green (No.1) to dark green (No. 6) and is calibrated with the SPAD meter (Plate.2). It is portable and can be easily carried to field. LCC can promote need based variable rate N application to crops based on soil N supply and crop demand. Under practical on farm situations LCC proved to be as good as the chlorophyll meter method in terms of high yield and improved N use efficiency. The chlorophyll meter and leaf colour chart are used currently in Asia for N management in rice and wheat (Singh *et al.*, 2002).

Blanket or package fertilizer recommendations over large areas are not efficient because indigenous nutrient supply varies widely among rice field in Asia (Dobermann and White, 1999). Farmers will benefit significantly if they can adjust N inputs to actual crop conditions and nutrient requirements. The chlorophyll meter (SPAD-soil plant analysis development) and leaf colour chart (LCC) are simple, easy and portable tools that measure the greenness of relative chlorophyll content of leaves (Inada, 1985; Kariya *et al.*, 1982 and Balasubramanian *et al.*, 2000a).

Soil testing kit, a farmer friendly tool for assessment of nutrient status of soil, can easily be utilized for scheduling topdressing of nitrogen in rice.

Applying fertilizer N following sufficiency index approach that ensures maintaining intensity of the colour of the uppermost fully opened rice leaves at 90 per cent or more of the intensity of the colour of the leaves in the over-fertilizer reference plot, resulted in application of only 70 kg N/ha. It resulted in grain yield of rice equivalent to that produced by applying 80 or 120 kg N/ha in four equal split doses (Singh *et al.*, 2006). Efficient fertilizer nitrogen use is, therefore, the key for obtaining more profits, higher economic crop yield and reducing losses. Major reason of low nitrogen recovery efficiency is inefficient splitting of fertilizer nitrogen doses coupled with nitrogen applications in excess of crop requirements. Sound management options need to be adopted which can guide fertilizer nitrogen application based on need of the crop plants as well as supply of nitrogen from other resources during the active growing season. Need based and field specific management of fertilizer nitrogen in rice is thus a need of the time (Singh *et al.,* 2009).

2.3 SPAD METER, LEAF COLOUR CHART (LCC) AND SOIL TESTING KIT IN NITROGEN NUTRITION

The chlorophyll meters are reliable alternatives to traditional tissue analysis as plant N nutritional diagnostic tools. Most widely used chlorophyll meter is the hand-held Minolta SPAD-502 which is developed by the soil plant analysis development (SPAD) section of the Minolta Camera Company, Japan. Since the cost of the SPAD meter restricts its widespread use by farmers.

Leaf colour chart (LCC) is a high quality plastic strip with different shades of green colour, ranging from light yellowish green to dark green. First LCC was developed in Japan (Furuya, 1987). An improved version of six-panel LCC (IRRI-LCC, six-panel) was developed through collaboration of the International Rice Research Institute (IRRI) with agricultural research systems of several countries in Asia (IRRI, 1996). Chinese researchers at Zheijiang Agricultural University developed a LCC (ZAU-LCC) with scale of eight green colour shades (3, 4, 5, 5.5, 6, 6.5, 7 and 8) and it was calibrated for Indica, Japonica and hybrid rice (Yang *et al.*, 2003). Researchers at the University of California (Davis) developed another eight panel LCC (UCD-LCC) with scale of eight green colour shades (1-8). A table on the back of UCD-LCC explains how the number values correspond to present leaf N (Boyd, 2001).

Leaf colour chart and SPAD values differ by plant growth stages, leaf thickness, plant population and soil or climatic factors and it may not be applicable to all the crops and varieties that differ in inherent leaf colour. Therefore it is necessary to calibrate or standardize as reported by various researchers across the world.

The leaf photosynthetic rate and leaf N concentration were closely related in rice and hence maintaining adequate leaf N throughout the growing period was crucial for achieving high yield (Yoshida, 1981).

Turner and Jund (1991) indicated that chlorophyll meter could be used to predict the requirement of nitrogen top dressing prior to panicle initiation and panicle differentiation stages in semi dwarf rice cultivars. SPAD meter measurement taken on the most recently matured leaf can range from 25-44 depending on N uptake and growth stage. It was recognized that SPAD values were influenced by plant growth stage, cultivar, leaf thickness, plant population and any soil or climatic factor causing leaf chlorosis. SPAD values did not indicate how much N to apply, but they only indicated the need for additional N (Turner and Jund, 1994). The monitoring of crop N status by SPAD will be useful to devise variable rate and field specific N application by taking into account the variable N supply and crop demand (Blackmer *et al.,* 1996). Kutty and Palaniappan (1996) and Singh *et al.* (2009) suggested that, leaf colour chart (LCC) and chlorophyll meter (SPAD) as important tools to diagnose the nitrogen status in rice to decide time of N top dressing.

SPAD based N application produced comparatively higher grain yield and agronomic efficiency of rice (Anon., 1997). These were comparable with the highest N level tried (135 kg N/ha) in high yielding varieties and hybrids. SPAD based N application and management of N according to recommended practice gave significantly higher grain yield (6.2 and 6.1 t/ha, respectively) compared to the recommended fixed schedule N fertilizer splits applied at key growth stages *i.e.,* 120 kg N/ha in 3 splits, 50 per cent as basal, 25 per cent at active tillering and 25 per cent at panicle initiation stage (Anon., 1998).

The SPAD value-based N application can increase grain yield and N use efficiency of both hybrid and inbred varieties and hybrid can give an advantage of 6.5 per cent due to heterosis over the inbred varieties (Peng *et al.,* 1998).

Kumar *et al.* (1999) compared different approaches of N management with SPAD and LCC in rice. They recorded higher grain yield in rice (4.8 t/ha) with SPAD-based management compared with 4.0 and 4.4 t/ha for fixed N rates of 90 and 135 kg N/ha, respectively, in *kharif.* SPAD management required 75 and 80 kg N/ha in *kharif* and *rabi*, respectively. They further observed higher AEN (agronomic efficiency of nitrogen) in SPAD-based management. Mean SPAD and LCC values were positively correlated at all the growth stages with mean grain yield of cultivars. Correlation coefficients between SPAD and LCC at different growth stages ranged from 0.78 to 0.90. Narasimhan *et al*. (1999) reported higher grain yield with LCC based N application, which might be due to higher dose of N (110 kg/ha) and increased number of spilt application of N (4 splits). Subbaiah *et al.* (1999) reported higher grain yield due to N management with SPAD 35. Even N management based on LCC 4 recorded significantly higher grain yield than the blanket recommendation and the former was on par with SPAD 35 N management under transplanted rice.

SPAD values differ with varieties, season, method of planting, N management practices, time and quantity of N application. Angadi *et al.* (1999) observed that the rice variety Abhilash responded significantly in terms of yield up to higher LCC threshold values of 4 and 5.0 during 1998 and 1999, respectively. Rice variety Intan responded only up to LCC threshold value of 3.5. In both the years, Abhilash recorded significantly higher grain yield at the higher LCC threshold value of 5.0 than the recommended practice. While, the grain yields of Intan at LCC threshold value of 3.5 was significantly higher than the recommended practice (100 kg N/ha) during 1998, while it was on par with others during 1999. The growth parameters like plant height and number of panicles/m^2 and grain and straw yields, were highest with the application of 20 kg N/ha as basal + SPAD based N (Balasubramanian *et al.*, 1999).

Babu *et al*. (2000a) from Thanjavur, Tamil Nadu reported that for modern varieties, SPAD threshold value of 35-37 is optimum during dry season, while SPAD 37 as suitable for wet season.

Babu *et al*. (2000b) observed that SPAD-guided N treatment recorded significantly higher grain yield than control, but it was at par with the local recommended dose in all the three cropping seasons. On-farm trial conducted at

Maligaya (Philippines) by Balasubramanian *et al*. (2000b) indicated that the SPAD threshold of 29 for high density broadcast rice (800 panicles/m^2) and 32 for high-density row-seeded rice (6560 panicles/m^2) as optional to maximize both grain yield and NUE.

Hussain *et al*. (2000) tested the approach of using sufficiency indices calculated from chlorophyll meter readings relative to well-fertilized reference plots and concluded that chlorophyll meter readings were significantly affected by N management practice, cultivar and time of application. Chlorophyll meter sufficiency indices were helpful in realizing greater agronomic efficiency of nitrogen (AEN) fertilizer over pre-set splits.

Kenchaiah *et al.* (2000) found higher grain yield under LCC based N management than the blanket recommendation. Kumar *et al*. (2000) reported increase in grain yield of rice due to nitrogen application with SPAD 35.

Porpavai *et al.* (2000) reported that yield obtained from LCC 3 based N applied plots was highest and comparable with SPAD-32, SPAD-35 and LCC 4 during dry season. While, during wet season, yield obtained from SPAD 35 based N applied plot was highest, which was comparable with LCC 4, SPAD 32 and LCC 3 based N applied plots. Hussain *et al.* (2000) also obtained the highest mean grain yield of 5.4 t/ha at N application based on 35 SPAD. The per cent increase in grain yield under SPAD value 35 was 161, 30, 20, 16.4 and 9 compared to control, nitrogen application at basal 50 per cent + tillering 25 per cent + panicle initiation 25 per cent, 1/3rd N each at 21, 42 and 56 DAS , SPAD value 29, SPAD value 32 and LCC reading 3, respectively. Application of 20 kg N/ha + SPAD-N produced the highest yield of 5.8 and 6.3 t/ha in dry season and wet season, respectively (Balasubramanian *et al.*, 2000a).

The highest gross revenues and highest yield of 5.8 t/ha were obtained with 20 kg N/ha basal plus SPAD based N supplementation in the wet sown condition (Balasubramanian *et al.*, 2000). Kutty *et al.* (2000) studied the relationships between leaf N concentrations (Nc), chlorophyll or SPAD meter readings and leaf colour chart (LCC) values in rice in Kerala and found that the coefficients of correlation between SPAD and LCC values were significant at all sampling dates including pooled data over the growth stages. He observed a significant relationship between leaf nitrogen concentration (Nc) with SPAD and LCC values.

A field experiment conducted at Thanjavur, Tamil Nadu by Ramanathan *et al*. (2000) concluded that the higher grain yield of rice could be obtained with SPAD 36-38 guided N management and it was on par with SPAD 33-35, but was significantly superior over SPAD < 32.

Stalin *et al*. (2000) in a study conducted in the Cauvery Delta of Tamil Nadu, India, reported that SPAD guided treatment had significantly lower grain yield than the Manage-N and Soil Test Crop Response (STCR) methods. This may be due to the relatively low amount of N applied (75 kg N/ha), suggesting that the SPAD threshold value for ADT-36 rice variety needs to be increased to maximize the yield.

Hegde *et al*. (2001) from Mugad (Karnataka), reported that rice varieties namely Abhilash and Intan responded to N management based on LCC up to the critical value 4.25 and 3.5, respectively with a total N application of 170 kg N/ha. Grain yield in LCC treatments were significantly higher than those under recommended N management.

Kumar *et al*. (2001) at Rajendranagar (Andhra Pradesh) concluded that SPAD-based N rate in rice resulted in significantly higher yields over 135 kg N/ha during rainy and winter seasons. SPAD and LCC values increased significantly with the increase in N levels. N application based on SPAD and LCC values were comparable with 135 kg N/ha and were superior over other treatments.

Results of the experiment conducted at Agricultural Research Station, Mugad, Karnataka, indicated that N management based on LCC 3 recorded significantly higher grain yield, growth attributing characters like leaf area index (LAI) and dry matter production and distribution and yield attributes like panicles per meter row length and filled grains per panicle as compared to recommended dose and check (Premalatha, 2001). Angadi *et al.* (2002) reported that LCC threshold values of 5.0 and 3.5 for Abhilash and Intan varieties respectively were optimum for getting higher grain yield. They concluded that LCC based N management was better than recommended practice.

Singh *et al.* (2002) reported that applying 30 kg N/ha each time the SPAD value fell below the critical value of 37.5 resulted in application of 90 kg N/ha, which produced rice yields equivalent to those with 120 kg N/ha applied in three splits. Similarly, N management based on LCC shade 4 helped to avoid over application of N to rice. In China, SPAD based real-time N management reduced the N rate substantially and maintained the yield of hybrid rice IR-68284H, but decreased the yield of inbred variety IR-72 (Peng *et al.*, 2002). The agronomic efficiency of applied N was very low for fixed-split (8 to 11) and fairly high for SPAD-based N management (16 to 22) (Balasubramanian *et al.,* 2002).

Results of field experiment conducted at Dharwad, Karnataka, India by Jayanthi (2002) indicated that application of recommended dose of N in more number of splits at 20 kg N/ha at critical value of LCC-3 was more beneficial in enhancing the growth and yield parameters of rainfed rice. A basal application of N at 20 kg/ha increased the growth parameters but did not significantly affect the yield and yield parameters. The yield and yield components of rice were significantly and favourably influenced when N was supplied up to reproductive phase (panicle initiation to 10% flowering) under LCC guided N management. Application of recommended dose of nitrogen at 20 kg/ha at LCC-3 value at biweekly observations after 21 days after rice emergence was found to be a better method of nitrogen management in rainfed rice.

Pandu (2002) observed that grain yield of drill sown upland rice due to N management at LCC 3 did not differ significantly from recommended dose of nitrogen (RDN). N management at LCC threshold value of 3 required less total N (70-90 kg/ha) than with RDN (100 kg/ha).

Porpavai (2002) experiments at the Soil and Water Management Research Institute (SWMRI), Kattuthottam, Thanjavur, India indicated that in dry season (Kuruvai) LCC colour shade 4 based nitrogen management and in wet season (Thaladi) LCC colour shade 5 based nitrogen management recorded higher grain yield and found comparable with SPAD 37 based nitrogen management.

Mohandas *et al.* (2003) noted that LCC threshold value of 5 for hybrids DRRH1 and ADTRH1 and 4.5 for inbred variety TRY-2 optimized rice yield and fertilizer use efficiency in saline sodic soils of Tamil Nadu, India. These studies indicated that for the crop need-based N management using chlorophyll meter or LCC was equally good for inbred and hybrid rice varieties to maximize their yield and N fertilizer use efficiency.

Yang *et al.* (2003) observed linear relationship between LCC scores and N content on dry weight (Ndw) basis at each growth stage (*r2* range of 0.25 - 0.97) and across growth stages (*r2* range of 0.46-0.62) in rice. Adjusting LCC scores for SLW (LCC/SLW) greatly improved the prediction of nitrogen content on dry weight across growth stages (*r2* range of 0.84-0.92), suggesting that leaf thickness affects LCC scores. Leaf colour chart scores were closely related to SPAD values (*r2* range of 0.62-0.98).

In Tamil Nadu, Budhar and Tamilselvan (2003) found that in wet seeded rice, application of N at 135 kg/ha in four splits at seedling (30 kg/ha), active tillering (45 kg/ha), panicle initiation (30 kg/ha) and flowering (30 kg/ha) stages based on LCC value of 4 recorded the highest grain yield. However, it was on par with yields of N treatment with LCC 5, in which N was applied at 165 kg/ha. The recommended N application recorded a lower yield than the LCC-based N treatments. In all, the highest agronomic efficiency of applied N, net income, and benefit cost ratios were noticed in the LCC 4-based N treatment.

Sheoran *et al.* (2004) from Haryana, India reported that a basal dose of N may have a distinct advantage and must be applied for better tillering, faster growth and ultimately higher yield of rice to enhance slower growth and lower yields associated with LCC approach.

Further, the use of LCC for scheduling N application may not be uniformly applicable to all the varieties that differ in inherent leaf colour, thereby necessitating individual/group standardization.

A field experiment conducted at Modipuram, (Uttar Pradesh) by Shukla *et al*. (2004) revealed that LCC < 3 for "Basmati-370, LCC < 4 for Saket-4 and LCC < 5 for Hybrid 6111/PHB-71 produced higher grain yield as compared to recommended spilt application of nitrogen. Khan *et al.* (2004) found higher grain yield in LCC-based N fertilization managed rice where threshold value for LCC was used 3.5 for transplanted rice.

Use of the LCC for N management consistently increased the rice grain yield and profit as compared with the farmers fertilizer practice across the three wet (Aman) and three dry (Boro) seasons, which each involved 1 to 5 villages and a total of 8 to 36 farmers. Use of LCC for N management without any other change in the farmers' fertilizer or crop management increased average grain yield by 0.1 to 0.7 t/ha across villages and seasons (Alam *et al.*, 2005).

Leaf Colour Chart (LCC) based N management significantly influenced rice yield and yield components. Among the N management schemes, LCC 5 recorded the highest grain yield over 3 years (Biradar *et al.*, 2005).

Budhar (2005) from Paiyur (Tamil Nadu) revealed that in both years (2000 and 2001), grain yield was significantly higher at LCC value 4 (135 kg N/ha in four splits) and it was on par with LCC value 5 (165 kg N/ha in five splits) compared to the recommended N (120 kg N/ha in three splits). Fan *et al*. (2005) conducted experiment at Harbin (China) and reported that 38 to 40 and 3.5 are the critical SPAD and LCC values, respectively for N application in rice crop.

Witt *et al.* (2005) according to spectral reflectance pattern described the composition of light that is reflected from a rice leaf across the whole spectrum of wavelength from blue (400 nm), over green (550 nm) to infrared (700 nm). Samson *et al.* (2005) achieved comparable or higher yields of 6 to 8 t/ha from the field experiments conducted at IRRI and PhilRice (Philippines), where real-time N management through LCC in the dry season was carried out. Velu and Thiyagarajan (2005) opined that the adoption of LCC critical value 4 as the optimum and the best method of N management strategy for getting higher yield in rice.

Reddy *et al*. (2005) conducted a field experiment in drum seeded rice at Gangavati (Karnataka). The data revealed that scheduling of N based on LCC threshold level of 6 at 40, 60 and 40 kg N/ha during early, rapid and late vegetative growth stages, respectively recorded significantly higher grain yield (74.68 q/ha) over other LCC levels and recommended practice.

Alam *et al.* (2006) reported increase in the mean rice grain yield by 0.3-0.4 t/ha on 20-33 farmers' fields across 2-5 villages and seasons simply by managing N through LCC. Application of 30 kg N/ha whenever intensity of colour of the uppermost fully opened leaf of rice plant was less than LCC shade 3 (LCC-3), it resulted in higher yields than application of 80 and 120 kg N/ha in four equal split doses at fixed times (Singh *et al.,* 2006).

Manjappa *et al*. (2006) from Sirsi (Karnataka) reported that the N rate based on LCC 5 recorded the highest average rice grain yield (6281 kg/ha), straw yield (8758 kg/ha) and number of panicles/m^2 (313.5). The N rate based on LCC 4 and the recommended N rate recorded similar values for these parameters.

A field experiment conducted in Vertisol of Gangavathi (Karnataka) by Reddy and Pattar (2006) reported that application of N to transplanted rice at 110 kg/ha in four splits at early (20 kg N/ha), rapid (60 kg N/ha in two equal splits) and late (30 kg N/ha) growth stages based on leaf colour chart value 6 registered significantly higher mean grain yield (6.31 t/ha) as compared to recommended and farmers practice.

Gunasekar *et al*. (2007a) from Tamil Nadu concluded that grain and straw yields of rice increased with increasing LCC levels. The physical and economic optimum doses were found to be 141 and 139 kg N/ha to get the grain yield of 5356 and 5350 kg/ha, respectively. LCC critical value 5 which received 30 kg N/ha each time with a total dose of 150 kg N/ha recorded a grain yield of 5045 kg/ha.

Jayanthi *et al.* (2007a) indicated that application of nitrogen either @ 20 or 30 kg/ha per application under LCC guidance significantly increased growth components *viz.,* number of tillers per meter length, plant height, Leaf Area Index (LAI) and Dry Matter Yield (DMY), yield components (number of panicles/m, panicle weight and number of filled grains) and grain yield over the two controls *viz.,* recommended practice and farmers' practice and lower N rate (10 kg/ha) in rice.

Jayanti *et al.* (2007b) proved that application of LCC based nitrogen either at the rate of 20 or 30 kg N/ha, accounted for significantly higher grain yield than lower rate (10 kg N/ha) and the two controls *viz.,* recommended practice and farmers' practice in rice. The highest harvest index (36.98%) was obtained when nitrogen was applied @ 20 kg N/ha basal dose plus LCC based N application@ 20 kg N/ha. After considering both the harvest index and partial factor productivity, he concluded that application of LCC based nitrogen @ of 20 kg N/ha at biweekly observations along with 20 kg N/ha as basal dose appears to be a better method of nitrogen management.

At Killikulam, Balaji and Jawahar (2007) indicated that the treatment LCC 4 had the highest 1000 grain weight (22.80 g) and had highest yield, followed by LCC 5 and also indicated that the level of consumed N of 130 kg/ha resulted in higher straw yield in rice. Higher the N doses in the LCC method, the higher was the straw yield. Ravi *et al.* (2007) reported that the rice hybrid PA6201 with application of green manure 6.25 t/ha combined with LCC critical value 5 based N applications significantly increased grain yield, nutrient uptake and in turn resulted in higher net return and B:C ratio.

Sharma and Masand (2008) reported that the LCC-3 produced significantly higher grain yield of rice than LCC-2 (7 per cent) and recommended dose of fertilizer (13 per cent). As suggested by Sudhalakshmi *et al.* (2008) nitrogen supply matches with the crop demand and there is considerable yield increase under LCC- N management and because of the optimum N supply, there is saving of nitrogenous fertilizers to the tune of 20-40 kg/ha. Sathiya and Ramesh (2009) reported that the nitrogen management at LCC value of 4 (150 kg N/ha) produced significantly higher tillers (369.3 per m^2) at maximum tillering stage, plant height (81.7 cm) at maturity, dry matter at flowering (5.71 t/ha) and grain yield (2915 kg/ha) than LCC value of 3 that produced grain yield of 2211 kg/ha.

A field experiment conducted at Srinagar (Kashmir) by Singh *et al.* (2009b) reported that LCC < 5 (180 kg N/ha applied in 6 splits) recorded significantly higher grain yield (6.61 and 6.70 t/ha in 2004 and 2005, respectively) but remained at par with application each of 20 kg N/ha at same LCC level (5.96 and 6.03 t/ha in 2004 and 2005, respectively) without basal dose of nitrogen application (total of 100 kg N/ha) as compared to recommended dose of 120 kg N (4.86 and 4.81 t/ha) and LCC < 3 (60 and 90 kg N/ha).

Application of N through farmers method recorded the highest grain yield of rice (44.53 q/ha) and was on par with recommended method (43.07 q/ha), LCC 5.0 (42.40 q/ha) to 5.5 (43.33 q/ha) and SPAD 37.5 (42.50 q/ha) to 40.0 (43.80 q/ha). But 90-100 kg N/ha was saved in LCC 5.0 to 5.5 and SPAD 37.5 to 40 treatments (Duttarganvi *et al.*, 2011).

Houshmandfar and Kimaro (2011) indicated that the critical LCC value of 4 with 25 kg N/ha for Tarom-Hashemi and critical LCC value of 4 with 35 kg N/ha for GRH-1 were found to be suitable for guiding N application to achieve the highest grain yield. Sen *et al.,* (2011) reported that the critical LCC score for real time nitrogen requirement for NDR 359 and Sarju 52 was found to be ≤ 5, while for HUBR 2-1 it was ≤ 4.

Fallah (2012) concluded that the critical LCC for local Tarom variety is 3 and SPAD value 32-34 as well. The split of nitrogen increased the total dry weight, panicle dry weight and number of filled grain per panicle, as a result, yield was increased.

Ghosh *et al*., (2013) reported that the SPAD value of 36 was found to be critical for Eastern India, unlike the value of 35 recommended for the Philippines and application of less amount of fertilizer N in split during tillering to heading stage under RTNM (real time N management) improved the growth and productivity of rice as compared to those in FTNM (fixed time N management).

Krishnakumar and Haefele (2013) experiment results showed that LCC 4 and 5 based N applications recorded higher grain yield as a result of higher soil available nutrients during the critical growth stages.

2.4 EFFECT OF DIFFERENT NITROGEN MANAGEMENT PRACTICES ON NITROGEN CONTENT AND UPTAKE

The leaf photosynthetic rate and leaf N concentration were closely related in rice and hence maintaining adequate leaf N throughout the growing period was crucial for achieving high yield (Yoshida, 1981).

The higher SPAD values indicated a higher foliar N concentration and N uptake (Kumar *et al*., 2000). Premalatha (2001) reported that N management based on LCC 4 recorded maximum available soil N and leaf N content. Kumar *et al*. (2001) observed that a higher SPAD and LCC values during winter, indicating higher N content in rice.

Pandu (2002) concluded that total N uptake and its accumulation in leaf and panicle was significantly higher with N management at LCC-3 in Dodiga rice variety compared to recommended N management. This was due to higher total dry matter production and its accumulation in grains. Shukla *et al*. (2004) found that LCC < 3 for Basmati-370, LCC < 4 for Saket-4 and LCC < 5 for Hybrid 6111/PHB-71 in rice and LCC < 4 with 125 kg N/ha produced higher nitrogen uptake as compared to recommended N application in splits.

Leaf colour chart 6 based nitrogen management in rice recorded significantly higher N uptake (Reddy and Pattar, 2006). The split application of N at higher doses effected higher N uptake of rice. Increasing N doses increased total P and K uptake by rice (Balaji and Jawahar, 2007).

Field experiment conducted in Tamil Nadu indicated that the rice crop require lower N at the early stages; more N during its grand growth period (panicle initiation to first flowering) and a comparatively lower N during the later stages of crop growth. Thus LCC could help in promoting need based nitrogen application vis-a-vis increased nutrient uptake (Gunasekar *et al.*, 2007b).

Kumar *et al.* (2007) from Tamil Nadu revealed that Leaf Colour Chart (LCC) based nitrogen management in rice crop, positively increases the nitrogen uptake. Ravi *et al.* (2007a) from Tamil Nadu reported that LCC critical value 5 based N application in rice recorded significantly higher leaf nitrogen concentration.

Houshmandfar and Kimaro (2011) reported that the grain yield and total N uptake were higher for LCC based N treatments than for fixed schedule recommended N application.

The literature on nitrogen uptake in rice indicate that the nitrogen uptake increases with increased levels of application and number of splits and uptake pattern varies with soil type and yield at large.

2.5 EFFECT OF DIFFERENT NITROGEN MANAGEMENT PRACTICES ON SAVING OF NITROGEN

Among all agricultural inputs, nitrogen is one of the costly inputs, which cannot be avoided from the system. Excess nitrogen application leads to ground water and soil health problems. So, judicious use of N can save the income of the farmers and reduce the soil health problems.

SPAD values of rice were positively correlated with leaf N concentration and with specific leaf weight. N concentration was more accurately estimated from SPAD values + specific leaf weight than from SPAD values alone Peng *et al.* (1992). Garcia *et al.* (1996) indicated that the SPAD method gave 7.6-8.8 per cent more grain yield with 22.4 per cent lower N fertilizer input and higher agronomic efficiency of applied N of 10-11 than the farmer's practice.

Leaf colour chart based N management reduced the N fertilizer use by 29 kg/ha and it also reduced the lodging, pest incidence and production cost of rice (De and Hai, 1999). Leaf LCC or SPAD based N management reduced the fertilizer use by 18 per cent and increased the grain yield of rice by 29 per cent compared to farmer's method (Hla Tin *et al.,* 1999). Mohandas *et al.* (1999) also reported considerable saving (46-54 per cent) in N-fertilizer use, without sacrificing the grain yield due to SPAD based N management compared with locally recommended blanket N rates. Use of LCC 4 as critical value reduced the N fertilizer by 20 kg/ha compared to five splits of urea application (Zaini and Erythrina, 1999).

Kumar *et al*. (1999) at Rajendranagar (Andhra Pradesh) noticed that lower amount of N applied in SPAD based N management can save 50-55 kg of N/ha without yield loss.

Babu *et al*. (2000b) reported that SPAD based N management resulted in saving of fertilizer rate by 50-65 kg N/ha during dry season and 78-95 kg N/ha during wet season.

Kenchaiah *et al.* (2000) recorded higher agronomic efficiency (AEN) due to higher grain yield with lesser N application in the SPAD-N and LCC-N plots with a saving of 10-20 kg/ha of fertilizer N. LCC-3 and SPAD-32 based N applied plots received lower N of 60 and 70 kg/ha in dry and wet season, respectively, indicating maximum N saving of 65 and 80 kg/ha respectively than local recommendation (125-150 kg/ha) in both dry and wet seasons (Porpavai *et al.*, 2000).

The partial factor productivity was found to be more in LCC based N management in drill sown rainfed rice and can result in saving of fertilizer N up to 20 kg/ha without reduction in yield (Jayanthi, 2002).

Haun *et al.* (2002) reported that N application method based on leaf colour diagnosis helped in saving N applied fertilizer and fixing or increasing grain yield of rice. The SPAD meter based N management appeared to be more efficient and would save 20-30 kg N/ha than the conventional N management practices to produce similar grain yield (Miah and Ahmed, 2002).

Ludhiana, Singh *et al.* (2002) reported that LCC is a tool used to measure leaf colour intensity. N application to rice based on LCC shade 4 was reasonably ideal and LCC is simple and easy that can help farmers avoid over application of N to rice. Singh *et al.* (2002) observed plant need-based N management through chlorophyll meter reduced N requirement of rice from 12.5 to 25 per cent, with no loss in yield.

Alam *et al.* (2004) recommended LCC for judicious use of nitrogen in rice cultivation. Khan *et al.* (2004) reported that LCC-based nitrogen application increased the grain yield of rice and reduced the urea use over farmers' practice. Maiti *et al.* (2004) reported the mean values of LCC and SPAD varied from 3.19-

5.31 and 27.36-39.26, respectively, in rice. The results showed that the amount of N can be saved as 20-42.5 and 27.5-47.5 kg N/ha through the use of LCC and SPAD in rice over the fixed-timing N treatment where 150 kg N/ha was applied in three 3 splits without reduction in the yield.

Ali (2005) reported that the requirement of N fertilizer based on SPAD reading was found 15 and 40 kg N/ha lower compared to conventional N management during wet and dry seasons, respectively.

Hussain *et al.* (2005) reported that the nitrogen applied by studying the LCC value at 14 days after panicle initiation and 10 days after panicle initiation would save 40 per cent of N as compared to blanket recommendation. LCC-4 based nitrogen management can save 15 kg N/ha as compared to blanket recommendation (Velu and Thiyagarajan, 2005).

Samson *et al.* (2005) from the field experiments conducted at IRRI and PhilRice (Philippines), where real-time N management through LCC in the dry season was carried out, observed reduced N fertilizer use by 45 to 80 per cent compared to the conventional N management with a fixed seasonal N rate of 210 kg N/ha, while achieving comparable or higher yields of 6-8 t/ha.

Maiti and Das (2006) showed that SPAD value of 37 and LCC value of 5 have been proved superior over SPAD 35 and LCC 4 for the best management of N in rice in an Inceptisol. Islam *et al.* (2007) reported that the adoption of LCC could save N by 25 kg/ha with highest saving of 31.4 kg/ha. They also observe that increased paddy yield per ha, reduced insecticide application and also increased economic yield.

Singh *et al*. (2007a) reported that following LCC based N management, from 9.4-54.2 kg N/ha, with an average of about 25 per cent less fertilizer N was used, without reduction in yield as compared to practice of farmers of applying blanket N at fixed time intervals.

Singh *et al.* (2007b) experimented the LCC-guided N management thus resulted in savings of 16 to 43 kg N/ha (24 kg N/ha, averaged across 48 experiments) compared with farmers' practice without any reduction in grain yield. By adopting LCC grade 5 based N top dressing with green manure incorporation had facilitated to save N to the tune of 50 kg/ha per rice crop than the recommended dose (Ravi *et al.,* 2007b).

Sathiya and Ramesh (2009) with LCC value of 4 observed the application of 150 kg N/ha in four splits *viz.,*1/6 at 15 DAS, 1/3 at tillering, 1/3 at PI, 1/6 at flowering and considered it to be a suitable nitrogen management technique in aerobic rice cultivation at Coimbatore. Thind *et al.* (2009) showed that real-time N management using an LCC can lead to substantial savings in fertilizer-N use, as the yields obtained following blanket recommendations (*i.e.,* fixed dose and fixed timing of fertilizer-N application) were similar.

Application of N through LCC 5 to 5.5 and SPAD 37.5 to 40.0 indicated saving of N by 90 to 100 kg/ha without significantly reduction in grain yield (Duttarganvi *et al*., 2011).

Houshmandfar and Kimaro (2011) indicated that saving of fertilizer N is possible through LCC based N management in rice with no yield lose by appropriately revising the fertilizer recommendation. Thus, there is considerable opportunity to increase farmers yield and N recovery efficiency levels through improved N management with the LCC.

Yoseftabar *et al.* (2012) revealed that SPAD based N application method helped in saving N applied fertilizer and significant increase in grain yield.

Ghosh *et al.* (2013) experiment results showed that SPAD meter based N application in RTNM (real time N management) produced rice yields similar to that of existing fertilizer recommendation in FTNM (fixed time N management); but, SPAD meter based N management saved 27 to 54 per cent fertilizer N in comparison to FTNM. Especially maintaining SPAD threshold 36, application of

35 and 25 kg N/ha could save the fertilizer N by 20 to 35 per cent as compared to FTNM with a marginal positive impact on grain yield.

From the above cited literature, it is inferred that LCC or SPAD based nitrogen management had beneficial effect on yield and yield components vis-a-vis substantial quantum of saving in fertilizer N as compared to recommended nitrogen management with fixed application.

2.6 EFFECT OF DIFFERENT NITROGEN MANAGEMENT PRACTICES ON NITROGEN USE EFFICIENCY (NUE)

The main reason for low N use efficiency is an inefficient splitting of N doses coupled with N applications in excess of crop requirements. When managed inefficiently, a large portion of the applied N can escape from soil-plant system to reach water bodies and the atmosphere thus creating pollution problems. Sound N management practices need to be established and followed to improve N use efficiency leading to high grain yield levels and minimal fertilizer N loss to the environment.

Peng *et al*. (1996) revealed that SPAD guided nitrogen management in rice increased the agronomic efficiency of applied N (AEN) by 27.3 per cent compared to farmers' method. Anon. (1997) opined that SPAD based N management improves agronomic efficiency of rice.

Garcia *et al.* (1996) indicated that the SPAD method gave 7.6-8.8 per cent more grain yield in rice with 22.4 per cent lower N fertilizer input than the farmers' practice. The agronomic efficiency of applied N (AEN) of 19 for SPAD method was significantly higher than the AEN of 10-11 for farmer's practice.

Agronomic efficiency and partial factor productivity (PFP) was higher in rice for SPAD based N application than in the N-50 and N-135 treatments (Kumar *et al.*, 1999).

Results of an experiment conducted at Thanjavur, Tamil Nadu by Babu *et al*. (2000a) indicated that SPAD threshold of 35 to 37 is optimum for nitrogen use efficiency and the respective AEN values for SPAD 35 and 37 were 49 and 31 in 1997 and 80 and 51 in 1998.

The AEN values in transplanted rice of the SPAD treatment were 1.5 to 2.5 times more than the local N recommendation (Babu *et al.*, 2000b).

Agronomic efficiency (AEN) and partial factor productivity of applied N (PFP-N) were higher in SPAD N management in rice according to Balasubramanian *et al*. (2000a).

Balasubramanian *et al*. (2000b) from Maligaya (Philippines) reported that the SPAD-29 and SPAD-35 recorded highest and lowest AEN in broadcast sown rice and for row-seeded rice SPAD-32 and SPAD-35 recorded highest and lowest AEN and thus, data indicated that SPAD-29 and SPAD-32 as optimum for AEN in broadcasted and row-seeded rice, respectively.

Kenchaiah *et al.* (2000) indicated that the agronomic efficiency of nitrogen was high due to higher grain yield with lesser N application in the SPADN and LCC-N plots with a saving of 10-20 kg/ha of fertilizer N.

Kumar *et al*. (2000) noticed higher AEN and PFP-N value with SPAD-35 N application in case of transplanted rice. Ramanathan *et al*. (2000) concluded that SPAD 33-35 based N management as optimum for higher NUE in transplanted rice. Stalin *et al*. (2000) reported that the NUE values (AEN and PFP-N) were higher due to SPAD method (due to less N application *i.e.,* 75 kg/ha), which could be attributed to right timing of N application.

Kumar *et al*. (2001) reported that the AEN and partial factor productivity (PFP) were higher for SPAD-based application (75 and 80 kg N/ha in the rainy and winter seasons, respectively) compared with recommended practice of 135 kg N/ha.

Balasubramanian *et al*. (2002) reported that SPAD based N management recorded higher N-use efficiency for inbred and hybrid (37 and 38, respectively) rice genotypes under submerged condition of cultivation.

Pandu (2002) from Dharwad, reported that N management under drill sown upland rice LCC-3 with vermicompost application seemed promising in respect of NUE and grain yield of rice. An increase in NUE and a 20 per cent saving of chemical fertilizer N could be attained with incorporation of vermicompost and N management at LCC-3 without significant reduction in yield.

Peng *et al*. (2002) reported that AEN was very low for fixed-split (AEN 8 to 11) and high for SPAD-based N management (AEN 16 to 22).

A study conducted by Mohandas *et al*. (2003) concluded that need based N management using chlorophyll meter or LCC recorded higher N fertilizer use efficiency in rice as compared to recommended N management practice. SPAD or LCC based N management improved fertilizer input by reducing total N input and by increasing grain yield (Peng *et al.*, 2003).

Need based nitrogen management with LCC < 3 for "Basmati-370, LCC < 4 for Saket-4 and LCC < 5 for Hybrid 6111/PHB-71 in rice and LCC < 4 with 125 kg N/ha in wheat crop in a system perspective produced higher AEN and NUE than split application of recommended nitrogen (Shukla *et al.,* 2004).

Maiti *et al.* (2004) reported that the SPAD and LCC treated N plot showed higher N use efficiency over fixed-scheduling N treatment in rice. The results further show that SPAD value of 37 and LCC value of 5 have been proved to be superior treatments over SPAD 35 and LCC 4 for the best management of N in rice in an Inceptisol.

Biradar *et al.* (2005) showed that the values of agronomic efficiency of applied N (AEN) (calculated as the increase in rice yield per kg of N applied) were generally higher at lower LCC threshold values. Alam *et al.* (2005) reported a further increase in NUE in rice in Bangladesh when the critical value for LCC was reduced from 4 to 3.5.

Site specific nitrogen management in rice reduced the total N applied by reducing total N application by 25 per cent in rice and thereby significantly increased fertilizer N use efficiency compared to farmer fertilization practice (Fan *et al.*, 2005).

Singh *et al.* (2006) reported that the higher fertilizer N-use efficiency was recorded with need-based N management using LCC-3 rather than LCC 4 as critical colour shade. Maiti and Das (2006) suggested that the N-use efficiency can be increased with SPAD, and LCC over fixed-timing N treated plots.

Balaji and Jawahar (2007) reported that the efficiency of the applied N was higher in the LCC and chlorophyll meter treatments. Jayanti *et al.* (2007b) reported that the PFP was higher when a total of 100 kg N/ha was applied @ 20 kg N/ha based on LCC observations indicating better utilization of the applied nitrogen.

Singh *et al*. (2007a) reported that application of fertilizer N when colour of the first fully expanded leaf was less than LCC shade 4, increased nitrogen use efficiency from 48 – 65 kg grain/kg N.

Use efficiencies of fertilizer N in transplanted rice were higher when N was applied using LCC-4 than the recommended practice of applying 120 kg N/ha in three equal splits. PFP-N was markedly higher (71 kg grain per kg N applied, averaged across different cultivars) with LCC-guided N management than the farmers' practice (56.5 kg grain per kg N) (Singh *et al.*, 2007b).

Huang *et al.,* (2008) reported that RTNM (real time N management) has increased agronomic N use efficiency when compared with FTNM (fixed time N management) because at lower N rate in RTNM the grain yields were similar or higher than that of FTNM.

Agronomic efficiency of rice increased with decreasing level of applied chemical N, except farmers practice. LCC treated plots were better than all other treatment as far agronomic efficiency of applied N is considered (Biswas *et al.,* 2008).

The chlorophyll meter indicates the need of a nitrogen top dressing that would result greater agronomic efficiency of nitrogen fertilizer than commonly pre-application of nitrogen (Hassan *et al.,* 2009).

Application of 20 kg N/ha at LCC < 5 (100 kg N/ha) recorded higher agronomic efficiency (AEN) of 29.4 and 32.7 kg grain per kg N applied and apparent recovery (ARN) of 52 and 57 per cent in 2004 and 2005, respectively as compared to rest of the treatments but statistically on par with LCC < 3 with a 30 kg N/ha as a basal and LCC < 5 under 20 kg N/ha as basal during 2004 and 2005, respectively except in 2004 with respect to agronomic efficiency (Singh *et al.,* 2009b).

Sen *et al.* (2011) reported that higher grain yield along with corresponding higher agronomic and recovery efficiency of N fertilizer and other parameters LCC < 5 for NDR 359, Sarju 52 and ≤ 4 for HUBR 2-1 were judged to be the critical values for proper N management.

According to Dwivedi (2012) synchronising fertilizer N input with crop demand results in enhanced N use efficiency. On-station and on-farm experiments in rice-wheat cropping system established the advantage of LCC-based N use over the conventional application in 2 or 3 splits.

Ghosh *et al.* (2013) revealed that agronomic N use efficiency can be increased at high yield level using SPAD meter based N management. Application of 55 to 88 kg N/ha in two to three splits during tillering to flowering as per need of the crop led to better N use efficiency. AEN of RTNM (real time N management) was increased by 37% to 75% as compared to FTNM (fixed time N management) (13.5 kg grain per kg N applied) over the years.

The literature brings out the fact that higher nitrogen use efficiency can be obtained by LCC or SPAD based nitrogen management.

2.7 EFFECT OF DIFFERENT NITROGEN MANAGEMENT PRACTICES ON ECONOMICS

Any technology has to be technically and economically viable to reach farmer's fields and therefore, the economic analysis of the results is very important. This also gives a clear idea about the optimum level of inputs that could be recommended to obtain maximum profit.

Narasimhan *et al.* (1999) reported that the chlorophyll meter based N application recorded the highest grain yield as well as benefit cost ratio.

Balasubramanian *et al.* (2000) recorded the highest gross revenues with the 20 kg N/ha basal plus SPAD-N and highest yield of 5.8 t/ha in the dry sown and 6.3 t/ha in the wet sown condition.

Field experiment on crop need based N management conducted at ARS Mugad, Karnataka, reveals that N-management at LCC-3 recorded significantly higher grain yield, net returns and B:C ratio than recommended and farmers practice (Premalatha, 2001).

From Dharwad, Angadi *et al*. (2002) recorded that LCC values 5 and 3.5 accounted significantly higher net returns in Abhilash and Intan rice varieties, respectively.

The economic profitability of management of N through LCC and SPAD was reported by Abdulrachman *et al.* (2002).

Application of nitrogen @ 20 kg/ha based on biweekly LCC increased the net return and B:C ratio of rainfed rice (Jayanthi, 2002). Pandu (2002) observed that N management at LCC 3 recorded significantly higher net returns and B:C ratio than that of RDN.

Shukla *et al.* (2004) compared LCC with the recommended N splits, in which a similar quantity of fertilizer N was applied, the LCC treatment combinations LCC 3 in Basmati-370 and LCC 4 in wheat gave 20 and 23 per cent higher net returns, respectively. In Saket-4 early sown wheat (PBW-343) in combination with, the fertilizer N application based on LCC 4 in rice and wheat was more profitable than any other treatment combination. In hybrid rice timely sown wheat (HD-2687) combination, the N application based on LCC 5 in rice and 4 in wheat gave extra net returns of 28 and 31 per cent respectively, over recommended N splits.

Biradar *et al.* (2005) study showed that the RDN was inadequate in achieving higher yields of irrigated rice in the TBP area. Whereas, economics indicated a higher benefit cost ratio for LCC-5 than with RDN. Maximum net income was observed at LCC value 4 (Rs. 16152 and 11164 per ha) in rice crop with a benefit cost ratio of 2.17 and 1.81 in 2000 and 2001, respectively (Budhar, 2005). Nitrogen management in drum seeded rice based on LCC-6 recorded significantly higher net monetary returns (Rs. 32791 per ha) and benefit cost ratio (2.81) than other treatments (Reddy *et al.*, 2005).

Reddy and Pattar (2006) noticed that higher mean net returns of Rs. 30960 per ha was realized with leaf colour chart 6 as against Rs. 27258 per ha in the case of recommended practice and Rs. 28032 per ha in case of farmers' practice. Similarly, the mean benefit cost ratio was significantly higher in case of leaf colour chart 6 (2.38) than all the other N management practices, including recommended (2.21) and farmers control (2.17).

Manjappa *et al*. (2006) at Sirsi (Karnataka) reported that LCC 5 based N management recorded significantly higher net returns (Rs. 27878 per ha) as compared to LCC 4 and recommended N application in lowland rice.

Gunasekar *et al*. (2007c) from Tamil Nadu opined that LCC critical value 5 at the rate of 30 kg N/ha each time could be adopted to get higher net income over blanket N in wet (drum) seed rice crop. Ravi *et al.* (2007) observed that the application of green manures at the rate of 6.25 t/ha combined with LCC critical value 5-based N application recorded higher net returns and B:C ratio in rice.

Singh *et al*. (2009b) reported that returns per rupee investment in account of applied N (Rs. 19.2 and 19.3 in 2004 and 2005, respectively) were recorded with LCC < 5, where 20 kg N/ha was applied in 5 equal splits without basal application in rice crop.

Duttarganvi *et al*. (2011) reported that increase in LCC from 3.5 to 5.0 increased the net returns and further increase to 5.5 did not show any beneficial effect. The benefit cost ratio was higher at LCC 4.5 (3.16) but on par with LCC 5.0 (3.14). Similarly increase in SPAD from 30 to 37.5 increased the net returns significantly but further increase to 40.0, had no beneficial effect. Though SPAD 40 showed the highest gross returns, decrease in net returns and benefit cost ratio was due to higher cost of cultivation.

The literature brings out the fact that net returns, gross returns and benefit cost ratio can be enhanced by application of nitrogen to match actual crop demand which may be practiced by split application or by LCC or SPAD based N management approaches.

Materials and Methods

3. MATERIALS AND METHODS

Field experiments were carried out to study the technical and economic feasibility of using chlorophyll meter (SPAD-502), leaf colour chart and soil testing kit for assessing the crop nitrogen status, to schedule N application in rice (*Oryza sativa* L.) based on crop need and to work out the economics. The materials used and the methods adopted during the investigation are presented in this chapter.

3.1 SITE DESCRIPTION

The investigations were conducted in a farmer's field *viz*., Bhuvana chandran, in Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state. The farm is located at 8.5º N latitude and 76.9º E longitude at an altitude of 29 m above mean sea level (MSL).

3.1.1 Climate and Season

The experimental site experiences warm humid tropical climate. The experiment was conducted during the *Virippu* season (first crop season), *i.e.,* June to October 2013. The data on various weather parameters, *viz*., weekly rainfall, maximum and minimum temperature, relative humidity and sun shine hours during the period are presented in Appendix - 1 and graphically represented in Fig 1.

3.1.2 Soil

Soil samples were collected prior to the experiment from 30 cm depth and a composite sample was used for the determination of physico-chemical properties. The important physico-chemical properties studied are given in Table 1.

The soil of the experimental site belonged to the textural class of sandy clay loam and of the taxonomical order Ultisol. It was acidic in reaction, high in

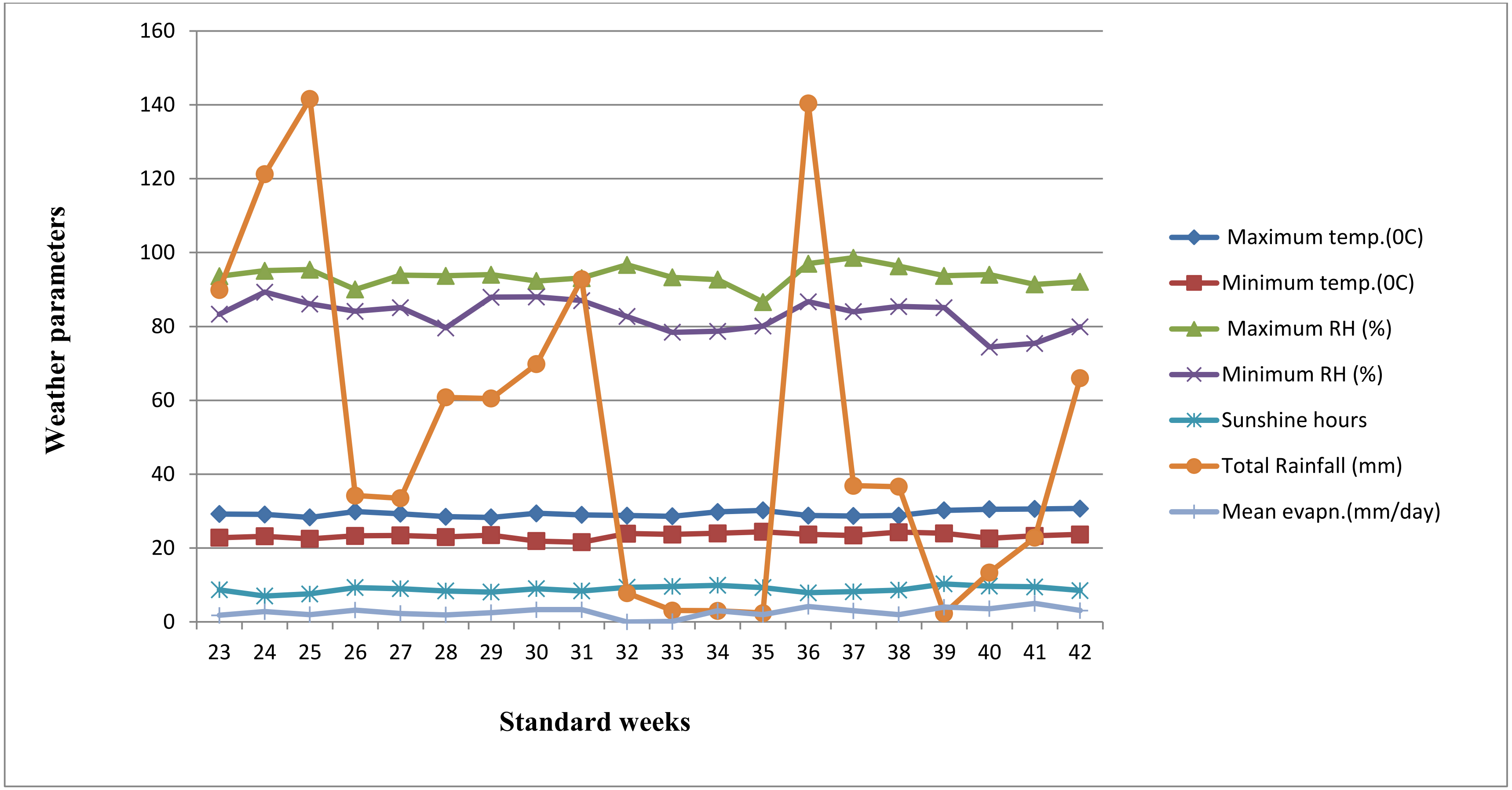

Fig 1. Weather data during the cropping period (June 2013 - October 2013)

Table 1. Physico-chemical properties of soil at experimental site

Parameters	Content	Status	Methodology
A. Mechanical composition			
Coarse sand (%)	51.74		Bouyoucos Hydrometer method (Bouyoucos,1962)
Fine sand (%)	14.25		
Silt (%)	8.01		
Clay (%)	26.0		
Textural class: Sandy clay loam			
B. Chemical properties			
Soil reaction (pH)	4.52	Acidic	1:2.5 soil solution ratio using pH meter (Jackson, 1973)
Organic carbon (%)	2.43	High	Walkley and Black's rapid titration (Jackson, 1973)
Available N (kg/ha)	405.6	Medium	Alkaline permanganate method (Subbaih & Asija, 1956)
Available P_2O_5 (kg/ha)	61.3	High	Bray colorimetric method (Jackson, 1973)
Available K_2O (kg/ha)	196	Medium	Ammonium acetate method (Jackson, 1973)

organic carbon content, medium in available nitrogen, high in available phosphorus and medium in available potassium content.

3.1.3 Cropping History of the Experimental Site

The experimental site selected was under continuous rice cultivation for the past three years.

3.2 MATERIALS

3.2.1 Crop and Variety

The rice variety used for the experiment was Uma, which is the most popular rice variety of the state developed by Rice Research Station, Moncompu, Kerala (Mo6 x Pokkali) (Pedigree selection, 1998), dwarf, medium tillering, non lodging, resistant to BPH and other major pests with dormancy up to 3 weeks. It is suited to three seasons especially to additional crop season of kuttanad, medium in duration with an yield potential of 6-7 t/ha.

The seeds of Uma was obtained from the Rice Research Station, Moncompu, Alappuzha.

3.2.2 Manures and Fertilizers

Well decomposed dry farm yard manure containing 0.55 per cent N, 0.23 per cent P_2O_5 and 0.46 per cent K_2O was used as the organic manure source. N, P and K were applied as urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) respectively.

3.2.3 Herbicides

Azimsulfuron – 50% DF (Segment) (post emergence herbicide) @ 28 g/ha was sprayed at 25 days after transplanting (DAT) to control the weeds.

3.2.4 Plant Protection Chemicals

One spray of ekalux @ 0.2 per cent and one spray of chlorpyriphos @ 0.2 per cent were applied against rice case worm. One spray of acephate @ 2 g/L and one spray of fipronil @ 0.2 per cent were applied against leaf folder. Two sprays of bavistin @ 0.1 per cent were applied to control brown leaf spot and blast diseases. One spray of ekalux @ 0.2 per cent and one spray of malathion @ 0.2 per cent were applied against rice gundhi bug/earhead bug and stem borer. Few grains were affected with false smut disease but effect was negligible.

3.2.5 Leaf Colour Chart

A leaf colour chart (LCC) developed from a Japanese Prototype is used to measure the leaf colour intensity. Leaf colour chart having values 2,3,4,5 was used for comparing the colour of the leaf. The leaf colour chart was obtained from the Cropping Systems Research Centre, Karamana, Thiruvananthapuram (Plate 1).

The LCC readings were collected from top most fully expanded leaf, because this leaf is highly related to the nitrogen status of rice. From each plot, 10 leaves from 10 randomly selected plants were selected. Colour of each selected leaf was measured by placing the middle part of the leaf on top of a colour strip of LCC.

During measurement, the leaf was shielded from the sun with our body, because leaf colour is affected by sun's angle and sunlight intensity.

The LCC readings were recorded at 10 days interval, starting at 10 DAT of rice till10 days after flowering. When the LCC value of six out of ten leaves fell below the critical value, 25 kg N/ha was top dressed immediately to correct N requirement.

3.2.6 SPAD Meter (Chlorophyll Meter)

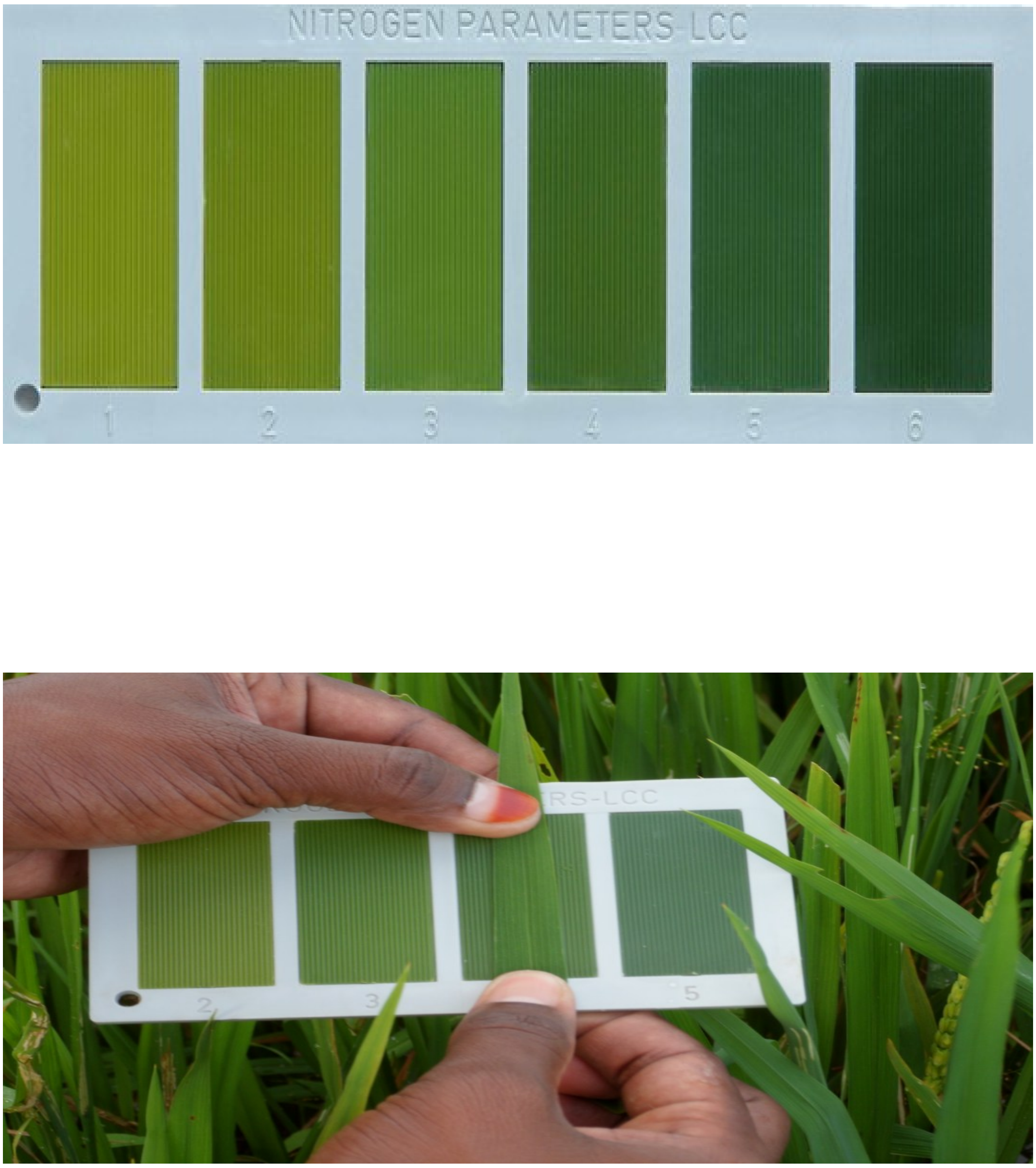

Plate 1. Leaf colour chart (LCC)

Plate 2. SPAD meter or Chlorophyll meter

The SPAD-502 (Soil Plant Analysis Development) or chlorophyll meter (Monilta Camera Co. Ltd., Japan) was used for recording the chlorophyll units of the rice crop. The SPAD meter was obtained from the Cropping Systems Research Centre, Karamana, Thiruvananthapuram (Plate 2).

This meter operates by clamping the sensor head onto a leaf blade. A rubber boot seals out external light, and creates a closed chamber around the area to be measured. Two light emitting diodes are used to emit light through the leaf at two wavelengths, 650 nm (red) and 940 nm (infrared), when the chamber is closed. Light in the 650 nm range lies between the two primary wavelengths associated with chlorophyll activity (645 and 663 nm). Meter operation is based on the inverse relationship between absorbed radiation in the 650 nm region of the spectra and that transmitted through the leaf. The 940 nm wavelength is not affected by leaf chlorophyll content and provides an internal meter calibration. A silicon photodiode receptor converts the transmitted light to analogue electrical signals, which are then converted into digital signals and used by the microprocessor to calculate the dimensionless SPAD unit value.

The SPAD meter readings were collected from top most fully expanded leaf, because this leaf is highly related to the nitrogen status of rice. From each plot, 10 leaves from 10 randomly selected plants were selected. Colour of each selected leaf was measured with SPAD meter by clamping the sensor head on the middle of the leaf blade.

The SPAD readings were recorded at 10 days interval, starting at 10 DAT of rice till 10 days after flowering. When the SPAD value of six out of ten leaves fell below the critical value, 25 kg N/ha was top dressed immediately to correct N requirement.

3.2.7 Soil Testing Kit

Soil testing kit was used for determining the available nitrogen status of the soil (Plate 3). Soil samples were collected one day prior to observation date,

Plate 3. Soil testing kit

dried under shade, crushed and used for analysis. When the nitrogen status in soil was low, then 25 kg N/ha was top dressed on the same day.

3.3 METHODS

3.3.1 Design and Layout

The field experiment was laid out in randomized block design with 9 treatments and 3 replications. The lay out plan of the experiment is given in Fig.2.

Design	:	Randomised Block Design (RBD)
No. of treatments	:	9
Replication	:	3
Plot size	:	5 m x 4 m
Spacing	:	20 cm x 15 cm

3.3.2 Treatments

T_1 : N application at LCC value 3.0

T_2 : N application at LCC value 4.0

T_3 : N application at LCC value 5.0

T_4 : N application at SPAD value 32

T_5 : N application at SPAD value 34

T_6 : N application at SPAD value 36

T_7 : N application based on soil test value using soil testing kit

T_8 : KAU Package of practices

T_9 : Absolute control

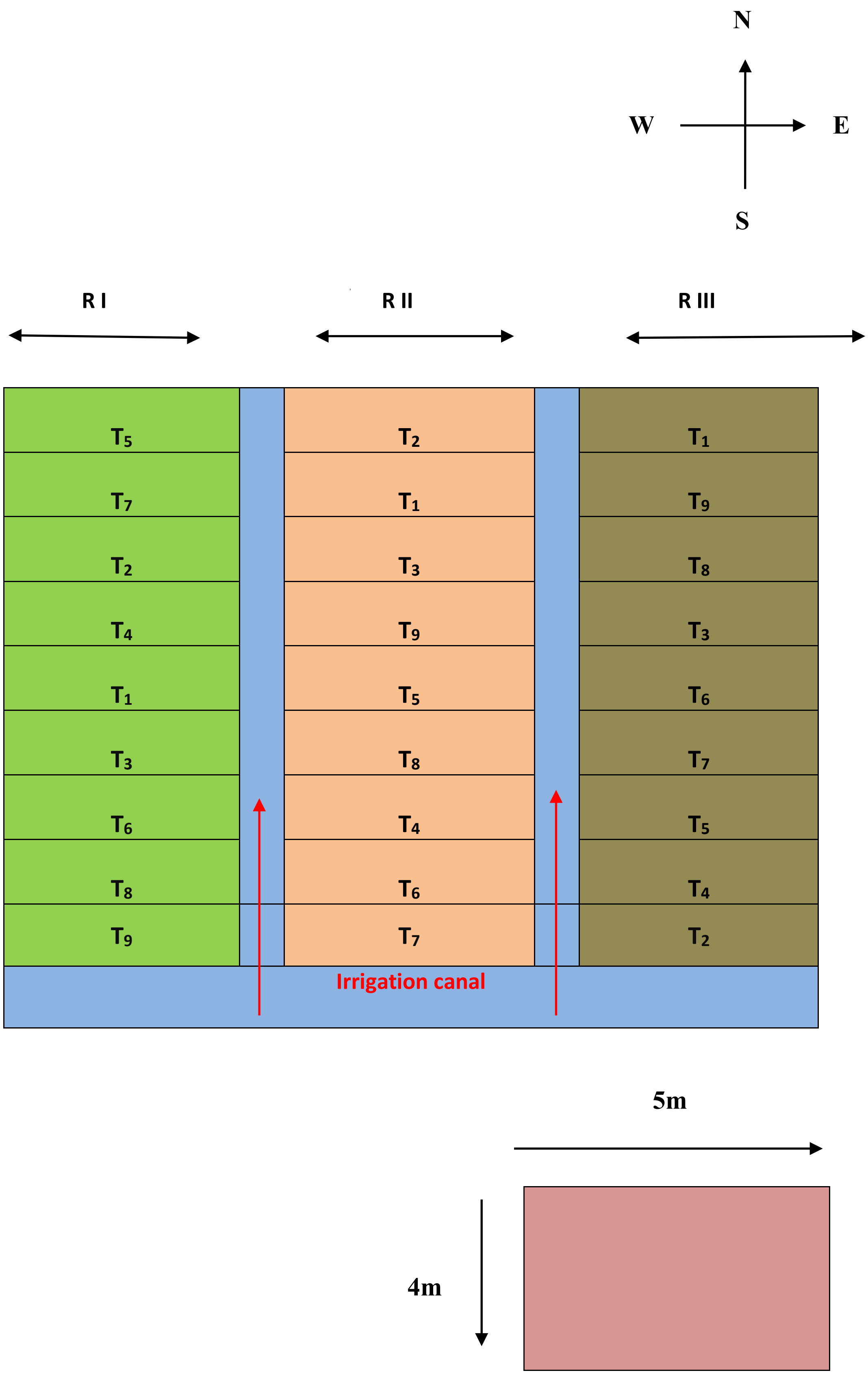

Fig 2. Lay out plan of the field experiment

3.3.3 Crop Management

All the cultural practices except nutrient management were carried out as per the Package of Practices Recommendations 'Crops' (KAU, 2011).

3.3.3.1 Nursery

The land was puddled and leveled thoroughly and pre germinated seeds were sown in the nursery @ 100 kg/ha. The nursery area was ploughed thoroughly after the application of FYM @ 1 kg/m^2 and raised beds of 5 to 10 cm height and 1 to 1.5 m width and of convenient length were prepared. Irrigation was started after 6 days of sowing of seeds and water was drained for 9 hours once in 5 days to encourage production of vigorous seedlings. Bird scaring was carried out for seven days initially.

3.3.3.2 Main Field Preparation

The experimental area was puddled twice and leveled. Weeds and stubbles were removed. Three blocks with nine plots each were laid out in randomized design. The blocks were separated with bunds of 30 cm height and width and irrigation channels of 60 cm width were provided alternatively. Each experimental plot was of 5 m x 4 m size, on the whole there were 27 plots.

3.3.3.3 Application of Manures and Fertilizers

Well decomposed farm yard manure was incorporated at the time of last ploughing. Full dose of phosphorus and potassium were applied to treatments 1 to 8 as basal dose. 20 kg N/ha was applied as basal in treatments 1 to 7 and top dressing of 25 kg N/ha was applied when the LCC value and SPAD value of six out of ten leaves fall below the critical level and soil N status reached to low. Half of the recommended dose of nitrogen was applied as basal, ¼ dose of nitrogen was applied at maximum tillering stage and remaining ¼ was applied at

Plate 4. General View of the Experimental site

Table 2. Fertilizer application pattern in different treatments during crop period

<table>
<tr><th rowspan="3">Treatment</th><th colspan="5">Nutrients applied</th></tr>
<tr><th colspan="3">N (kg/ha)</th><th>P (kg/ha)</th><th>K (kg/ha)</th></tr>
<tr><th>Basal</th><th colspan="2">Top dressing</th><th>Basal only</th><th>Basal only</th></tr>
<tr><td>T_1</td><td rowspan="7">20</td><td rowspan="7" colspan="2">25
(When the readings fell below the critical level)</td><td rowspan="8">45</td><td rowspan="8">45</td></tr>
<tr><td>T_2</td></tr>
<tr><td>T_3</td></tr>
<tr><td>T_4</td></tr>
<tr><td>T_5</td></tr>
<tr><td>T_6</td></tr>
<tr><td>T_7</td></tr>
<tr><td>T_8</td><td>45</td><td>22.5</td><td>22.5</td></tr>
<tr><td>T_9</td><td>-</td><td colspan="2">-</td><td>-</td><td>-</td></tr>
</table>

panicle initiation stage to treatment 8 as per the Package of Practices Recommendations 'Crops' (KAU, 2011). The fertilizer application pattern in different treatments are given in Table 2.

3.3.3.4 Application of Lime

Lime @ 600 kg/ha was applied in two split doses *viz*., just after the second tillage and at tillering stage.

3.3.3.5 Transplanting

Twenty six days old seedlings were transplanted @ 2-3 seedlings per hill at a spacing of 20 cm x 15 cm and a depth of 3-4 cm. Gap filling and thinning were done two weeks after sowing so as to maintain a uniform plant population at two seedlings per plant.

3.3.3.6 Water Management

The water level was maintained at about 2 cm during transplanting. Thereafter the water level was increased gradually to about 5 cm and the water level was maintained at 5 to 10 cm throughout the growth period except when drained for fertilizer application. Water was drained 13 days before harvest. Field bunds were strengthened as and when necessary.

3.3.3.7 Pest and Disease Management

Rice case worm, leaf folder, gundhi bug/earhead bug, brown leaf spot, false smut and blast were the common pests and diseases observed in the plot. The recommended prophylactic measures were taken up to control the pests and diseases.

3.3.3.8 Harvest

The crop was harvested leaving two rows on all sides as border rows. The net plot area was harvested separately, threshed, winnowed and weight of grains and straw from individual plots were recorded.

3.4 OBSERVATIONS

3.4.1 Observations on the Crop

Six sample plants were selected randomly from the net plot area of each plot and tagged. Two rows from all sides of the plot were left as border rows. The following observations were recorded from the sample plants and the mean values worked out.

3.4.1.1 Growth and Growth Attributes (Maximum Tillering, PI, Harvest)

3.4.1.1.1 Plant Height

The plant height was recorded at maximum tillering, panicle initiation and harvest stages using the method described by Gomez (1972). Height of six randomly selected plants from the net plot area was measured from the base of the plant to the tip of the longest leaf at vegetative stage and to the tip of the longest ear head at harvest stage. The mean of the observations was expressed in centimeters.

3.4.1.1.2 Leaf Area Index (LAI)

The leaf area index was calculated at maximum tillering, panicle initiation and harvest stages using the method suggested by Yoshida *et al*. (1976). The maximum length 'l' and width 'w' of all the leaves of the middle tiller of the six sample hills were recorded from all the plots and leaf area index was calculated.

Leaf area of a single leaf = l x w x k

k – adjustment factor (0.75 at maximum tillering, panicle initiation and flowering and 0.67 at harvest stage).

$$\text{LAI} = \frac{\text{Sum of leaf area / hill of 6 hills (cm}^2\text{)}}{\text{Area of land covered by the 6 hills (cm}^2\text{)}}$$

3.4.1.1.3 Days to 50 per cent Flowering

Number of days taken for 50 per cent flowering was recorded.

3.4.1.1.4 Tillers / Hill

Tiller count was taken from six tagged observation hills at maximum tillering, panicle initiation and harvest stages and the mean value was recorded as number of tillers/hill.

3.4.1.1.5 Dry Matter Production (Harvest)

The dry matter production was recorded at harvest stage. From each plot six sample hills were uprooted, separated into grain and straw, dried under shade and later in an oven at 65-70 ^{o}C. The dry weight of each plant was recorded separately as grain, straw and total dry matter production, using an electronic weighing balance and expressed in t/ha.

3.4.1.2 Yield Attributes and Yield

3.4.1.2.1 Productive Tillers / m^2

At harvest, the number of productive tillers was recorded from the six randomly selected sample hills in the net plot area as well as on unit area basis and was expressed as number of productive tillers / m^2.

3.4.1.2.2 Grain Weight / Panicle

Six randomly selected panicles were harvested individually, threshed, cleaned, dried and weighed to express the grain weight in grams per panicle at 14 per cent moisture.

3.4.1.2.3 Filled Grains / Panicle

The number of filled grains per panicle was obtained directly by counting the number of filled grains from six panicles randomly taken from each plot and taking the mean number of grains per panicle.

3.4.1.2.4 Sterility Percentage

The number of filled and unfilled grains per panicle was obtained from six randomly selected panicles separately and chaff percentage was worked out using the following relationship.

$$\text{Sterility percentage (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Number of total grains per panicle}} \times 100$$

3.4.1.2.5 Thousand Grain Weight

One thousand grains were counted from the cleaned and dried produce from each plot and the weight of the grains was recorded in grams.

3.4.1.2.6 Grain Yield

The net plot area was harvested individually, threshed, cleaned, dried and weighed to express the grain yield in t/ha at 14 per cent moisture.

3.4.1.2.7 Straw Yield

The straw harvested from net plot area was dried to constant weight under sun and then weighed to express the straw yield in t/ha.

3.4.1.2.8 Harvest Index (HI)

The harvest index was worked out using the formula suggested by Donald and Hanohlin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.2 Chemical Analysis

3.4.2.1 Soil Analysis

Composite soil samples were collected from the whole plot before starting the experiment and soil samples were collected from each plot separately at the time of harvest to determine the soil reaction, organic carbon, available nitrogen, available phosphorus and available potassium.

3.4.2.1.1 Soil Reaction

The soil reaction was determined using the digital pH meter (Jackson, 1973).

3.4.2.1.2 Organic Carbon

Organic carbon content was determined using the Walkley and Black rapid titration method (Jackson, 1973) and expressed in percentage.

3.4.2.1.3 Available N, P and K Status of Soil Before and After the Crop

Available nitrogen content was determined using the alkaline permanganate method suggested by Subbiah and Asija (1956) and expressed in kg N/ha. Available phosphorus content of the soil was determined by Dickman and Bray's molybdenum blue method using a Spectrophotometer and expressed as kg P_2O_5/ha. Available potassium content was determined in neutral normal ammonium acetate extract, estimated in a Flame Photometer (Jackson, 1973) and expressed in kg K_2O/ha.

3.4.2.2 Plant Analysis

3.4.2.2.1 N, P and K Content

The plant samples and grain samples were dried in an electric hot air oven to constant weight, ground and passed through a 0.5 mm sieve. The required quantity of samples (grain and straw) were weighed out accurately in an electronic balance, subjected to acid extraction before carrying out the chemical analysis and N, P and K content were assessed.

The total nitrogen content was estimated by modified Microkjeldal method (Jackson, 1973). Total phosphorus content was found out using Vanado Molybdo Phosphate Yellow Colour method. The intensity of colour developed was read in Spectrophotometer at a wavelength of 470 nm (Jackson, 1973). Total potassium content in plant was determined using EEL Flame Photometer (Jackson, 1973).

3.4.2.2.2 N, P and K Uptake

The total uptake of nitrogen, phosphorus and potassium by the rice plant at harvest was calculated as the product of nutrient content and the respective plant dry weight and expressed as kg/ha.

3.4.2.2.3 Chlorophyll Content

The chlorophyll content of the leaves of different treatments were analyzed by using DMSO (di methyl sulphoxide) method. 500 mg leaf sample was weighed, cut into small pieces and taken in a test tube. 10 ml DMSO : 80 per cent acetone mixture (1:1) was poured into these test tubes and placed in dark for over night at room temperature. The pigments were extracted into the solution. Chlorophyll content was measured from the leaf extract by a spectrophotometer (Yoshida *et al.,* 1976) and expressed in mg/g.

3.4.3 Computed Parameters

3.4.3.1 Agronomic Efficiency

Agronomic efficiency (AE) was calculated by using the formula, and expressed as kg yield increase per kg nutrient applied (Fageria, 1992).

Agronomic efficiency (AE) = (Y-Yo)/F = RE x PE

Y = crop yield with applied nutrients;

Yo = crop yield with zero fertilizer;

F = fertilizer rate;

RE = recovery efficiency;

PE = physiological efficiency

3.4.3.2 Physiological Efficiency

Physiological efficiency (PE) was worked out by using the formula, and expressed as kg yield increase per kg fertilizer nutrient uptake (Fageria, 1992).

Physiological efficiency (PE) = (Y-Yo)/(U-Uo)

Y = crop yield with applied nutrients;

Yo = crop yield with zero fertilizer;

U = plant nutrient uptake of above ground biomass at physiological maturity;

Uo = plant in uptake with zero fertilizer

3.4.3.3 Apparent Recovery Efficiency

Apparent recovery efficiency (RE) was computed by using the formula, and expressed as kg increase in uptake per kg applied (Fageria, 1992).

Apparent recovery efficiency (RE) = (U-Uo)/F

U = plant nutrient uptake of above ground biomass at physiological maturity;

Uo = plant in uptake with zero fertilizer;

F = fertilizer rate

3.4.3.4 Partial Factor Productivity

Partial factor productivity (PFP) was worked out by using the formula, and expressed as kg yield per kg nutrient applied (Fageria, 1992).

Partial factor productivity (PFP) = Y/F = (Yo/F)+AE

Y = crop yield with applied nutrients;

Yo = crop yield with zero fertilizer;

F = fertilizer rate;

AE = Agronomic efficiency

3.4.3.5 Internal Utilization Efficiency

Internal utilization efficiency (IE) was calculated by using the formula, and expressed as kg yield per kg nutrient uptake (Fageria, 1992).

Internal utilization efficiency (IE) = Y/U

Y = crop yield with applied nutrients;

U = plant nutrient uptake of above ground biomass at physiological maturity

3.4.4 Relation Between SPAD and LCC Values

Functional relationships between SPAD meter readings and LCC readings were worked out using MS Excel (2007) at the maximum tillering and panicle initiation stages.

3.4.5 Economic Analysis

For analyzing the economics of cultivation, net income and benefit cost ratio were determined based on cost of cultivation and prevailing price of the crop produce.

3.4.5.1 Net Income

Net income was computed using the formula,

Net income (Rs/ha) = Gross income – Cost of cultivation

3.4.5.2 Benefit Cost Ratio (BCR)

B:C ratio was calculated using the formula,

$$\text{B:C ratio (BCR)} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.5 STATISTICAL ANALYSIS

The data generated from the experiment were statistically analyzed using Analysis of Variance technique (ANOVA) as applied to Randomized Block Design (Panse and Sukhatme, 1985) and the significance was tested using F test (Snedecor and Cochran, 1967). Wherever the F values were found significant, critical difference was worked out at five per cent and one per cent probability levels. The significance of the control treatments with the other treatment combinations was also tested. The data which required transformation were appropriately transformed and analyzed.

Results

4. RESULTS

A field experiment was conducted at farmer's field to study the technical and economic feasibility of using chlorophyll meter, leaf colour chart and soil testing kit for assessing the crop nitrogen status, to schedule N application in rice based on crop need and to work out the economics. The data recorded from the study was analyzed statistically and the results are presented in this chapter.

4.1 OBSERVATIONS ON CROP

4.1.1 Growth and Growth Attributes

4.1.1.1 Plant Height, cm

The data on the influence of the nitrogen management practices on plant height at different stages of crop growth *viz.* maximum tillering, panicle initiation and harvest are presented in Table 3.

The perusal of the data on plant height revealed significantly influence of nitrogen management practices at different growth stages of the crop *viz.,* maximum tillering, panicle initiation and harvest.

At maximum tillering stage, plant height (76.28 cm) was highest with N application based on soil test value using soil testing kit (T_7) and it was significantly superior to all the other treatments followed by N application at LCC value 5.0 (T_3). Lowest plant height (66.31 cm) was recorded by control (T_9).

At panicle initiation stage, the highest plant height (88.84 cm) was recorded by N application at LCC value 5.0 (T_3) and it was on par with N application based on soil test value using soil testing kit (T_7) followed by N application at LCC value 4.0 (T_2) which was on par with N application at SPAD value 36 (T_6) and KAU package of practices (T_8). The lowest plant height (75.69 cm) was recorded by control (T_9).

Table 3. Effect of nitrogen management practices on plant height, cm

Treatments	Maximum tillering stage	Panicle initiation stage	Harvest stage
T_1	71.21	81.83	110.67
T_2	71.29	86.39	114.25
T_3	75.63	88.84	119.25
T_4	70.53	81.27	110.33
T_5	70.65	80.93	111.09
T_6	70.44	85.47	115.05
T_7	76.28	88.83	120.24
T_8	72.29	85.67	116.13
T_9	66.31	75.69	105.85
SEm (±)	0.166	0.385	0.348
CD(0.05)	0.50	1.15	1.04

Table 4. Effect of nitrogen management practices on Leaf Area Index (LAI)

Treatments	Maximum tillering stage	Panicle initiation stage	Harvest stage
T_1	5.10	4.61	3.95
T_2	5.11	4.79	4.56
T_3	5.92	5.28	4.71
T_4	4.82	4.27	3.70
T_5	5.05	4.60	3.96
T_6	5.07	4.86	4.62
T_7	5.85	5.29	4.77
T_8	5.52	5.03	4.61
T_9	4.57	4.01	3.39
SEm (±)	0.033	0.033	0.023
CD(0.05)	0.10	0.10	0.07

At harvest stage, the highest plant height (120.24 cm) was recorded by N application based on soil test value using soil testing kit (T_7) and it was on par with N application at LCC value 5.0 (T_3). The lowest plant height (105.85 cm) was recorded by control (T_9).

4.1.1.2 Leaf Area Index (LAI)

The data on the influence of the nitrogen management practices on leaf area index revealed significant variation at maximum tillering, panicle initiation and harvest stages (Table 4).

At maximum tillering stage, N application at LCC value 5.0 (T_3) recorded significantly higher leaf area index (5.92) and was on par with N application based on soil test value using soil testing kit (T_7) followed by KAU package of practices (T_8). The lowest leaf area index (4.57) was recorded by control (T_9).

N application based on soil test value using soil testing kit (T_7) recorded significantly higher leaf area index (5.29) at panicle initiation stage and was on par with N application at LCC value 5.0 (T_3) followed by KAU package of practices (T_8). The lowest leaf area index (4.01) was recorded by control (T_9).

At harvest stage also, N application based on soil test value using soil testing kit (T_7) recorded higher leaf area index (4.77) which was on par with N application at LCC value 5.0 (T_3) and significantly superior to all the other treatments. The lowest leaf area index (3.39) was recorded by control (T_9).

4.1.1.3 Days to 50 per cent Flowering

The results on days to 50 per cent flowering are presented in Table 6. Days to 50 per cent flowering did not vary significantly with the different nitrogen management practices.

4.1.1.4 Tillers/Hill

The number of tillers /hill was significantly influenced by the nitrogen management practices at different growth stages of the crop *viz.,* maximum tillering, panicle initiation and harvest and the results are presented in Table 5.

N application based on soil test value using soil testing kit (T_7) recorded significantly higher number of tillers/hill (22.47) at maximum tillering stage and was on par with N application at LCC value 5.0 (T_3) followed by KAU package of practices (T_8). The lowest tiller number (15.13) was recorded by control (T_9).

At panicle initiation stage also, the highest tiller number (20.27) was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) followed by KAU package of practices (T_8) which was on par with N application at SPAD value 36 (T_6) and N application at LCC value 4.0 (T_2). The lowest tiller number (13.47) was recorded by control (T_9).

At harvest stage, N application at LCC value 5.0 (T_3) recorded significantly higher number of tillers/hill (17.87) and was on par with N application based on soil test value using soil testing kit (T_7) followed by KAU package of practices (T_8) which remained at par with N application at SPAD value 36 (T_6) and N application at LCC value 4.0 (T_2). The lowest tiller number (12.33) was recorded by control (T_9).

4.1.1.5 Dry Matter Production

The results on dry matter production at harvest stage are presented in Table 6. The dry matter production varied significantly between the treatments.

The highest dry matter production (21.33 t/ha) was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) followed by N application at SPAD value 36

Table 5. Effect of nitrogen management practices on number of tillers/hill

Treatments	Maximum tillering stage	Panicle initiation stage	Harvest stage
T_1	18.00	16.27	14.53
T_2	18.40	17.00	15.40
T_3	22.33	20.20	17.87
T_4	18.40	16.40	14.13
T_5	18.47	16.67	14.73
T_6	18.60	17.07	15.47
T_7	22.47	20.27	17.80
T_8	19.40	17.53	15.80
T_9	15.13	13.47	12.33
SEm (±)	0.256	0.197	0.196
CD(0.05)	0.77	0.59	0.59

Table 6. Effect of nitrogen management practices on days to 50 per cent flowering and dry matter production

Treatments	Days to 50 per cent flowering (in DAT)	Dry matter production (t/ha)
T_1	74	18.19
T_2	75	19. 33
T_3	75	21.04
T_4	74	18.18
T_5	74	18.55
T_6	75	19.60
T_7	75	21.33
T_8	75	19.35
T_9	74	17.68
SEm (±)	-	0.272
CD(0.05)	-	0.817

(T_6) which was on par with N application at LCC value 4.0 (T_2) and KAU package of practices (T_8). The lowest dry matter production (17.68 t/ha) was recorded by control (T_9).

4.1.2 Yield Attributes and Yield

4.1.2.1 Productive Tillers/m²

The data on the effect of nitrogen management practices on number of productive tillers/m^2 at harvest stage are presented in Table 7. Productive tiller count was significantly influenced by the treatments.

The results revealed that the highest number of productive tillers/m^2 (508.87) was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) followed by KAU package of practices (T_8) which was on par with N application at LCC value 4.0 (T_2) and N application at SPAD value 36 (T_6). The lowest productive tiller number (330.33) was recorded by control (T_9).

4.1.2.2 Grain Weight/Panicle

The results pertaining to grain weight/panicle are presented in Table 7. Data on grain weight/panicle showed that nitrogen management practices had no significant impact.

4.1.2.3 Filled Grains/Panicle

The results on the number of filled grains/panicle as influenced by different nitrogen management practices are presented in Table 8. The results indicated that there was no significant effect for the different nitrogen management practices on filled grains/panicle.

Table 7. Effect of nitrogen management practices on productive tillers/m^2 and grain weight/panicle

Treatments	Productive tillers/m^2	Grain weight/panicle (g)
T_1	422.13	3.397
T_2	451.13	4.383
T_3	506.60	3.810
T_4	402.00	3.943
T_5	420.00	3.593
T_6	451.07	4.013
T_7	508.87	3.917
T_8	453.33	3.957
T_9	330.33	3.027
SEm (±)	4.446	0.426
CD(0.05)	13.331	NS

Table 8. Effect of nitrogen management practices on filled grains/panicle, sterility percentage and thousand grain weight

Treatments	Filled grains/panicle	Sterility percentage	Thousand grain weight (g)
T_1	116.00	30.62	25.50
T_2	132.33	25.58	26.17
T_3	127.33	33.80	26.17
T_4	115.33	28.58	25.50
T_5	114.33	30.19	25.83
T_6	132.00	26.84	26.67
T_7	129.00	32.65	26.00
T_8	131.67	26.71	26.17
T_9	109.67	23.03	25.33
SEm (±)	8.166	2.124	0.225
CD(0.05)	NS	NS	0.674

4.1.2.4 Sterility Percentage

The data on the effect of nitrogen management practices on sterility percentage, presented in Table 8 revealed that the effect of the treatments on sterility percentage was not significant.

4.1.2.5 Thousand Grain Weight

The thousand grain weight was found to vary significantly with nitrogen management practices, and the results are presented in Table 8.

N application at SPAD value 36 (T_6) recorded the highest thousand grain weight (26.67 g) and was on par with N application at LCC value 4.0 (T_2), N application at LCC value 5.0 (T_3), N application based on soil test value using soil testing kit (T_7) and KAU package of practices (T_8). The value was lowest (25.33 g) in control (T_9).

4.1.2.6 Grain Yield

The results on grain yield as influenced by the nitrogen management practices are presented in Table 9.

The results indicated that the grain yield was significantly influenced by the various nitrogen management practices. Grain yield recorded was the highest (7.94 t/ha) under N application at SPAD value 36 (T_6) and was on par with N application at LCC value 4.0 (T_2), N application based on soil test value using soil testing kit (T_7) and KAU package of practices (T_8). The lowest grain yield (5.95 t/ha) was recorded by control (T_9).

4.1.2.7 Straw Yield

The data on straw yield as influenced by the nitrogen management practices are presented in Table 9.

Table 9. Effect of nitrogen management practices on grain yield, straw yield and harvest index

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
T_1	6.15	11.76	0.342
T_2	7.74	11.45	0.403
T_3	7.34	13.52	0.352
T_4	6.05	11.83	0.338
T_5	6.25	12.04	0.341
T_6	7.94	11.66	0.405
T_7	7.54	13.73	0.354
T_8	7.64	11.55	0.398
T_9	5.95	10.99	0.351
SEm (±)	0.148	0.191	0.003
CD(0.05)	0.444	0.574	0.010

Table 10. Effect of nitrogen management practices on soil reaction and organic carbon content at the time of harvest

Treatments	Soil reaction	Organic carbon (%)
T_1	4.33	2.17
T_2	4.51	2.31
T_3	4.30	2.54
T_4	4.36	2.34
T_5	4.32	2.30
T_6	4.41	2.31
T_7	4.41	2.16
T_8	4.31	2.69
T_9	4.41	2.45
SEm (±)	0.073	0.074
CD(0.05)	NS	0.223

Among all the treatments, N application based on soil test value using soil testing kit (T_7) recorded significantly higher straw yield (13.73 t/ha) and it was on par with N application at LCC value 5.0 (T_3). The lowest straw yield (10.99 t/ha) was registered by control (T_9).

4.1.2.8 Harvest Index

The data summarized in Table 9 showed that the different nitrogen management practices had significant effect on harvest index. The highest harvest index (0.405) was recorded with N application at SPAD value 36 (T_6) and was on par with N application at LCC value 4.0 (T_2) and KAU package of practices (T_8). The lowest harvest index (0.338) was recorded by N application at SPAD value 32 (T_4).

4.2 CHEMICAL ANALYSIS

4.2.1 Soil Analysis

The fertility status of the soil at the time of harvest was assessed by measuring the soil parameters *viz.,* soil reaction, organic carbon, available nitrogen, available phosphorus and available potassium.

4.2.1.1 Soil Reaction

The data on the soil reaction are presented in Table 10. The nitrogen management practices had no significant effect on soil reaction.

4.2.1.2 Organic Carbon

The data on the soil organic carbon content are presented in Table 10. The perusal of the data showed that the nitrogen management practices had significant effect on soil organic carbon content. KAU package of practices (T_8) recorded highest organic carbon content (2.69 %) and was on par with N application at LCC value 5.0 (T_3).

4.2.1.3 Available N, P and K Status of Soil After the Crop

The data on available nitrogen, available phosphorus and available potassium of the soil after the experiment are presented in Table 11.

There was no significant for the different nitrogen management practices on the available nitrogen, phosphorus and potassium status of the soil.

4.2.2 Plant Analysis

4.2.2.1 N, P and K Contents

4.2.2.1.1 N, P and K Contents in Grain

The data on the N, P and K contents of grain are presented in Table 12. Nitrogen management practices had significantly influenced the N, P and K contents of the grain.

N application based on soil test value using soil testing kit (T_7) recorded significantly higher nitrogen content of 1.648 per cent in grain and was on par with N application at LCC value 5.0 (T_3) and N application at LCC value 4.0 (T_2) followed by N application at SPAD value 36 (T_6) which was on par with KAU package of practices (T_8). The lowest grain nitrogen content (1.244 %) was recorded by the control (T_9).

The phosphorus content in grain was significantly higher in treatment receiving N based on soil test value using soil testing kit (T_7) (0.202 %) and was on par with N application at LCC value 5.0 (T_3) followed by N application at LCC value 4.0 (T_2) which was on par with KAU package of practices (T_8) and N application at SPAD value 36 (T_6). The lowest phosphorus content in grain (0.144 %) was recorded by control (T_9).

The highest potassium content (0.196 %) in grain was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with

Table 11. Effect of nitrogen management practices on available nutrient status of soil at the time of harvest, kg/ha

Treatments	Available nitrogen	Available phosphorus	Available potassium
T_1	301.05	64.28	150.84
T_2	334.50	56.31	131.57
T_3	347.05	56.31	128.12
T_4	321.96	67.93	146.31
T_5	334.50	63.60	151.96
T_6	338.68	57.90	132.96
T_7	342.87	56.31	125.66
T_8	334.50	56.76	127.18
T_9	313.60	69.30	173.28
SEm (±)	12.708	2.907	9.403
CD(0.05)	NS	NS	NS

Table 12. Effect of nitrogen management practices on N, P and K contents in grain, %

Treatments	Nitrogen	Phosphorus	Potassium
T_1	1.399	0.163	0.147
T_2	1.555	0.182	0.175
T_3	1.617	0.200	0.194
T_4	1.368	0.163	0.148
T_5	1.337	0.161	0.144
T_6	1.524	0.181	0.169
T_7	1.648	0.202	0.196
T_8	1.493	0.182	0.175
T_9	1.244	0.144	0.121
SEm (±)	0.038	0.003	0.006
CD(0.05)	0.114	0.010	0.018

N application at LCC value 5.0 (T_3) followed by N application at LCC value 4.0 (T_2) which was on par with KAU package of practices (T_8) and N application at SPAD value 36 (T_6). The lowest potassium content in grain (0.121 %) was recorded by control (T_9).

4.2.2.1.2 N, P and K Contents in Straw

The data on the N, P and K contents of straw are presented in Table 13. Nitrogen management practices significantly influenced the N, P and K contents of the straw.

N application based on soil test value using soil testing kit (T_7) recorded significantly highest nitrogen content of 1.182 per cent in straw and was on par with N application at LCC value 5.0 (T_3) followed by N application at LCC value 4.0 (T_2) which was on par with N application at SPAD value 36 (T_6) and KAU package of practices (T_8). The lowest nitrogen content in straw (0.777 per cent) was recorded by control (T_9).

The phosphorus content (0.272 %) in straw was significantly higher in N application at LCC value 5.0 (T_3) and was on par with N application based on soil test value using soil testing kit (T_7) followed by N application at SPAD value 36 (T_6) which was on par with N application at LCC value 4.0 (T_2) and KAU package of practices (T_8). The lowest phosphorus content in straw (0.171 %) was recorded by control (T_9).

The highest potassium content (1.940 %) in straw was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) and KAU package of practices (T_8) followed by N application at SPAD value 36 (T_6) which was on par with N application at LCC value 4.0 (T_2). The lowest potassium content in straw (1.333 %) was recorded by control (T_9).

Table 13. Effect of nitrogen management practices on N, P and K contents in straw, %

Treatments	Nitrogen	Phosphorus	Potassium
T_1	0.850	0.206	1.637
T_2	0.995	0.249	1.803
T_3	1.151	0.272	1.933
T_4	0.808	0.199	1.633
T_5	0.839	0.201	1.647
T_6	0.995	0.250	1.807
T_7	1.182	0.270	1.940
T_8	0.964	0.245	1.903
T_9	0.777	0.171	1.333
SEm (±)	0.046	0.005	0.021
CD(0.05)	0.139	0.014	0.063

Table 14. Effect of nitrogen management practices on N, P and K uptake, kg/ha

Treatments	Nitrogen uptake	Phosphorus uptake	Potassium uptake
T_1	188.29	34.21	201.59
T_2	234.33	42.58	220.03
T_3	274.59	51.44	275.70
T_4	178.07	33.45	202.40
T_5	184.36	34.28	207.40
T_6	236.95	43.52	224.01
T_7	286.33	52.30	281.02
T_8	225.53	42.15	233.24
T_9	154.59	27.40	154.04
SEm (±)	6.941	0.938	5.560
CD(0.05)	20.810	2.812	16.668

4.2.2.2 N, P and K Uptake

The data on N, P and K uptake are presented in Table 14. The results revealed that the nitrogen management practices had significant effect on N, P and K uptake.

Higher nitrogen uptake (286.33 kg/ha) was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) followed by N application at SPAD value 36 (T_6) which was on par with N application at LCC value 4.0 (T_2) and KAU package of practices (T_8). The lowest nitrogen uptake (154.59 kg/ha) was recorded by control (T_9).

N application based on soil test value using soil testing kit (T_7) recorded significantly higher phosphorus uptake of 52.30 kg/ha and was on par with N application at LCC value 5.0 (T_3) followed by N application at SPAD value 36 (T_6) which was on par with N application at LCC value 4.0 (T_2) and KAU package of practices (T_8). The lowest phosphorus uptake (27.40 kg/ha) was recorded by control (T_9).

The potassium uptake (281.02 kg/ha) was significantly higher in N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) followed by KAU package of practices (T_8) which was on par with N application at SPAD value 36 (T_6) and N application at LCC value 4.0 (T_2). The lowest potassium uptake (154.04 kg/ha) was recorded by control (T_9).

4.2.2.3 Chlorophyll Content

The data pertaining to chlorophyll content are presented in Table 15. Data showed that nitrogen management practices had no significant impact on chlorophyll a. But chlorophyll b and total chlorophyll were significantly influenced with different nitrogen management practices.

Table 15. Effect of nitrogen management practices on chlorophyll content, mg/g

Treatments	Chlorophyll a	Chlorophyll b	Total Chlorophyll
T_1	0.436	0.671	1.105
T_2	0.432	0.732	1.165
T_3	0.426	0.854	1.279
T_4	0.432	0.682	1.114
T_5	0.432	0.723	1.152
T_6	0.429	0.741	1.170
T_7	0.428	0.852	1.280
T_8	0.426	0.788	1.213
T_9	0.435	0.512	0.948
SEm (±)	0.002	0.024	0.035
CD(0.05)	NS	0.072	0.104

Table 16. Effect of nitrogen management practices on agronomic efficiency, physiological efficiency, apparent recovery efficiency

Treatments	Agronomic efficiency (kg/kg N applied)	Physiological efficiency (kg/kg N uptake)	Apparent recovery efficiency (%)
T_1	4.409	8.862	0.749
T_2	25.514	24.029	1.154
T_3	9.582	11.987	0.828
T_4	2.208	17.462	0.522
T_5	6.647	21.540	0.661
T_6	28.345	25.173	1.162
T_7	10.947	12.300	0.808
T_8	18.76	23.873	0.843
T_9	0	0	0
SEm (±)	2.977	8.95	0.103
CD(0.05)	8.927	NS	0.31

N application at LCC value 5.0 (T_3) recorded significantly higher chlorophyll b (0.854 mg/g) and was on par with N application based on soil test value using soil testing kit (T_7) and KAU package of practices (T_8). The lowest chlorophyll b (0.512 mg/g) was recorded by control (T_9).

The highest total chlorophyll (1.28 mg/g) was recorded by N application based on soil test value using soil testing kit (T_7) and was on par with N application at LCC value 5.0 (T_3) and KAU package of practices (T_8). The lowest total chlorophyll content (0.948 mg/g) was recorded by control (T_9).

4.3 COMPUTED PARAMETERS

Computed parameters are worked out to find the use efficiency of the applied nutrients and nutrients taken up by the crop.

4.3.1 Agronomic Efficiency

The data on the effect of different nitrogen management practices on agronomic efficiency are presented in Table 16.

The threshold value of SPAD 36 (T_6) recorded the highest (28.35 kg/kg N applied) agronomic efficiency of applied fertilizer N followed by LCC value 4.0 (T_2). The lowest agronomic efficiency (2.21 kg/kg N applied) was recorded by control (T_9).

4.3.2 Physiological Efficiency

The data on physiological efficiency are presented in Table 16.

N application at SPAD value 36 (T_6) recorded the highest (25.17 kg/kg N uptake) physiological efficiency followed by N application at LCC value 4.0 (T_2). The lowest (8.86 kg/kg N uptake) physiological efficiency was recorded by N application at LCC value 3.0 (T_1).

4.3.3 Apparent Recovery Efficiency

The data on apparent recovery efficiency are presented in Table 16.

N application at SPAD value 36 (T_6) recorded the highest (1.16 %) apparent recovery efficiency followed by N application at LCC value 4.0 (T_2). The lowest (0.52 %) apparent recovery efficiency was recorded by N application at SPAD value 32 (T_4).

4.3.4 Partial Factor Productivity

The data on the effect of different nitrogen management practices on partial factor productivity are presented in Table 17.

N application at SPAD value 34 (T_5) recorded the highest (138.88 kg/kg N applied) partial factor productivity followed by N application at LCC value 3.0 (T_1). The lowest (50.63 kg/kg N applied) partial factor productivity was recorded by N application at LCC value 5.0 (T_3).

4.3.5 Internal Utilization Efficiency

The data on internal utilization efficiency was presented in Table 17.

Absolute control (T_9) was recorded the highest (38.85 kg/kg N uptake) internal utilization efficiency followed by N application at SPAD value 32 (T_4).

The lowest (26.33 kg/kg N uptake) internal utilization efficiency was recorded by N application based on soil test value using soil testing kit (T_7).

4.4 RELATION BETWEEN SPAD AND LCC VALUES

The relationship between SPAD values and LCC values was found to be linear at both stages *viz,.* maximum tillering stage and panicle initiation stage. At both stages LCC- 3 coincided with SPAD- 32, LCC- 4 with SPAD- 36 and LCC-5

Table 17. Effect of nitrogen management practices on partial factor productivity, internal utilization efficiency

Treatments	Partial factor productivity (kg/kg N applied)	Internal utilization efficiency (kg/kg N uptake)
T_1	136.673	33.717
T_2	110.540	32.913
T_3	50.627	26.803
T_4	134.473	34.017
T_5	138.880	33.980
T_6	113.373	33.670
T_7	51.993	26.330
T_8	84.877	33.453
T_9	0	38.850
SEm (±)	2.453	1.563
CD(0.05)	7.355	4.686

Table 18. Effect of nitrogen management practices on economics

Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit cost ratio
T_1	94826	139830	45004	1.47
T_2	96358	165930	69572	1.72
T_3	100962	165340	64378	1.64
T_4	94826	138340	43514	1.46
T_5	94826	142370	47544	1.50
T_6	96358	169760	73402	1.76
T_7	100962	169870	68908	1.68
T_8	96710	164530	67820	1.70
T_9	92942	134120	41178	1.44

with SPAD- 40. As far as the when yield is correlated with LCC and SPAD it was found that highest yield was recorded with LCC- 4 and SPAD- 36. From the figure also it was evident that LCC- 3 coincided with SPAD- 32, LCC- 4 with SPAD- 36 and LCC- 5 with SPAD- 40.

4.5 ECONOMIC ANALYSIS

4.5.1 Net Income

The perusal of data on net returns are presented in Table 18.

The highest net returns (Rs.73402 per ha) was recorded by N application at SPAD value 36 (T_6) followed by LCC value 4.0 (T_2). The lowest net returns (Rs.41178 per ha) was recorded by control (T_9).

4.5.2 Benefit Cost Ratio

The data presented in Table 18, showed that the benefit cost ratio varied with different nitrogen management practices.

The highest benefit cost ratio (1.76) was recorded by N application at SPAD value 36 (T_6) followed by LCC value 4.0 (T_2). The lowest benefit cost ratio (1.44) was recorded by control (T_9).

Discussion

5. DISCUSSION

The results of the field experiment entitled "Need based nitrogen management in rice (*Oryza sativa* L.) using diagnostic tools" at farmer's field, Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state during the *Virippu* season (first crop season), 2013, presented in the previous chapter, are briefly discussed in this chapter.

5.1 INFLUENCE OF NITROGEN MANAGEMENT PRACTICES ON CROP GROWTH CHARACTERS

Nutrient management is a major component of soil and crop management system. Knowing the required nutrients for all growth stages and understanding the soil's ability to supply those needed nutrients are critical for profitable crop production. Data presented in tables 3 to 6 showed that different nitrogen management practices had significant effect on growth characters of rice.

Plant height increased progressively with the growth of the crop. Plant height was highest with N application based on soil test value using soil testing kit (T_7) at maximum tillering and harvest stages. However, at panicle initiation stage N application at LCC value 5.0 (T_3) recorded highest plant height. The increase in plant height in treatments T_7 and T_3 might be due to the increased level of N fertilization (145 kg/ha) as compared to other treatments (Table 19). The higher level of N might have encouraged the carbohydrate synthesis which in turn resulted in the taller plants. Balasubramanian *et al.* (1999) also noticed increase in plant height with application of 20 kg N/ha as basal and SPAD based N application.

Leaf area index (LAI) was found to increase up to maximum tillering and decreased later. This could be due to the senescence of leaves after the vegetative phase. Leaf area index was significantly higher with N application LCC value 5.0 (T_3) during maximum tillering stage, whereas it was significantly higher when N was applied based on soil test value using soil testing kit (T_7) at panicle initiation and harvest stage. The higher application of N (145 kg/ha) in treatments T_3 and T_7 might have resulted in more protein synthesis and meristematic growth through hormonal synthesis. Application of N in more number of splits might be responsible for retaining more number of active leaves till the harvest in the above treatments. Singh and Ghosh (1990) observed that the number of tillers/m^2 and LAI was reduced at fifty per cent recommended fertilizer dose as compared to full dose of recommended fertilizer.

Nitrogen management practices had no significant effect on days to 50 per cent flowering. However, the treatments which received lower quantities of nitrogen (LCC-3, SPAD-32, SPAD-34 and control) came to flowering earlier than the treatments which received higher quantities of nitrogen (LCC-4, LCC-5, SPAD-36, soil test kit and KAU POP).

Number of tillers increased up to maximum tillering stage and there after a decrease was observed which could be due to the senescence of the secondary tillers. Irrespective of the crop growth stage, the number of tillers varied in accordance with the quantity of nitrogen applied, higher tiller count being recorded in treatments receiving higher quantity of nitrogen. The number of tillers per hill was significantly more with N application based on soil test value using soil testing kit (T_7) during maximum tillering stage and panicle initiation stage. At harvest, N application at LCC value 5.0 (T_3) recorded more number of tillers per hill. The higher application of nitrogen in treatments T_3 and T_7 (145 kg N/ha) as per crop need at different crop growth intervals might have helped in better utilization of nitrogen for growth and development. Munda (1989) and Jayanthi (2007a) observed higher number of tillers with higher dose of N application.

The dry matter production increased significantly with increase in N fertilization. The highest dry matter production was recorded by N application based on soil test value using soil testing kit (T_7) and N application at LCC value

5.0 (T_3) mainly due to higher straw yield. Treatments T_7 and T_3 which received N in higher quantities (145 kg N/ha) with more number of splits @ 25 kg/ha recorded significantly higher dry matter production compared to other treatments. This could be due to higher photosynthetic area, better interception of solar radiation and presence of photosynthetically active leaves for longer time as evidenced by significantly higher LAI in these treatments. The results are in agreement with the findings of Jayanthi *et al.* (2007a).

5.2 INFLUENCE OF NITROGEN MANAGEMENT PRACTICES ON YIELD ATTRIBUTES AND YIELD

Nitrogen management practices significantly influenced the productive tiller count and thousand grain weight. But the grain weight/panicle, filled grains/panicle and sterility percentage were not affected significantly by nitrogen management practices.

All the yield parameters and grain yield were favorably influenced when N was applied at higher rate using diagnostic tools.

Data depicted in Table 7 revealed that the highest number of productive tillers was recorded by N application based on soil test value (T_7) and was on par with N application at LCC-5 (T_3) treatments which received higher quantity of N (145 kg/ha) followed by KAU POP (T_8) which received 90 kg/ha in 3 splits and was on par with N application at LCC-4 (T_2) and SPAD-36 (T_6) which received 70 kg/ha. Adequate N supply during reproductive growth phase may probably be responsible in enhancing yield parameters and in turn the yield.

As far as thousand grain weight is concerned, N application at SPAD-36 (T_6) recorded highest thousand grain weight (26.67 g) and was on par with LCC-4 (T_2), LCC-5 (T_3), soil test value based N application (T_7) and KAU POP (T_8). Lower thousand grain weight in treatments *i.e.,* N application at LCC-3, SPAD-32 and SPAD-34, which received only 45 kg/ha could be attributed to the inadequate N to meet the crop needs.

Grain yield was higher with N application at SPAD-36 (T_6) and was on par with LCC-4.0 (T_2), soil test value based N application (T_7), and KAU POP (T_8). From Table 9 it can be deciphered that grain yield was highest in N application at SPAD-36 (T_6) (7.94 t/ha) and was on par with LCC-4.0 (T_2) (7.74 t/ha), KAU POP (T_8) (7.64 t/ha) and soil test value based N application (T_7) (7.54 t/ha). It was obviously due to the favourable nutrition resulting in higher number of productive tillers/m^2 and thousand grain weight. Furthermore, the application of N at threshold values SPAD- 36 and LCC- 4 mainly coincided with critical growth stages like maximum tillering and panicle initiation stages.

Data presented in Table 9 and Fig 5 revealed that when the LCC critical value is increased from 3 to 4, an yield increase of 25.85 per cent was obtained where as when LCC value is increased from 4 to 5 a slight reduction in yield was noticed. As far as SPAD critical value is concerned, SPAD-36 recorded 31.24 per cent increase in yield over SPAD- 32 and 27.04 per cent yield increase over SPAD- 34. In SPAD- 34 nitrogen was applied after 60 DAT based on crop demand and that might be the reason for the slight increase in yield in SPAD- 34 over SPAD- 32. In SPAD- 32 nitrogen was applied after 70 DAT, plant might have suffered for want of N at the critical stages of crop growth, hence the yield reduction.

In the case of N application based on soil test value using soil testing kit (T_7), the increase in yield was due to highest number of productive tillers/m^2 and similar trend was observed in N application at LCC- 5.0 (T_3) also. The grain yield with SPAD- 36 and LCC- 4 which received 70 kg N/ha were on par with KAU POP (when N was applied @ 90 kg/ha in 3 splits). Hence a saving of 20 kg N/ha was achieved compared to KAU POP. In Kerala rice is being cultivated in a area of 2.08 lakh ha. About 50 per cent of the area in Kerala is under high yielding variety cultivation. Hence nearly 20.8 lakh kg N can be saved, ultimately result in less consumption of chemical fertilizers. Kenchaiah *et al*. (2000) also found higher grain yield under LCC based N management than the blanket recommendation. However, in LCC- 3, SPAD- 32 and SPAD- 34, the amount of

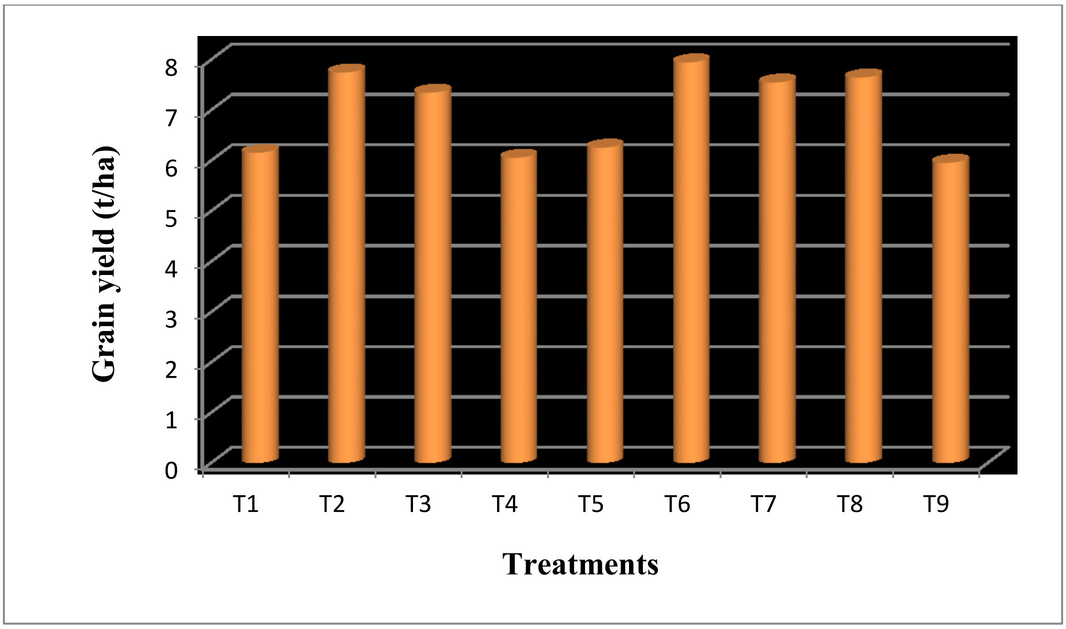

Fig 5. Effect of nitrogen management practices on grain yield

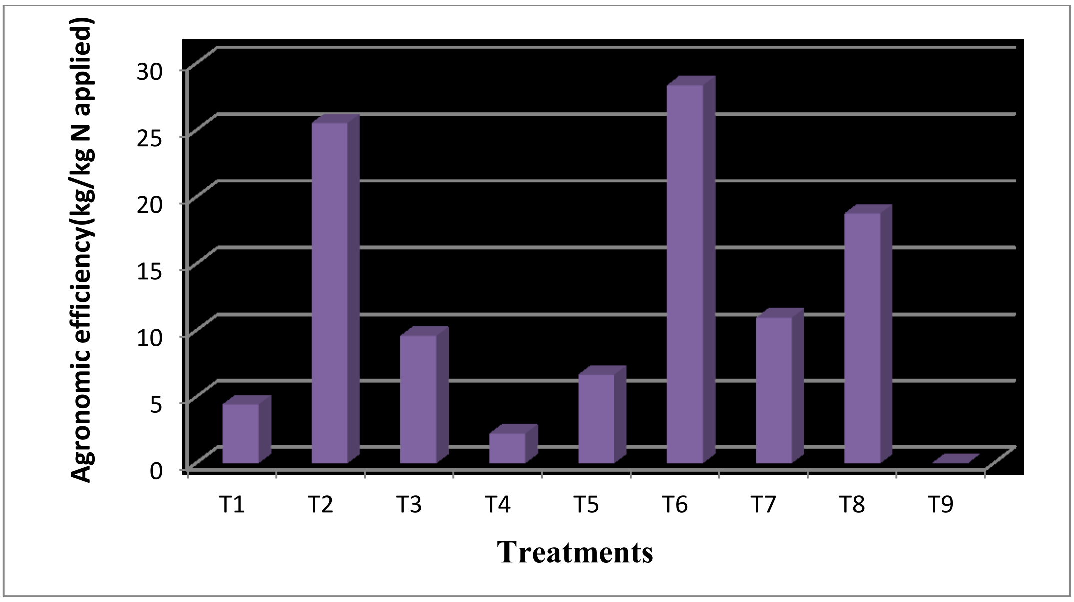

Fig 6. Effect of nitrogen management practices on agronomic efficiency

N applied was less (45 kg N/ha) and plant might have suffered for want of N at the critical stages of crop growth. Similarly, Angadi *et al.* (1999), recorded higher grain yield in rice variety Abhilash at a higher LCC threshold of 5 than the recommended practice in rice. Peng *et al.* (1996) reported 8.4 per cent increase in rice grain yield in SPAD based N management compared to farmer's method. The results are in line with the findings of Kumar *et al.* (1999), Subbaiah *et al.* (1999), Porpavai *et al.* (2000), Mohandas *et al.* (2003) and Ravi *et al.* (2007).

The straw yield was higher with LCC- 5 and soil test based N application. This might be probably due to the application of higher amounts of nitrogen (145 kg/ha) in these two treatments which encouraged higher vegetative growth and hence higher straw yield. This was attributed to their favourable influence on vegetative growth rather than on grain yield.

The highest harvest index (0.405 and 0.403 respectively) was recorded by N application at SPAD- 36 (T_6) and at LCC- 4.0 (T_2). The harvest index increased with increasing N rates up to 70 kg/ha in LCC based and SPAD based nitrogen application. Jayanthi *et al.* (2007b) reported that the harvest index favourably increased with increasing N rates in LCC based nitrogen application. Similar results were also reported by Peng *et al.* (1996) in LCC based N management in rice.

5.3 NITROGEN USE EFFICIENCY

Nutrient use efficiency can be expressed several ways. Mosier *et al.* (2004) described 4 agronomic indices commonly used to describe nutrient use efficiency: partial factor productivity (PFP, kg crop yield per kg nutrient applied); agronomic efficiency (AE, kg crop yield increase per kg nutrient applied); apparent recovery efficiency (RE, kg nutrient taken up per kg nutrient applied); and physiological efficiency (PE, kg yield increase per kg nutrient taken up).

Nitrogen use efficiency (NUE) is dependent to a large extent on the synchronization between crop nitrogen demand and the available N supply (Singh *et al*., 2006). Furthermore, it depends on the total amount of N application. The total nitrogen applied with LCC- 3, SPAD- 32 and SPAD- 34 was only 45 kg/ha, whereas in the case of LCC- 4 and SPAD- 36 it was 70 kg/ha, and it was 145 kg/ha with LCC- 5 and soil test based N application. However, under KAU package of practices it was 90 kg/ha, applied in 3 splits.

NUE decreased with increase in LCC values as well as SPAD values. NUE was significantly higher with N-management by LCC- 3 compared to LCC- 4 and LCC- 5. Similar trend was noticed with SPAD meter also with SPAD- 32 recording higher NUE than SPAD- 34 and SPAD- 36. Singh *et al.* (2006) reported that the higher fertilizer N-use efficiency was recorded with need-based N management using LCC- 3 rather than LCC- 4 as critical colour shade. This study suggested that to obtain high N-use efficiency, fertilizer N application should be guided by LCC- 3. The increase in NUE using LCC resulted from better synchronization of timing of fertilizer N applications and the crop's needs for N fertilizer (Singh *et al.,* 2007a; Balaji and Jawahar 2007). Nitrogen losses from the soil-plant system are large, leading to low fertilizer N-use efficiency when N application is not synchronized with crop demand (Singh *et al*., 2002).

The decreased NUE with increasing amounts of N applied can be attributed to relatively less improvement in tonnage in presence of higher nutrient supplementation beyond certain level as generally observed in all nutrients (law of diminishing returns) (Bock and Hergert, 1991). Improving nutrient efficiency is an appropriate goal for all involved in agriculture, and the fertilizer industry, with the help of scientists and agronomists, is helping farmers work towards that end. However, effectiveness cannot be sacrificed for the sake of efficiency. Much higher nutrient efficiencies could be achieved simply by sacrificing yield, but that would not be economic.

The critical value of LCC- 4 and SPAD- 36 recorded the highest agronomic, physiological and recovery efficiency of nitrogen. Peng *et al*. (1996) reported increased agronomic efficiency of applied N (AEN) by SPAD based N management compared to farmers' practice. Kumar *et al*. (1999) observed higher AEN in SPAD based N management. Higher NUE was also reported by Subbaiah *et al*. (1999), Kenchaiah *et al*. (2000) and Balasubramanian *et al*. (2002) in rice.

Improving nutrient efficiency is a worthy goal and fundamental challenge facing the fertilizer industry, and agriculture in general. The opportunities are there and tools are available to accomplish the task of improving the efficiency of applied nutrients. However, we must be cautious that improvements in efficiency do not come at the expense of the farmer's economic viability or the environment. Judicious application of fertilizer, best management practices; right rate, right time, right place, targeting both high yields and nutrient efficiency will benefit farmers, society, and the environment alike.

5.4 RELATION BETWEEN SPAD AND LCC VALUES

Data presented in Table 9 and Fig 7 revealed that when LCC critical value increased from 3 to 4, an yield increase of 25.85 per cent was obtained where as when LCC value increased from 4 to 5 a reduction in yield was noticed probably due to high sterility percentage. As far as SPAD critical value is concerned, SPAD- 36 recorded 31.24 per cent increase in yield over SPAD- 32 and 27.04 per cent yield increase over SPAD- 34. In SPAD- 34, nitrogen was applied only after 60 DAT based on crop demand and that might be the reason for the slight increase in yield in SPAD- 34 over SPAD- 32. In SPAD- 32 nitrogen was applied only after 70 DAT, hence the yield reduction. Fig 3 and 4 clearly showed the relation between SPAD and LCC. LCC-3 coincided with SPAD- 32, LCC- 4 with SPAD- 36 and LCC- 5 with SPAD- 40. In rice variety Uma, SPAD- 36 gave higher grain yield and it coincided with LCC- 4. From the economic point also the same trend was noticed. Since SPAD/ chlorophyll meter is expensive, farmer can use LCC as a cheap and simple diagnostic tool for N scheduling in rice, based on crop demand.

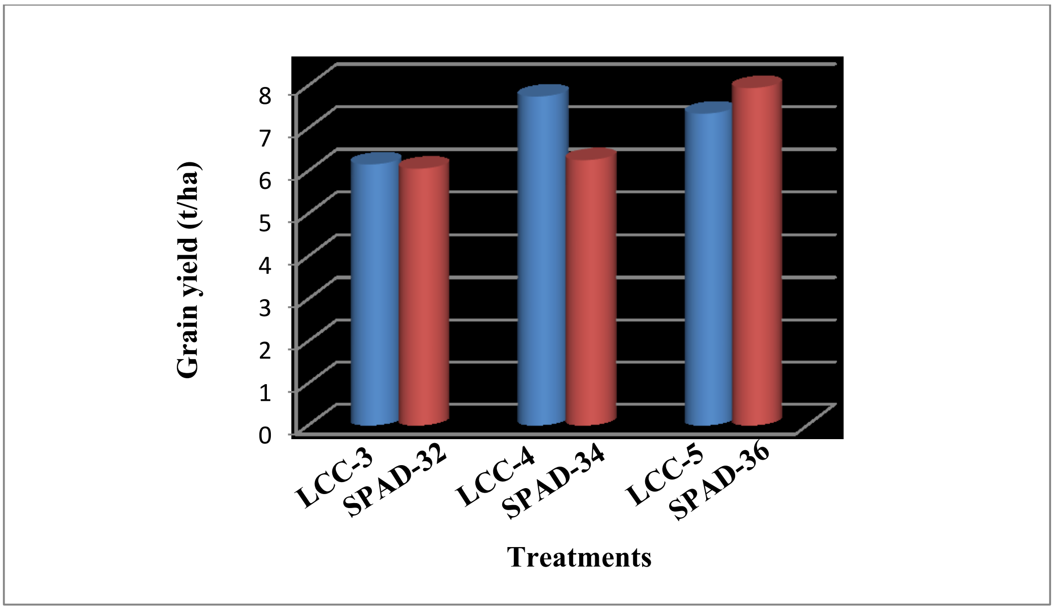

Fig 7. Relation between LCC and SPAD values in relation to grain yield

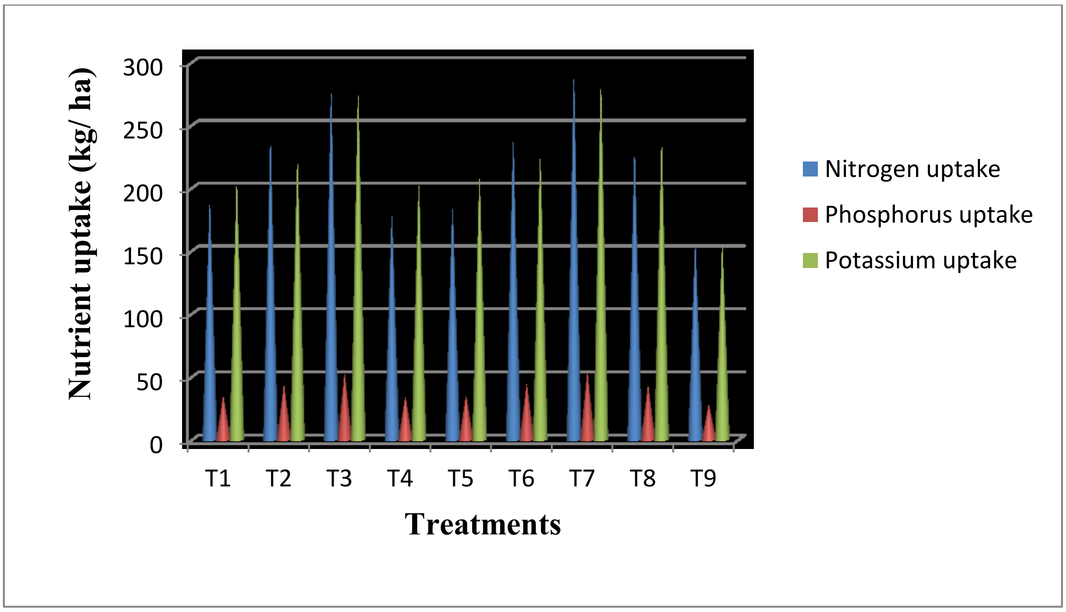

Fig 8. Effect of nitrogen management practices on N, P and K uptake

5.5 NITROGEN UPTAKE

Uptake of nutrients is associated with the metabolic activities of plants, the concentration of the nutrients, dry matter production and distribution of ions in the external medium. Nutrient removal is a function of climate, soil properties, amount and method of fertilizer application and the variety of rice (De Datta, 1981) where cultural practices and morphological variations account for differences in nutrient removal. In addition to this dry matter production, yield also governed the nutrient removal.

N application based on soil test value using soil testing kit (T_7) and N application at LCC- 5.0 (T_3) recorded significantly higher N uptake over other treatments. This might be probably due to the higher dry matter production. It was mainly attributed to the application of higher dose of N than RDF and with higher availability of N in soil. Ravi *et al.* (2007) reported that, application of green manure combined with LCC critical value 5 based N applications significantly increased grain yield and nutrient uptake of hybrid rice. Among the LCC and SPAD treatments, N application at LCC value 5.0 (T_3) recorded significantly higher N uptake over LCC- 4 and LCC- 3 and N application at SPAD value 36 (T_6) recorded higher N uptake over SPAD- 34 and SPAD- 32.

The total chlorophyll was increased significantly with increase in N fertilization (Fig 9). This is probably due to higher uptake of N fertilizer.

5.6 NUTRIENT STATUS OF THE SOIL AT THE TIME OF HARVEST

Nitrogen management practices had no significant effect on soil reaction, available nitrogen, available phosphorus and available potassium status of the soil at the time of harvest. But the organic carbon content of the soil was significantly higher under KAU package of practices (T_8).

The data presented in table 11 indicated that the status of available nitrogen and potassium contents of the soil after the experiment was lower than

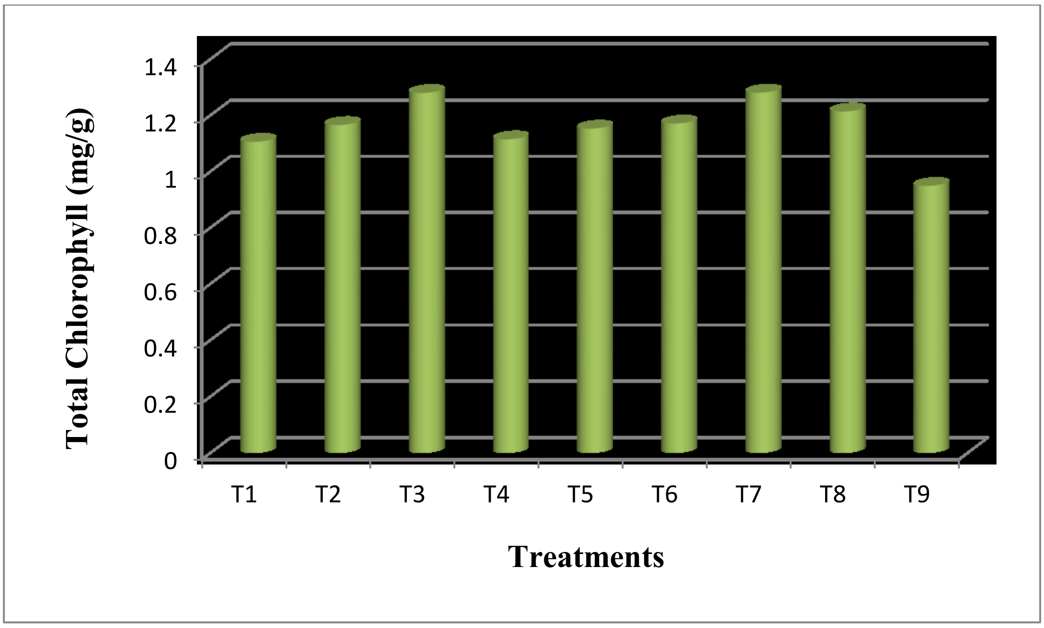

Fig 9. Effect of nitrogen management practices on total chlorophyll

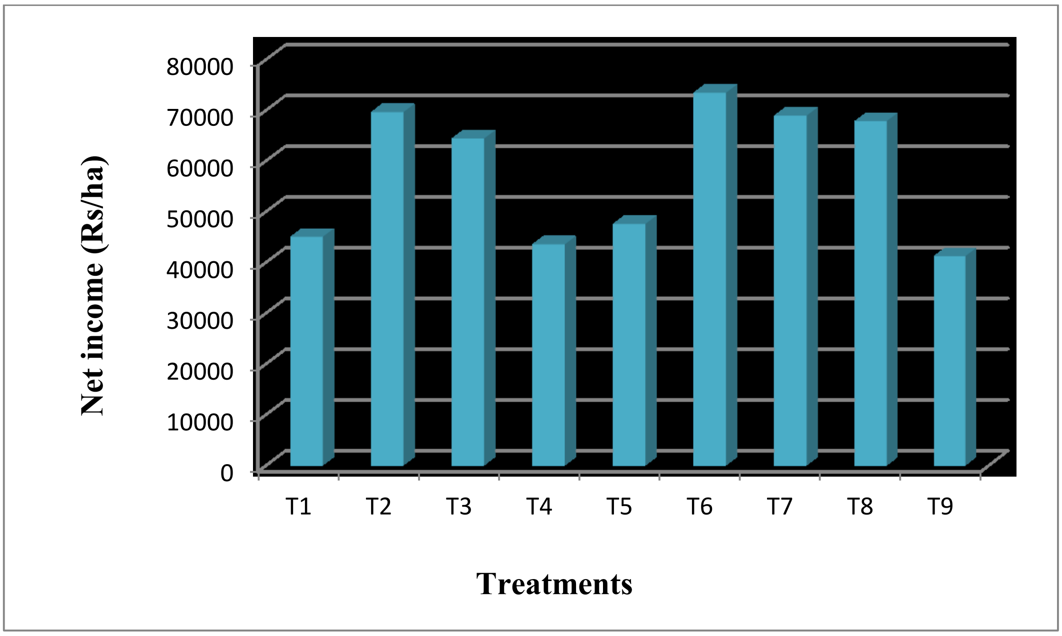

Fig 10. Effect of nitrogen management practices on net income

that of the initial status. But in the case of available phosphorus content, it was lower in treatments which received higher amounts of N fertilizer and vice versa.

The available nitrogen content of the soil increased with increasing N fertilizer applied. But the available phosphorus and potassium content of the soil decreased with increasing N fertilizer applied. This may be because the treatments which received higher amounts of N fertilizer also extracted higher amounts of phosphorus and potassium.

5.7 ECONOMICS

The economic returns measure the profitability of a system. The input cost and farm income change from time to time and place to place thus profitable nutrient management system in crop production also varies accordingly.

N application based on soil test value using soil testing kit (T_7) recorded higher gross returns, but the net income and B:C ratio were higher under N application at SPAD value 36 (T_6) and LCC value 4.0 (T_2). This was due to the higher grain yield and reduction in amount of N fertilizer applied (70 kg/ha).

N application with SPAD value 32 and 34 and LCC- 3 was inadequate for the variety Uma because it resulted in application of only 45 kg N/ha, and thus resulted in low yield. N application with LCC- 5 and based on soil test value was not economical because of the higher dose of N (145 kg/ha) and less improvement in grain yield.

Based on the economic analysis, it can be inferred that the LCC value 4 or SPAD value 36 is critical to realize higher profit in rice variety Uma. Applying 20 kg N/ha as basal and 25 kg N/ha each time, when the SPAD value fell below the critical value 36 or LCC value 4, resulted in application of 70 kg N/ha and these two treatments produced 3.93 per cent and 1.31 per cent higher yields respectively, compared to KAU POP treatment i.e. 90 kg N/ha applied in 3 splits. Hence a saving of 20 kg N/ha was achieved with a higher yield compared to POP.

The high cost of chlorophyll meter keeps it out of reach of many farmers the leaf colour chart (LCC) is an inexpensive alternative to the chlorophyll meter. Hence, the LCC based N management is the better option than SPAD based N management practices in farmer's point of view.

Summary

6. SUMMARY

An experiment entitled "Need based nitrogen management in rice (*Oryza sativa* L.) using diagnostic tools" was undertaken in a farmer's field in Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state during the *Virippu* season (first crop season), 2013. The main objectives of the experiment were to study the technical and economic feasibility of using chlorophyll meter (SPAD meter), leaf colour chart (LCC) and soil testing kit for assessing the crop nitrogen status, to schedule N application in rice based on crop need and to work out the economics.

The field experiment was laid out in Randomised Block Design (RBD) with three replications. The treatments included N application at LCC value 3.0, LCC value 4.0 and LCC value 5.0, N application at SPAD value 32, SPAD value 34 and SPAD value 36, N application based on soil test value using soil testing kit, KAU package of practices and absolute control. The rice variety used for the experiment was Uma. Observations were recorded at maximum tillering, panicle initiation and harvest stages. LCC readings, SPAD readings and soil N status readings with soil testing kit were recorded at 10 days interval, starting from 10 DAT of rice till 10 days after flowering. When the LCC and SPAD readings of six out of ten leaves fell below the critical value and soil N status showed low values, 25 kg N/ha was top dressed on the same day. The results obtained in present investigation are summarized in this chapter.

The treatments N application at LCC value 3.0, SPAD value 32 and SPAD value 34 received only 45 kg N/ha. The treatments N application at LCC value 4.0 and SPAD value 36 received 70 kg N/ha whereas in KAU POP 90 kg N/ha in 3 splits was recommended. The treatments N application at LCC value 5.0 and N application based on soil test value using soil testing kit received higher quantity of nitrogen (145 kg N/ha).

The growth parameters such as plant height, leaf area index (LAI), number of tillers per hill and dry matter production were increased significantly with increase in N fertilization. N application at LCC value 5.0 and N application based on soil test value using soil testing kit recorded significantly higher values for growth parameters such as plant height, leaf area index (LAI), number of tillers per hill and dry matter production at all growth stages, *viz*., maximum tillering, panicle initiation and harvest stages. But days to 50 per cent flowering did not vary significantly with the different nitrogen management practices.

N application at LCC value 4.0 and SPAD value 36 recorded higher values for yield attributes such as grain weight/panicle, filled grains/panicle and thousand grain weight. The minimum sterility percentage was observed at N application at LCC value 4.0, SPAD value 36 and KAU package of practices. But the number of productive tillers/m^2 was highest for the treatments N application based on soil test value using soil testing kit and N application at LCC value 5.0.

N application at SPAD value 36 and LCC value 4.0 recorded significantly higher grain yield (7.94 t/ha and 7.74 t/ha respectively) and was on par with KAU POP (7.64 t/ha) and soil test based N application (7.54 t/ha).

When LCC critical value is increased from 3 to 4, an yield increase of 25.85 per cent was obtained where as when LCC value is increased from 4 to 5 a slight reduction in yield was noticed. As far as SPAD critical value is concerned, SPAD- 36 recorded 31.24 per cent increase in yield over SPAD- 32 and 27.04 per cent yield increase over SPAD- 34.

The increase in grain yield in treatments SPAD- 36 and LCC- 4 which received 70 kg N/ha were 3.93 per cent and 1.31 per cent respectively over KAU POP (when N was applied @ 90 kg/ha in 3 splits).

The straw yield was significantly higher under N application based on soil test value using soil testing kit and N application at LCC value 5.0 (13.73 t/ha and 13.52 t/ha respectively).

The highest harvest index (0.405 and 0.403 respectively) was recorded by N application at SPAD- 36 (T_6) and at LCC- 4.0 (T_2) and was on par with KAU POP (0.398).

The agronomic efficiency, physiological efficiency and apparent recovery efficiency were higher under N application at SPAD value 36 and N application at LCC value 4.0. The partial factor productivity and internal utilization efficiency were decreased with increase in the total amount of N applied due to the higher fertilizer cost or less grain yield.

As far as the relation between LCC and SPAD readings concerned, LCC-3 coincided with SPAD- 32, LCC- 4 with SPAD- 36 and LCC- 5 with SPAD-40. In rice variety Uma, SPAD- 36 gave higher grain yield and it coincided with LCC-4. From economic point also the same trend was noticed.

There was a gradual increase in total chlorophyll with the increase in LCC value and SPAD value. The highest total chlorophyll was recorded by N application based on soil test value using soil testing kit and N application at LCC value 5.0.

The uptake of the major nutrients, N, P and K was significantly higher at N application based on soil test value using soil testing kit and LCC value 5.0.

N application based on soil test value using soil testing kit recorded higher gross returns. But the net income and B:C ratio were higher under N application at SPAD value 36 and LCC value 4.0.

N application at SPAD value 36 and LCC value 4.0 resulted in application of 70 kg N/ha and these two treatments produced 3.93 per cent and 1.31 per cent higher yields respectively, compared to KAU POP treatment (90 kg N/ha applied in 3 splits). Hence a saving of 20 kg N/ha was achieved with SPAD and LCC based N management compared to KAU POP. The present investigation strongly recommend LCC and SPAD meter as efficient diagnostic tools for monitoring plant N status *in situ* in rice field so as to determine the right time of N top dressing, synchronized with the actual crop demand.

It can be concluded from the present study that the rice variety Uma performed best with application of 20 kg N/ha as basal and 25 kg N/ha each applied as top dressing at 40 and 60 DAT (based on LCC-4 or SPAD-36). P and K were applied as per KAU POP. Thus the use of LCC or SPAD meter are efficient tools which helped in reducing the recommended dose of N from 90 kg/ha to 70 kg/ha. Since, the high cost of chlorophyll meter keeps it out of reach of many farmers, the leaf colour chart (LCC) is an inexpensive alternative to the chlorophyll meter. Hence, the LCC based N management is the better option than SPAD based N management practices in farmer's point of view.

6.1 FUTURE LINE OF WORK

The present investigation has led to the identification of following researchable areas for future exploration:

- Standardization of LCC and SPAD values for other rice varieties in different seasons in different agro climatic situations in Kerala.
- Standardisation of integrated nitrogen management (INM) strategies using LCC and SPAD.
- Foliar application of nitrogen based on LCC and SPAD need to be studied.
- The effect of slow release or coated N can be tried with LCC and SPAD values.
- Need based/real time nitrogen management through LCC and SPAD in rice based cropping systems need to be explored.

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Need Based Nitrogen Management in Rice (*Oryza sativa* L.) Using Diagnostic Tools

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(2012 - 11 - 199)

Abstract of the
thesis submitted in partial fulfilment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

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2014

8. ABSTRACT

An investigation entitled "Need based nitrogen management in rice (*Oryza sativa* L.) using diagnostic tools" was carried during the *Virippu* season (first crop season), 2013 at farmer's field, Kalliyoor Panchayath, Thiruvananthapuram district, Kerala state. The main objectives of the experiment were to study the technical and economic feasibility of using chlorophyll meter (SPAD meter), leaf colour chart (LCC) and soil testing kit for assessing the crop nitrogen status, to schedule N application in rice based on crop need and to work out the economics.

The field experiment was laid out in Randomised Block Design (RBD) with three replications. The treatments were N application at LCC value 3.0, 4.0 and 5.0, N application at SPAD value 32, 34 and 36, N application based on soil test value using soil testing kit, KAU POP and absolute control.

N application at LCC value 5.0 and N application based on soil test value recorded significantly superior values for plant height, LAI, number of tillers per hill, dry matter production, number of productive tillers/m^2, higher straw yield, higher uptake of N, P and K and total chlorophyll of leaves. N application based on soil test value recorded higher gross income.

N application at LCC value 4.0 and SPAD value 36 recorded higher values for grain weight/panicle, filled grains/panicle, thousand grain weight, net income and B:C ratio. Sterility percentage was also minimum for N application at LCC value 4.0, SPAD value 36 and KAU package of practices. N application at SPAD value 36 and LCC value 4.0 recorded significantly higher grain yield, harvest index, agronomic efficiency, physiological efficiency and apparent recovery efficiency. The grain yield with SPAD- 36 and LCC- 4 which received 70 kg N/ha were on par with KAU POP which received 90 kg N/ha in 3 splits. Hence a saving of 20 kg N/ha was achieved with a higher yield compared to POP.

The nutrient status of the soil after the experiment did not show any significant difference except in organic carbon content. The organic carbon recorded was significantly higher under KAU package of practices.

The partial factor productivity and internal utilization efficiency decreased with increase in the total amount of N applied due to higher input cost on fertilizer or less grain yield. The relationship between SPAD values and LCC scores was found to be linear.

It can be concluded from the present study that the rice variety Uma performed best with application of 20 kg N/ha as basal and 25 kg N/ha each applied as top dressing at 40 and 60 DAT (based on LCC-4 or SPAD-36). P and K were applied as per KAU POP. Thus the use of LCC or SPAD meter are efficient tools which helped in reducing the recommended dose of N from 90 kg/ha to 70 kg/ha. Since, the high cost of chlorophyll meter keeps it out of reach of many farmers, the leaf colour chart (LCC) is an inexpensive alternative to the chlorophyll meter. Hence, the LCC based N management is the better option than SPAD based N management practices in farmer's point of view.

സംഗ്രഹം

വിളകൾക്ക് ആവശ്യമായ സമയത്ത് കൃത്യമായ അളവിൽ വളപ്രയോഗം നടത്താനായി സഹായിക്കുന്ന ഉപാധികളായ ക്ലോറോഫിൽ മീറ്റർ അഥവാ സ്പാഡ്മീറ്റർ, ലീഫ് കളർ കാർഡ്, മണ്ണുപരിശോധനാകിറ്റ് എന്നിവ ഉപയോഗിച്ച് നെല്ലിനു വേണ്ട നൈട്രജൻ ചിട്ടപ്പെടുത്താനുള്ള ഒരു പഠനം തിരുവനന്തപുരം ജില്ലയിലെ കാഞ്ഞിരത്തടി പാടശേഖരത്തിൽ ജൂലൈമുതൽ ഒക്ടോബർവരെയുള്ള കാലയളവിൽ നടത്തുകയുണ്ടായി. ഉമ എന്ന നെല്ലിനത്തിലാണ് മേല്പറഞ്ഞ പരീക്ഷണം നടത്തിയത്. ഇലയിലെ നൈട്രജൻ നിലവാരവും, തദ്വാരാ, ഹരിതകത്തിന്റെ അളവും, സ്പാഡ്മീറ്റർ, ലീഫ്കളർ കാർഡ് ഇവയുപയോഗിച്ച് മനസ്സിലാക്കി, നൈട്രജൻ വളപ്രയോഗം ചിട്ടപ്പെടുത്തുകയുണ്ടായി. അതുപോലെതന്നെ മണ്ണിലെ നൈട്രജന്റെ അളവ് മണ്ണുപരിശോധനാകിറ്റുവഴി മനസ്സിലാക്കി അതനുസരിച്ച് വളപ്രയോഗം സ്വീകരിച്ചു. ഇതോടൊപ്പം കാർഷികസർവ്വകലാശാല ശുപാർശ ചെയ്യുന്ന വളവും (ഹെക്ടറൊന്നിന് 90 : 45 : 45 കിലോഗ്രാം നൈട്രജൻ, ഫോസ്ഫറസ്, പൊട്ടാഷ്), രാസവളമില്ലാത്ത ഒരു രീതിയും സ്വീകരിച്ചു.

സ്പാഡ്മീറ്ററും ലീഫ്കളർകാർഡും ഉപയോഗിക്കേണ്ടത് നട്ട് 10 ദിവസത്തിനു ശേഷം മുതൽ കതിരുവന്ന് 10 ദിവസം കഴിയുന്നതുവരെയുള്ള കാലയളവിലാണ്. രണ്ടു പരിശോധന തമ്മിലുള്ള ദൈർഘ്യം10 ദിവസമാണ്. പ്രധാന ചിനപ്പിന്റെ ഏറ്റവും പ്രായം കുറഞ്ഞ, പൂർണ്ണമായി വിരിഞ്ഞ ഇലയാണ് നിറം വിലയിരുത്താൻ തെരഞ്ഞെടുക്കേണ്ടത്. ഓരോ കണ്ടത്തിൽ നിന്നും ഇപ്രകാരം 10 ഇലകൾ വിലയിരുത്തി, സ്പാഡ് വാല്യൂ അഥവാ ലീഫ് കളർകാർഡ് വാല്യൂ നിശ്ചയിക്കാവുന്നതാണ്.

ഈ പഠനത്തിൽ ഉമ എന്ന അത്യുൽപാദന ശേഷിയുള്ള നെല്ലിനത്തിന് സ്പാഡ്വാല്യൂ 36 അല്ലെങ്കിൽ ലീഫ്കളർകാർഡ് നിലവാരം4 എന്ന കണക്കിന് വളപ്രയോഗം നടത്തിയപ്പോഴാണ് ഏറ്റവും കൂടുതൽഉല്പാദനവും, ലാഭവും, വളപ്രയോഗത്തിന്റെ കൂടിയ കാര്യക്ഷമതയും ഉണ്ടായത് എന്നു കാണാൻ കഴിഞ്ഞു. സ്പാഡ് വാല്യൂ 36 ൽ താഴെയാണെങ്കിലോ ലീഫ്കളർകാർഡ് നിലവാരം 4 ൽ താഴെയാണെങ്കിലോ മാത്രം ആപാടത്ത് നൈട്രജൻവളം ഹെക്ടറൊന്നിന് 25 കിലോഗ്രാംഎന്ന തോതിൽ നൽകിയാൽ മതി.

ഇപ്രകാരം സ്പാഡ്മീറ്ററും ലീഫ്കളർ കാർഡും ഉപയോഗിച്ചുള്ള വള പ്രയോഗം നടത്തിയാൽ 20 കിലോഗ്രാം നൈട്രജൻ വളം ഹെക്ടറൊന്നിന് ലാഭിക്കാൻ കഴിയുമെന്ന് കണ്ടെത്തി. മാത്രമല്ല നൈട്രജൻ ആവശ്യത്തിനുള്ള മണ്ണിൽ നൈട്രജൻ വളങ്ങൾ മൂന്നു തവണകളായി (20 കിലോഗ്രാം അടിവളം, 25 കിലോഗ്രാം വീതം 40 ദിവസത്തിലും 60 ദിവസത്തിലും) നൽകുന്നതാണ് ലാഭകരമെന്ന് മനസ്സിലാക്കി. ലീഫ്കളർകാർഡിന് വില കുറവായതുകൊണ്ട് സാധാരണ കർഷകർക്ക് ഇത് വളരെ ഫലപ്രദമായി ഉപയോഗിക്കാൻ കഴിയും.

ഓരോ പ്രദേശത്തിനും യോജിച്ച നെല്ലിനങ്ങൾക്ക്, ഏറ്റവും അനുയോജ്യമായ ലീഫ്കളർകാർഡ് നിലവാരം പരീക്ഷണം നടത്തി തീരുമാനിക്കേണ്ടതാണ്.

APPENDIX – I

Standard week wise weather parameters during the experimental period (June 2013 - October 2013)

Standard week	Temperature (^0C)		Relative Humidity (%)		Sunshine hours	Total Rainfall (mm)	Mean evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum			
23	29.2	22.8	93.6	83.3	8.7	89.9	1.8
24	29.1	23.2	95.1	89.3	7.0	121.2	2.8
25	28.3	22.5	95.4	86.1	7.6	141.6	2.0
26	29.9	23.3	90.0	84.1	9.3	34.2	3.2
27	29.3	23.4	93.9	85.1	9.0	33.5	2.3
28	28.5	23.0	93.7	79.6	8.4	60.8	1.9
29	28.3	23.5	94.0	87.9	8.1	60.5	2.5
30	29.4	21.9	92.3	88.0	9.0	69.8	3.3
31	29.0	21.6	93.1	87.0	8.4	92.8	3.3
32	28.8	23.9	96.7	82.7	9.4	7.8	0.0
33	28.6	23.7	93.3	78.4	9.6	3.1	0.1
34	29.8	24.0	92.7	78.7	9.9	3.0	3.0
35	30.2	24.4	86.6	80.1	9.3	2.4	2.0
36	28.8	23.7	97.0	86.7	7.9	140.4	4.2
37	28.7	23.4	98.6	84.0	8.2	36.9	3.0
38	28.8	24.3	96.3	85.4	8.6	36.6	2.0
39	30.2	24.0	93.7	85.1	10.3	2.3	4.0
40	30.5	22.6	94.0	74.4	9.7	13.4	3.6
41	30.6	23.3	91.4	75.4	9.5	22.8	5.0
42	30.7	23.7	92.1	79.9	8.5	66	3.1

APPENDIX – II

Average input cost and market price of produce

S. No.	Items	Cost
	INPUTS	
A	**Seed**	Rs. 37 per kg
B	**Labour**	
1.	Women	Rs. 554 per day
2.	Men	Rs. 554 per day
C	**Cost of manures and fertilizers**	
1.	Farm yard manure (FYM)	Rs. 400 per t
2.	Lime	Rs.15 per kg
3.	Urea	Rs. 8 per kg
4.	Rajphos	Rs. 10 per kg
5.	Muriate of potash (MOP)	Rs. 17.5 per kg
	OUTPUT	
	Market price of grain	Rs. 17 per kg
	Market price of straw	Rs. 3 per kg